W00273

NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

DESCRIPTIVE REPORT

Type of Survey	**Hydrographic Multibeam Survey**
Project No.	**OSD-UNH-08**
Registry No.	**W00273**

LOCALITY

State	**Maine**
General Locality	**Castine**
Sub-locality	**Castine Harbor and Bagaduce River**

2008

UNH Summer Hydrographic Field Course 2008

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DATE

NOAA FORM 77-28 U.S. DEPARTMENT OF COMMERCE REGISTRY No NATIONAL OCEANIC
(11-72) AND ATMOSPHERIC ADMINISTRATION

HYDROGRAPHIC TITLE SHEET

W00273

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

FIELD No

State **Maine**

General Locality **Castine**

Sub-Locality **Castine Harbor and Bagaduce River**

Scale **1:20,000** Date of Survey **6/14/08 - 6/20/08**

Instructions dated Project No. **OSD-UNH-08**

Vessel **R/V Coastal Surveyor**

Chief of party **Andrew Armstrong, University of New Hampshire**

Surveyed by **UNH CCOM students**

Soundings by echo sounder, hand lead, pole **MBES**

Graphic record scaled by

Graphic record checked by Automated Plot

Verification by **Atlantic Hydrographic Branch**

Soundings in fathoms *feet* at MLW MLLW **MLLW**

REMARKS:

Multibeam data were acquired by students from CCOM/JHC of the University of New Hampshire summer hydrographic field course. All times are in UTC. Horizontal datum WGS 84.

The purpose of this survey is to provide contemporary surveys to update National Ocean Service (NOS) nautical charts. All separates are filed with the hydrographic data. Any revisions to the Descriptive Report (DR) generated during office processing are shown in bold red italic text. The processing branch maintains the DR as a field unit product, therefore, all information and recommendations within the body of the DR are considered preliminary unless otherwise noted. The final disposition of surveyed features is represented in the OCS nautical chart update products. All pertinent records for this survey, including the DR, are archived at the National Geophysical Data Center (NGDC) and can be retrieved via http://www.ngdc.noaa.gov/.

University of New Hampshire
Center for Coastal and Ocean Mapping
Joint Hydrographic Center

DESCRIPTIVE REPORT

Bagaduce River, Castine, ME

2008 Summer Hydrographic Field Course

R/V Coastal Surveyor

3 July 2008

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A. AREA SURVEYED

A1. Project Description

This report details a survey of Castine Harbor and the Bagaduce River in Maine which was conducted between June 14 and June 20, 2008 by the Center for Coastal and Ocean Mapping / Joint Hydrographic Center (CCOM/JHC) Summer Hydrography 2008 class with support of the Maine Maritime Academy (MMA) and Tidal Energy Device Evaluation Center (TEDEC) tidal energy power project. The purpose of the survey was to provide the required foundation data for tidal modeling and environmental assessments for the TEDEC project. The TEDEC partners were awarded a permit by the US Federal Energy Regulatory Commission to conduct exploratory research for possible locations of renewable power devices in the area.

This survey represents the only known modern survey conducted in the Bagaduce River since the initial survey in the late 1880s. This survey meets the requirements specified in the NOS (National Ocean Service) Hydrographic Surveys Specifications and Deliverables (April, 2007) and the OCS (Office of Coast Survey) Field Procedures Manual for Hydrographic Surveying (June 2008), and may be used to update NOAA chart 13309.

Survey data were collected with a Kongsberg Simrad EM3002 dual-head system bow-mounted on the R/V Coastal Surveyor. Horizontal control was provided using a Trimble 5700 Real-Time Kinematic Global Positioning System (RTK-GPS). A tide gauge was installed on a fixed pier in Castine Harbor, providing water level measurements which allowed the data to be reduced to the Mean Lower Low Water (MLLW) datum. All survey data were processed using CARIS HIPS and SIPS software and a final Combined Uncertainty and Bathymetry Estimator (CUBE) surface was created at a resolution of 0.5 meters.

A2. Survey Area

The survey was conducted in the area adjacent to Castine Harbor and along the Bagaduce River in Maine. The survey bounds are approximately 44°25’46”N, 68°49’34”W, and 44°21’59”N, 68°44’43”W (Fig. 1). The survey coverage was greater than 100% throughout the survey area with exception of isolated holidays (Fig. 2).

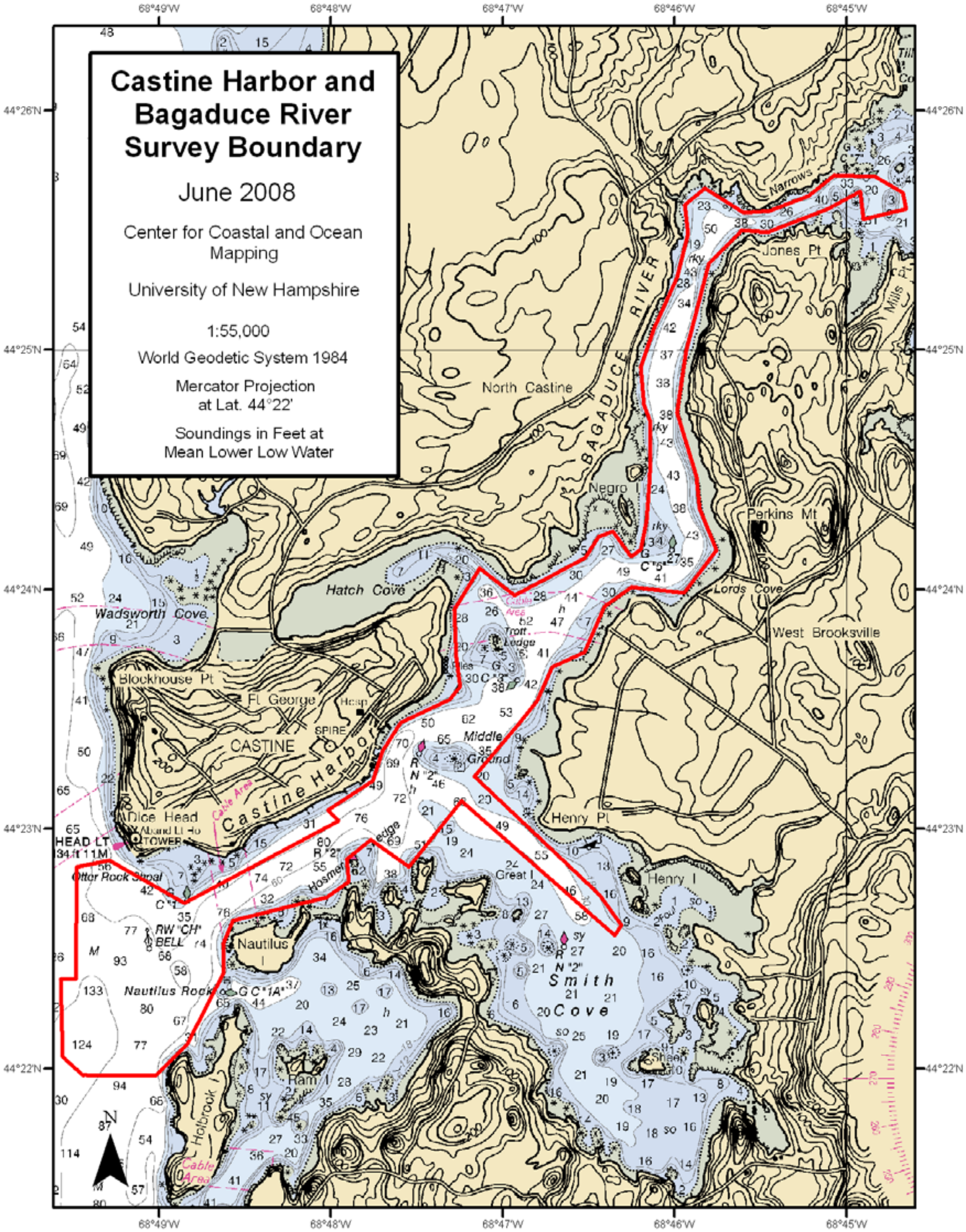


Figure 1: Survey area displayed on NOAA chart 13309

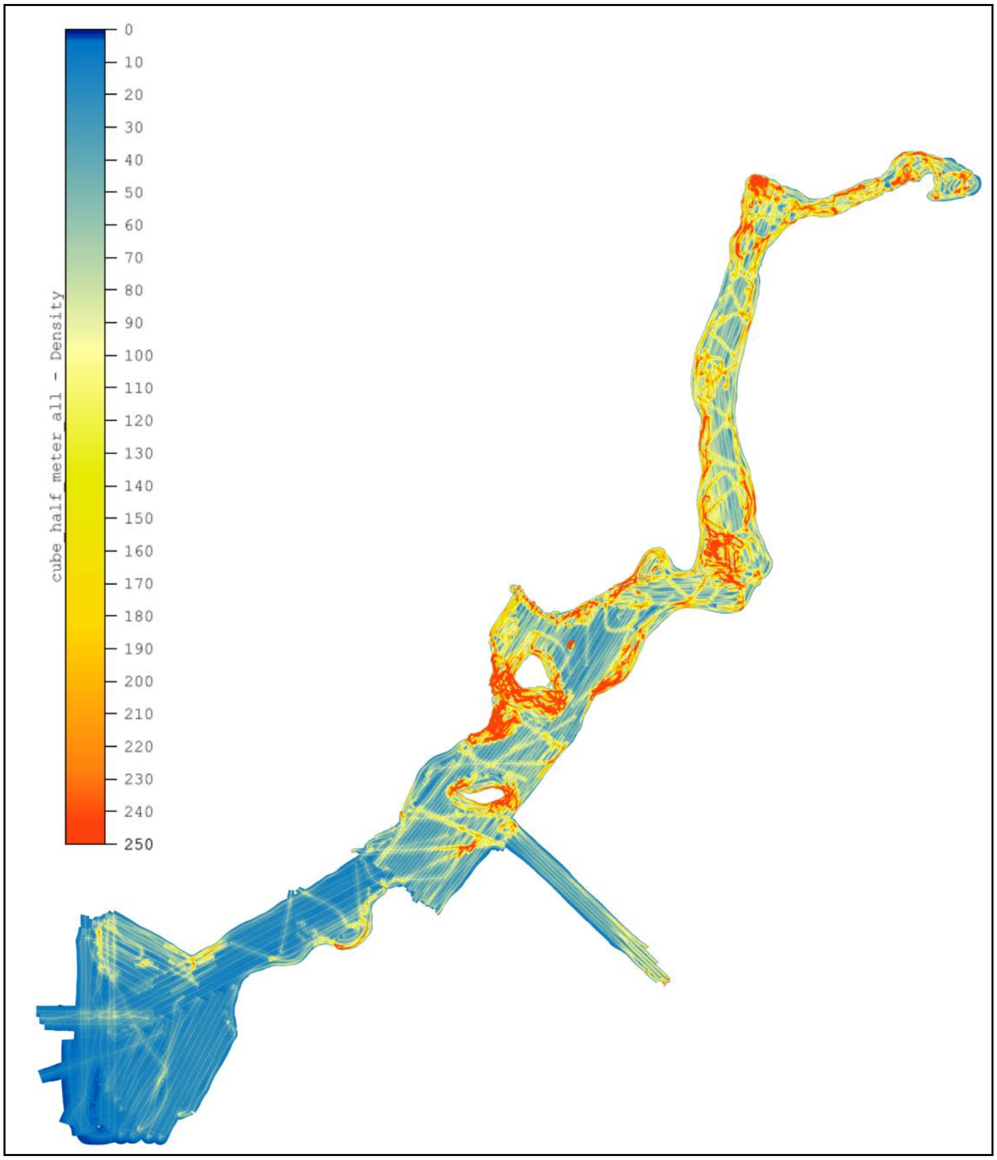


Figure 2. Data density derived from CARIS CUBE Surface application from survey area showing number of soundings per grid cell (0.5 m) emphasizing that >100% coverage was obtained over almost all of the area.

The total area covered in this survey by the R/V Coastal Surveyor was approximately 3.5 NM^2 as is shown below (Table 1).

Table 1 - Mileage for the RV Coastal Surveyor

Survey Statistics	
Linear Nautical Miles of Mainscheme Multibeam	151.0
Linear Nautical Miles of Crosslines	15.0
Total Square Nautical Miles	3.5

B. DATA ACQUISITION AND PROCESSING

B1. Equipment

1.0 Survey Vessel

Multibeam data were acquired using the R/V Coastal Surveyor (Figure 3), CCOM's research vessel, designed specifically for coastal hydrographic surveys. Vessel dimensions and specifications are shown in Table 2 (Section 1.1). The vessel is equipped with a roll stabilization system and a hydraulic ram-mount on the bow, which was used as a mount for the transducers (transducer heads submerged in Figure 3).

Figure 3: R/V Coastal Surveyor. Note the hydraulic mount on the bow.

1.1 Vessel Specifications

Table 2 - Vessel Specifications

Dimensions:	40' x 12' x 3.7'
USCG:	Designated Research Vessel, subchapter "C"
Flag:	U.S.
Registry:	U.S. Coastwise and Registry
Official Number:	999206
Tonnage:	16 GRT 11 DWT
Lab space:	9' x 11' 6' x 10'
Speed:	10 knots
Minimum speed for full roll stabilization:	5 knots
Minimum survey speed:	2.5 knots
Propulsion:	1 x Cat 3116; 205 shp cont."A"; 2.57:1 reduction
Auxiliary:	1 x Isuzu/Lima 20 kw; 240/120 V; 60 Hz;
Power distribution:	38 ea. 115 volt receptacles 2 ea. 230 volt receptacles 1 ea. 12 volt receptacles 7 ea. 24 volt receptacles
Fuel capacity:	400 gallons
Potable water:	60 U.S. gallons
Roll stabilization:	Niad active fins
Loran:	Micrologic Mariner
DGPS:	Magellan 1200XL GPS w/ Magellan 19019 DBR
Magnetic compass:	Ritchie 5"
Fluxgate compass:	Robertson RFC 300
Radar:	Furuno 1933CCBB NavNet
Autopilot:	Robertson AP 300DL
VHF:	Standard Omni 25 watt
Side Band:	Sea 222
Cellular phone:	Motorola 5 watt
Air conditioning:	3 x 1.25 tons
Heating:	3 x 16,000 BTU

2.0 Hardware

2.1 Hardware Systems Inventory

Table 3 - Hardware Systems Inventory

	Hardware Equipment	Manufacturer	Model	Serial Number
Vertical Control	Water Level/Temperature Sensor	AANDERAA Instruments	3796A	34
	Compensating Unit	AANDERAA Instruments	3848	NA
	Datalogger	AANDERAA Instruments	3634	
	Alkaline Battery, 9 Volt, 15 Ah	AANDERAA Instruments	3651	
Horizontal Control	GPS Receiver	Trimble	5700/R7	
	GPS Antenna	Zephyr Geodetic, Trimble		60035091
	2 Radio Modems	Trimark™ 3, Trimble		
	2 Radio Antennas	Trimble		
Sound Velocity	Sound Profile Velocimeter	Odom Digibar Pro	DB 1200	98536
	Surface Sound Velocimeter	Applied Microsystems	Smart SV&T	5218
Attitude Positioning	Inertial Motion Unit (IMU)	Applanix	IMU-200 POS/MV	179
	Position Compute System (PCS)	Applanix	320 V4 POS/MV	2171
	GPS primary Antenna (port)	Trimble	Zephyr	60004297
	GPS secondary Antenna (starboard)	Trimble	Zephyr	60008122
Echo Sounding	2 Sonar Heads	Kongsberg	EM3002	322 / 481
	Operator Station	Kongsberg	EM3002 HWS 10 WS	103
	Processing Unit	Kongsberg	EM3002 PU	1014

2.2 Vertical Control Equipment

Tidal data were collected from an Aanderaa tide gauge installed on 8 May 2008 on a fixed pier in Castine Harbor at 44°23'10.94"N, 68° 47'48.19"W. Power supply issues resulted in gaps in the tide data in the first week after installation, however, a continuous record of data is available from the 17th May. The tide gauge station included an Aanderaa pressure sensor, air pipe cable, compensating unit, alkaline battery, and datalogger hooked into a UNIX computer provided by MMA (Figure 4). The hydrostatic pressure sensor and thermistor measured depth and water temperature from the fixed, submerged position. The air pipe and compensating unit compensate directly for the barometric pressure influence. The watertight datalogger 3634, stored in the adjacent white shed (Figure 4) read, recorded, and displayed the water level and temperature data.

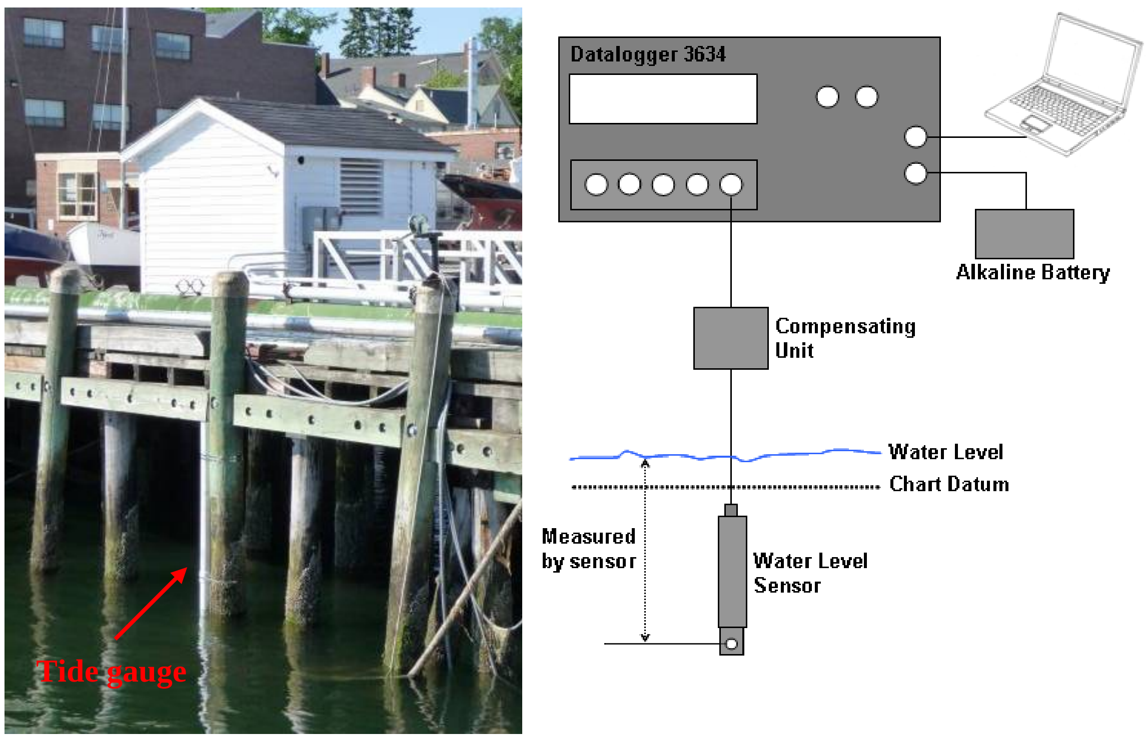


Figure 4. Location of Tide Gauge within PVC Pipe stilling well on Castine Pier and a schematic of the tide gauge configuration (adapted from Aanderaa Instruments, 1999; 2000).

2.3 Horizontal Control Equipment

A real-time kinematic (RTK) base station was established on the roof of Curtis Hall, MMA to provide corrections to the R/V Coastal Surveyor's horizontal positioning during the survey. The base station system included a tripod-mounted Trimble 5700 GPS receiver connected to a tripod-mounted Trimble Trimark 3 Radio Modem, which transmitted the RTK signal to a Trimble Trimark 3 Radio Modem mounted onboard the vessel. The phase measurement corrections received from GPS satellites were transmitted via the Trimark-3 radio modem to the Applanix POS/MV in order to continuously update the vessel's horizontal positioning with an instrument accuracy of 0.1 meters.

2.4 Sound Velocity Equipment

The Applied Microsystems Smart SV&T velocimeter (Figure 5)- mounted between the two transducer heads on the R/V Coastal Surveyor- was used to continuously measure surface sound speed at the transducer face. The surface sound speed information was used to correct refraction of sound in the water in order to ensure accurate beam formation.

The Odom Digibar Pro sound velocimeter was used during the survey in order to obtain accurate sound velocity profiles throughout the survey area. Unlike traditional Conductivity, Temperature, and Depth (CTD) sensors, velocimeters measure sound speed directly, automatically compensating for pressure, salinity, and temperature. The system comprises a sound velocity probe attached to a hand held data logger via a 50m long cable.

Figure 5 The Applied Microsystems Smart SV&T velocimeter

2.5 Echo Sounding Equipment

A Kongsberg Simrad EM 3002D dual-head system was using to acquire multibeam bathymetry data during the survey (Figure 6). The EM 3002 system operates at frequencies in the 300 kHz band which is ideal for shallow depths. The transducer forms 160 beams, with beam widths of 1.5° by 1.5° at nadir. The port and starboard transducers were mounted at approximately -40° and 40°, respectively. The operational frequency of the port transducer was set at 293 kHz, while the starboard transducer was set at 307 kHz, ensuring that there was no interference during data acquisition. Instrument specifications are shown on Table 4.

Table 4 - EM3002 Specifications

Frequencies.	293, 300, 307 kHz
Number of soundings per ping:	Dual sonar heads (Max 508)
Maximum ping rate.	40 Hz
Maximum angular coverage:	200 degrees for dual sonar heads
Pitch stabilization	Yes
Roll stabilization	Yes
Heave compensation	Yes
Pulse length	150 μs
Range sampling rate	14, 14.3, 14.6 kHz
Depth resolution	1 cm
Transducer geometry	Mills cross
Beam spacing	Equidistant or equiangular (equiangular option selected)
Beamforming:	• Time delay with shading • Dynamically focused receive beams

Figure 6: EM 3002 transducers bow-mounted on the R/V Coastal Surveyor

3.0 Software

3.1 Software Systems Inventory

The software systems used for the acquisition and processing of all data for this survey are shown in Table 5

Table 5 - Software Systems Inventory

	Software Equipment	Version
Data Acquisition	HYPACK 2008	Version 8 / Version 6.2 (version available on the vessel)
	Seafloor Information System - SIS	N/A
	POS-Pac	N/A
Data Processing	Hyper Terminal	Version 5.1
	Velocwin	Version 8.92
	CARIS HIPS and SIPS	Version 6.1
	ArcGIS 9.2	Version 9.2
	Fledermaus	Version 6.7
	Python	Version 2.4
	PuTTY	Version 0.60
	Matlab	Version MATLAB 7.6 (R2008a)

3.2 Data Acquisition Software

- Hypack Hydrographic Software package was used to generate the Total Propagated Error (TPE editor application), which was used to address the survey IHO specifications. In addition, it was used to create the survey plan and to display line plans for navigation during survey operations.
- Seafloor Information System (SIS) was provided by Kongsberg as the data acquisition user interface to accompany the EM3002D dual-head multibeam system.

- POSPac software suite was supplied by Applanix for use with their POS/MV system. POS-Pac was used to compute the inertial navigation solution by processing the raw attitude measurements of the IMU and the GPS position information.

3.3 Data Processing Software

- The NOAA Velocwin software was used to process sound velocity profiles collected by the Odom Digibar Pro. It produces a *.svp and *.asvp, which can be directly loaded into CARIS HIPS and SIPS.
- Matlab was used to compute a smoothed 6-minute running average of the Castine water level in order to facilitate the extraction of the higher high, lower high, higher low, and lower low tidal peaks. A copy of the full Matlab code is included in Appendix IV.
- Python was used to convert the raw data acquired from the tide gauge installed in Castine, from engineering units into International System of Units (SI).
- All multibeam data processing (excluding cross-check analysis) was conducted in CARIS.
- Fledermaus was used to create grids to allow evaluation during processing and for the cross-check analysis of the survey.
- ArcGIS was used to create survey area maps, coverage extents, and final chart products. It was also used to compare this survey to NOAA chart 13309 and junction survey H-10131.

4.0 Personnel Inventory

A full list of faculty, students and survey vessel crew who participated in this survey is shown in Table 6.

Table 6 - Survey Personnel

Group Participants	Instructors and CCOM Support	R/V Coastal Surveyor Crew
Robert Bogucki	Capt. Andy Armstrong	Nicola Groh
Daniela Gonçalves	Dr. Semme Dijkstra	Capt. Ben Smith
Koji Ito	Andy McLeod	
Kathleen Jamison	Marc Moser	
Priyantha Jinadasa		
Lori Knell		
Neil Tinmouth		
Jashim Uddin		
Dr. Rochelle Wigley		
Monica Wolfson		

B2. QUALITY CONTROL

1.0 Procedures

1.1 Survey Planning

Survey planning was carried out in HYPACK prior to and during the survey. A HYPACK Total Propagated Error (TPE) uncertainty model was used to estimate the swath width of the EM3002D based on the multibeam characteristics, approximate area depth, and IHO Special Order specifications.

The planned survey line spacing varied between 16 and 41 m, approximately 3 times water depth, and was designed to provide a minimum of 150% bottom coverage. Survey lines were typically oriented parallel to charted contours.

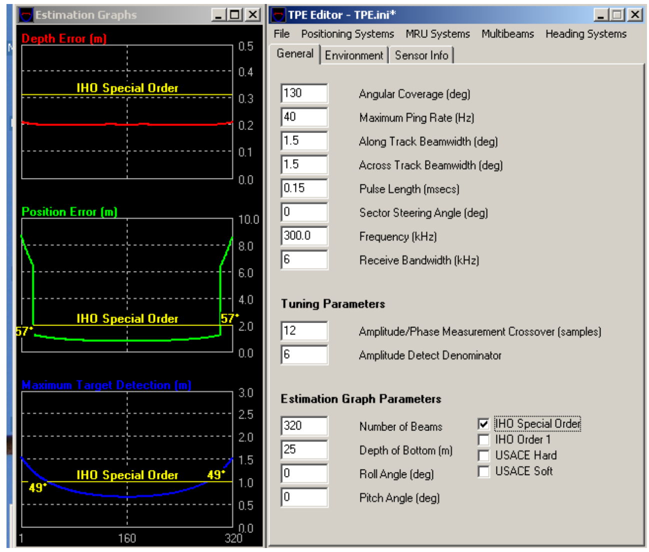
1.2 Multibeam Echo Sounder Acquisition and Monitoring

At the start of each survey day, a pre-survey protocol was run to determine and troubleshoot any possible errors that were detected. SIS Built-In Self Tests (BISTS) were run for the EM3002 dual-head system to ensure that each transducer was working properly. The height of the hydraulic mount (measured from the reference point on the mount plate to the bottom of the curved top) was measured to ensure consistency. The

GAMS parameters located under the installation settings of the POS/MV were also checked prior to enabling Ethernet logging.

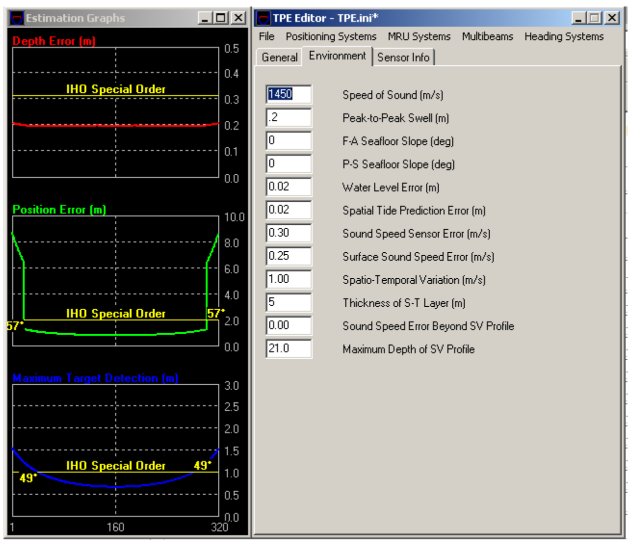
Multibeam data were acquired, logged, and monitored in real time using Kongsberg SIS-formatted (*.all) files in manual, equiangular mode, with a beam opening angle of 57/10 (port) and 10/57 (starboard). The vessel maintained a speed of 5-6 knots during the survey to ensure adequate along track bottom detection. The SIS data acquisition software produced a constantly updated on-the fly data grid, which allowed for real-time monitoring of the data coverage. Profile, plan, and rear views of individual swath data also allowed the data quality to be observed in real-time. For each transducer head, beams formed at angles of 1 - 10° were automatically flagged as rejected in order to avoid issues in the data of the outer beams. Beams formed at angles of 57° and greater were also flagged as rejected, as determined by the results of the HYPACK TPE model (Figure 7).

A single incident with the SIS software was noted at 16.09 UTC on 17 June 2008 when the software froze for several seconds during data acquisition and the dynamic positioning of the vessel was therefore not updated in real-time (see *Incident Report V.3. SIS Incident – 6/17/08 in Separates*).

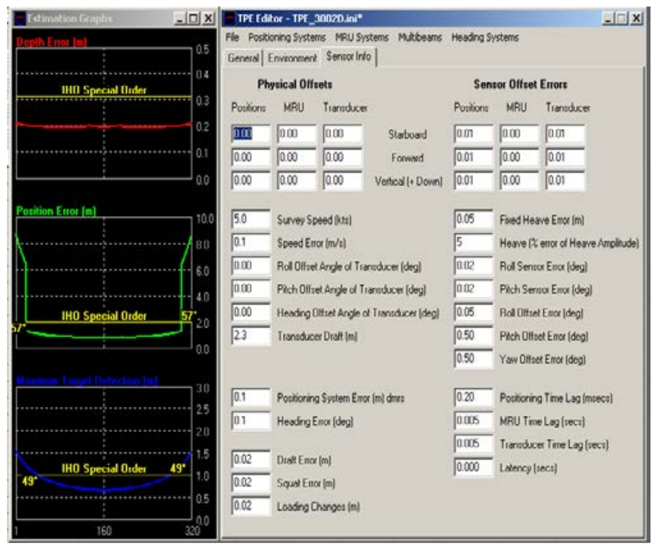


Tab settings

- Positioning Systems: Applanix Pos MV 320 RTK
- MRU Systems: Applanix Pos MV RTK
- Multibeam: SIMRAD EM3000D – modified
- Heading Systems: POS MV 320

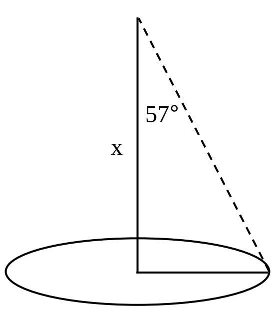


Changing port-starboard slope decreases opening angle for maximum target detection to 44°



Left as default settings, but changed draft

Footprint model based on opening angle



Effective Ping rate = sound speed velocity/ two-way travel time of outermost beams (greatest range)

Radius of beam footprint * effective ping rate = **maximum travel speed**

SWATH WIDTH = 3X water depth

Figure 7: Screen grab from the HYPACK TPE model

1.3 Survey Cross-lines

39 cross-lines, totaling 15 lineal nautical miles, were run during the survey to determine the accuracy of the echo sounder measurements. Crosslines comprised 10% of the 151 nautical miles of total lines run during the survey. For a more detailed description of the cross line analysis refer to the detailed description in the *Separates Section IV*. Cross Line Comparisons. The cross line analysis showed that IHO special order requirements were met, although only Order 1 was achieved in the Bagaduce Narrows, but this may result from a lack of a cross line in the area.

1.4 Holidays in Survey Data

Prior to the end of the survey on 6/19/08, multibeam data were examined and gridded in CARIS using the swath angle method in order to indentify holidays in the data coverage. A final line was created in HYPACK based on the location of these holidays. While all attempts were made to infill these holidays during the final two days of survey, low tide caused some of the areas to be too dangerous to maneuver.

1.5 Junction Analysis

This survey was compared to H-10131 (1984) as a quality check and to ensure continuity of the survey coverage and depth with overlapping surveys. Survey H-10131 adjoins this survey at its western limits in Castine Harbor (Figure 8).

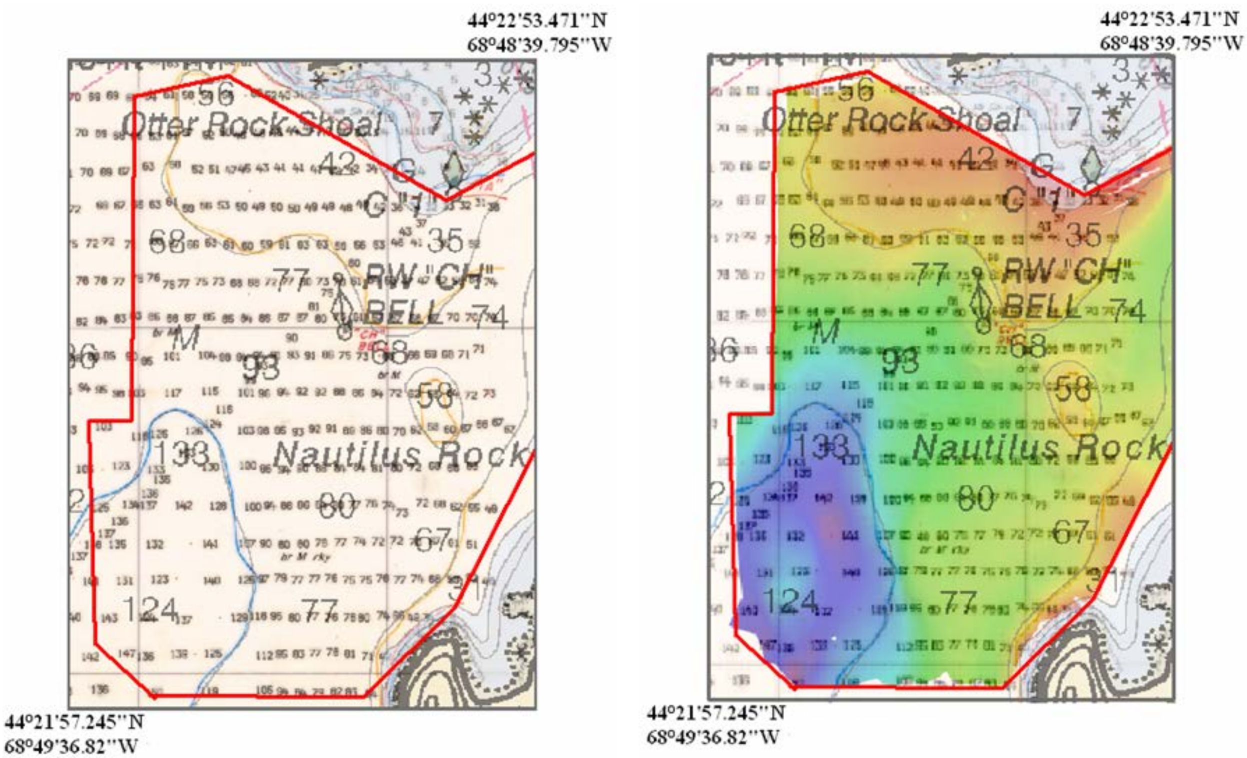


Figure 8: A) The results of NOAA survey H-10131. The red outline represents the junction with our survey. B) The same figure with our survey results overlain.

B3. Corrections to Echo Soundings

1.0 Vessel Mobilization

1.1 Sensor Offsets

Mobilization of the R/V Coastal Surveyor occurred on 10 June 2008. The vessel offsets were measured at this time with respect to the ship's reference point located at the center point on top of the Inertial Motion Unit (IMU). The vessel offsets measured were not used as there were discrepancies, particularly in the vertical, with the surveyed offsets published for the R/V Coastal Surveyor. The offset values entered into SIS were based on the 2007 offsets (Table 7), which include both new measurements and data from 2006. As a result the Z offset used for this survey was ascertained to be incorrect and the depth measurements require a vertical adjustment (see *Incident Report V.8. Z offset values – 7/02/08 in Separates*).

Table 7 - Sensor Offsets

Offsets			Comments
	Vessel	**Coastal Surveyor**	
	Sonar System	**EM3002D**	
	Positioning System	**POS/MV Model 320**	
Swath 1	Roll (°)	-0.15	
Swath 2	Roll (°)	0.3	
Offsets	IMU to Trans1 X	-0.225	Averaged distance between heads
	IMU to Trans1 Y	9.054	
	IMU to Trans1 Z	1.456	
	Nav to Trans1 X	0.958	
	Nav to Trans1 Y	9.152	
	Nav to Trans1 Z	5.055	
	Trans1 Roll	40	
Offsets	IMU to Trans2 X	0.225	Averaged distance between heads
	IMU to Trans2 Y	9.099	
	IMU to Trans2 Z	1.453	
	Nav to Trans2 X	1.400	
	Nav to Trans2 Y	9.197	
	Nav to Trans2 Z	5.052	
	Trans2 Roll	-40	

1.2 Patch Test

A patch test of the EM3002 dual-head system was conducted on June 11, 2008 (DN 160). An appropriate area was identified in the vicinity of Concord Point, New Hampshire, where the patch test was conducted (Figure 9). Patch test data were processed on site using the SIS patch utility. The pitch, roll, and heading biases obtained for the port and starboard transducers were entered into the Installation Parameters menu in SIS (Table 8). The latency between GPS reception from the radio modem and integration by the acquisition system was also measured during the patch test. A secondary roll test was intended to be conducted at the end of the calibration, however, due to time constraints this roll test was not conducted.

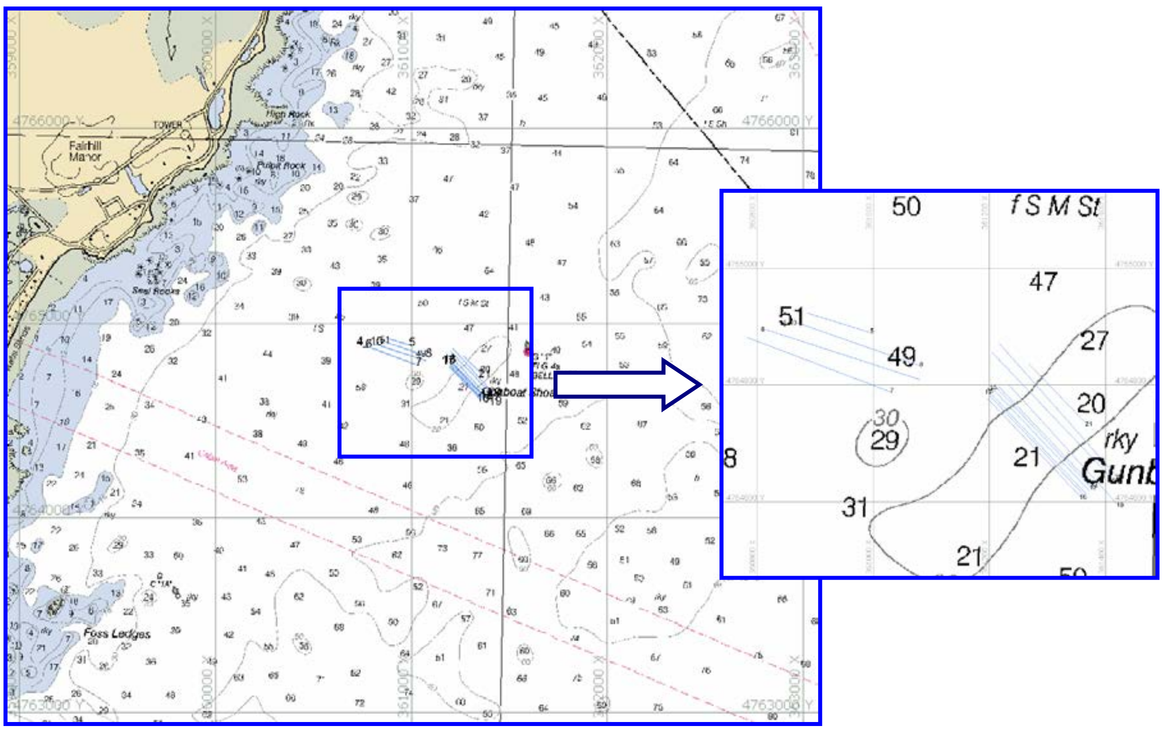


Figure 9: Patch test lines shown on NOAA chart 13283. Soundings in Feet (MLLW)

Table 8 - Angular Offsets

	Roll (º)	Latency (º)	Pitch (º)	Heading (º)
Head 1	39.01	0	2.31	359.5
Head 2	-41.9	0	2.09	359.8

A second partial patch test was performed in Castine, ME on June 20, 2008 after an initial inspection of the data showed a possible roll artifact. Three test lines west of Nautilus Rock were run (Figure 10). The lines were then processed in CARIS and the CARIS calibration tool was used to resolve the roll bias of each transducer head. A roll bias of -0.15° and 0.30° were determined for the port and starboard transducers, respectively. For a full description of the second patch test, please refer to *Separates section VIII. Patch Test.*

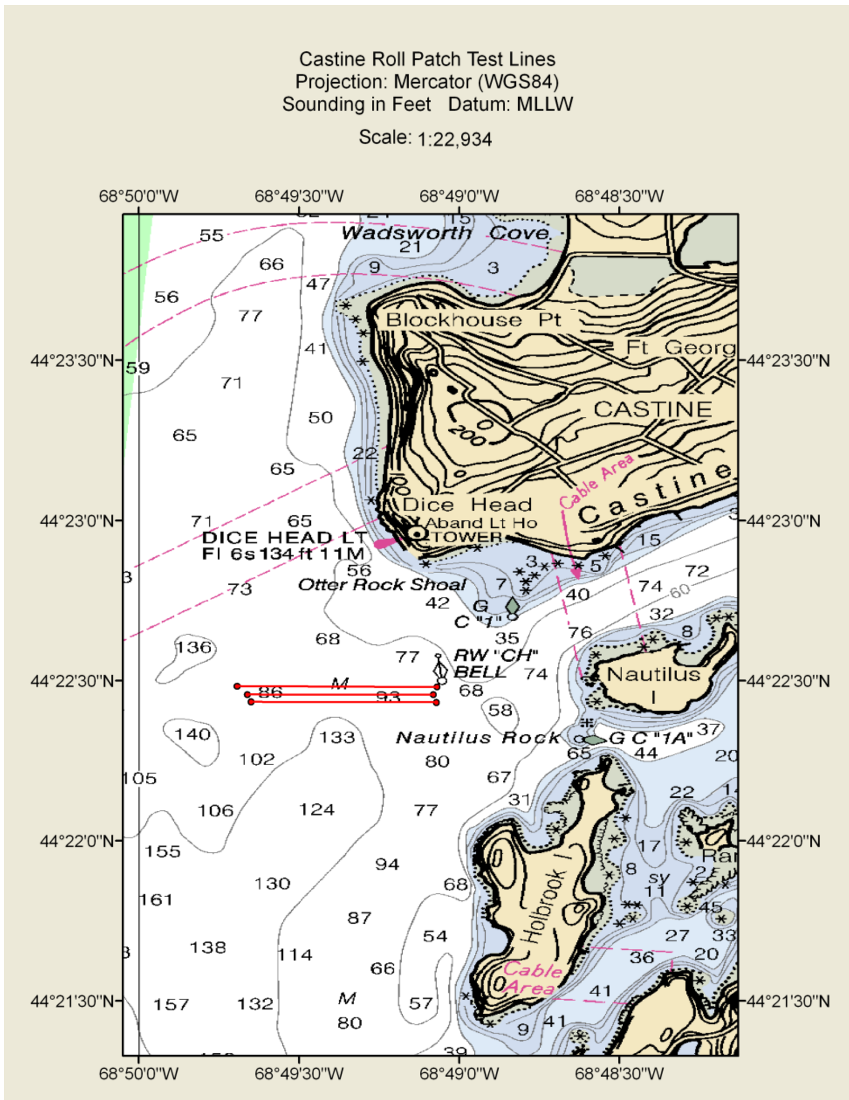


Figure 10: NOAA Chart 13309, showing location of the roll patch test lines run in Castine

3.0 POS/MV Correctors

An Applanix POS/MV unit was set up to receive phase-differential RTK position offsets from the GPS base station. The configuration allowed the POS/MV to integrate sub-meter positional solutions with highly-accurate vessel attitude positions obtained from the IMU. When the GPS Azimuth Measurement Subsystem (GAMS) was online, positional solutions were received from 5 or more satellite fixes with a Positional Dilution of Precision (PDOP) of 3 or less. When these conditions were not satisfied, the GAMS solution became dormant but continued to track satellites without processing the phase-differential corrections.

A calibration of the GAMS system was conducted at the start of survey on 6/14/08 in Castine Harbor following the auto-start procedure laid out in the POS/MV V4 Installation and Operation Guide. The GAMS parameters in the setup menu were initially set to zero, with the exception of the heading calibration threshold which was set to 0.500°. The vessel then made aggressive figure-8 maneuvers until the GAMS solution came online and the values in the parameter setup menu were automatically updated (Table 9).

Table 9 – POS/MV Calibration

POS/MV Post-Calibration Values	
Two Antenna Separation (m)	2.198
Heading Calibration Threshold	0.500
Heading Calibration	0
Baseline Vector	
X Component (m)	0.043
Y Component (m)	2.190
Z Component (m)	-0.023

4.0 Dynamic Draft Correctors

4.1 Static Draft and Loading

The static draft of the R/V Coastal Surveyor was observed by measuring the distance between the water line in the draft tube and the reference point on the IMU. These measurements were made throughout the survey while sound velocity casts were being taken. The values were recorded and entered directly into SIS as the waterline value in the installation parameters menu (Table 10).

Table 10 - Waterline Measurements

Date and Time	Water Line
2008-163 12:00	0.499
2008-167 12:56	0.514
2008-167 14:36	0.523
2008-167 17:45	0.512
2008-168 14:42	0.520
2008-168 15:05	0.517
2008-168 17:23	0.510
2008-168 18:07	0.516
2008-169 12:45	0.517
2008-169 14:35	0.519
2008-169 17:00	0.523
2008-169 20:21	0.521
2008-170 13:24	0.495
2008-170 14:57	0.510
2008-170 17:04	0.500
2008-170 19:17	0.495
2008-171 13:10	0.498
2008-171 16:21	0.520
2008-171 18:34	0.520
2008-172 12:50	0.520
2008-172 15:14	0.570*

*erroneous value which should be 0.517. Corrected in CARIS (refer to Separates V.7.)

Two separate draft measurement incidents occurred during the survey. No measurements were taken on the first day (*Separate SectionV.2. Draft Incident – 6/14/08*) and the draft value determined during the patch test was used. A second incident involved the incorrect input of a draft measurement into SIS. The final draft measurement taken on 6/20/08 (JD 172) at 15:14 UTC was entered into SIS as 0.570 m. It was noted that this value was outside the range of the draft values recorded throughout the survey and that a correction to the draft was required. A correction value of 0.517 m was determined based on prior static draft measurements (Refer to *Separates section V. Survey Incident Report* for more detail).

4.2 Settlement and Squat

Measurements of settlement and squat for the R/V Coastal Surveyor using RTK-GPS were previously made by the Summer Hydro 2006 class (Figure 11 and Table 1).

Eighteen measurements were conducted at various speeds, each approximately 3 minutes long. Ellipsoidal height, pitch, speed-over-ground, speed-through-water, and engine RMS were recorded at 1-second intervals for each run. Eight of the measurement runs were conducted against the tidal current, eight with the current, and two stations with respect to the current. Local tidal heights were recorded during the measurements in order to correct the ellipsoidal heights. The change in height of the transducer face was then calculated from the tide-corrected ellipsoidal heights recorded by the POS MV and referenced to the IMU. Separate pitch measurements were not included in the settlement or squat analysis, as they are already corrected for by the IMU itself.

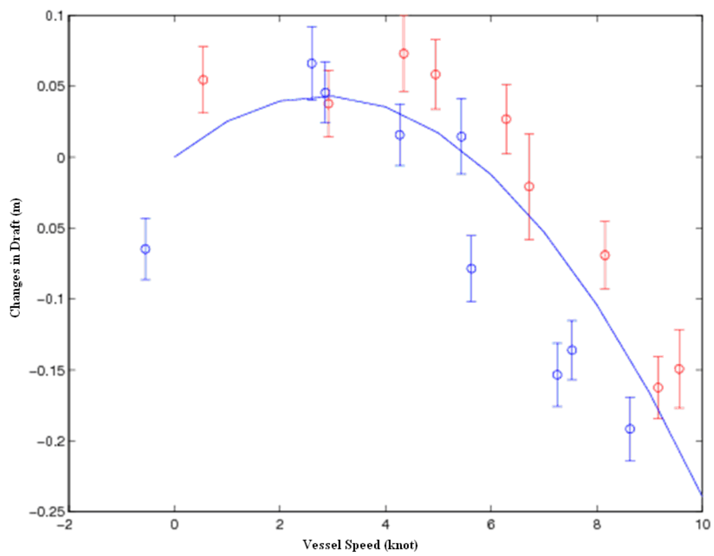


Figure 11: Graph of Squat and Settlement vs. Speed of the R/V Coastal Surveyor though the water (red represents against current and blue with current). Values measured in 2006.

Table 11 - Settlement and squat due to speed of the R/V Coastal Surveyor

Vessel Speed (knots)	Settlement and Squat (m)
0	0.000
1	0.025
2	0.040
3	0.043
4	0.035
5	0.017
6	-0.012
7	-0.053
8	-0.104
9	-0.166
10	-0.239

5.0 Sound Speed Correctors

Sound speed profiles were taken at the start of each survey day, and again throughout the day as warranted by the data. A total of 26 sound velocity profiles where taken during the survey (Figure 12). A comparison of the cast data was conducted in order to determine sound speed variations in different parts of the survey area (Figure 13). When the discrepancy between the sound speed measured at the transducer face and that of the sound speed profile (compared at the same depth automatically in SIS) exceeded 5 m/s (indicated by a red flag on the SIS software interface), another cast was typically taken unless the red flag dropped shortly afterwards. The sound velocity and temperature data for each cast is included in *Separates Section II, Sound Speed Data*.

The sound velocity varied considerably throughout the survey and notes were kept in the *Acquisition Logs* whenever a warning flag (yellow and red) was observed on SIS. The warmer water in the shoaler areas in association with strong tidal currents often resulted in considerable variation in the surface layer sound speed. Many lines were surveyed with differences of >3 m/s although the effects of refraction does not appear to have affected the quality of the data.

Two separate *Incident Reports* are described for the SV measurements. The cable connection to the data logger sheared and required temporary repairs after which it worked without any further issues (*Incident Report V.4. SVP Cable Incident – 6/19/08 in Separates Section*). In addition, an error occurred in downloading data from the datalogger and the same cast was downloaded 3 times. Although an attempt was made to correct this in post-processing, it was unsuccessful and the first cast data downloaded for real-processing in SIS was used (*Incident Report V.6. Sound Speed Incident – 6/19/08 in Separates*).

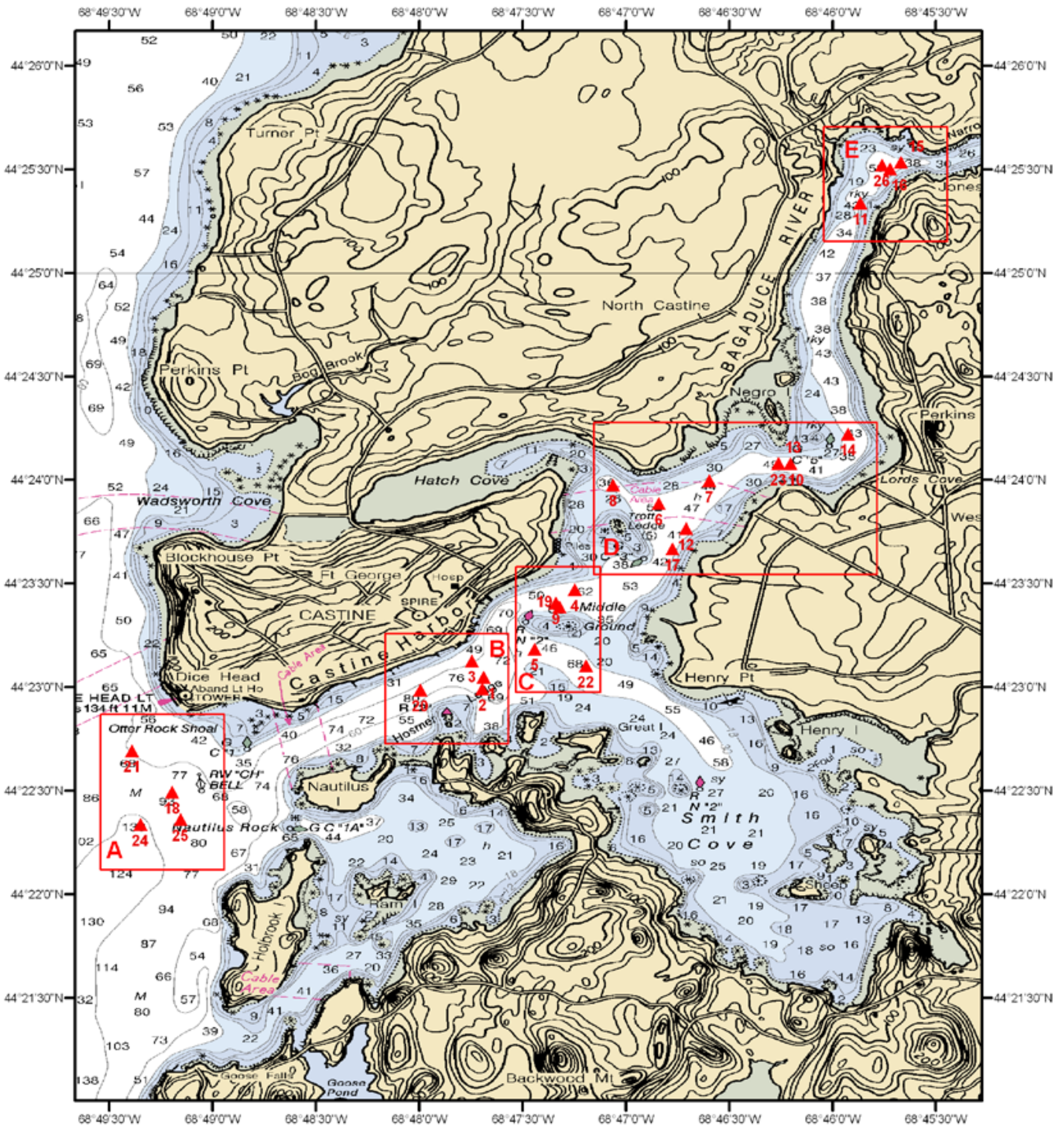


Figure 12 - Location map of sound velocity casts, grouped by area throughout the survey

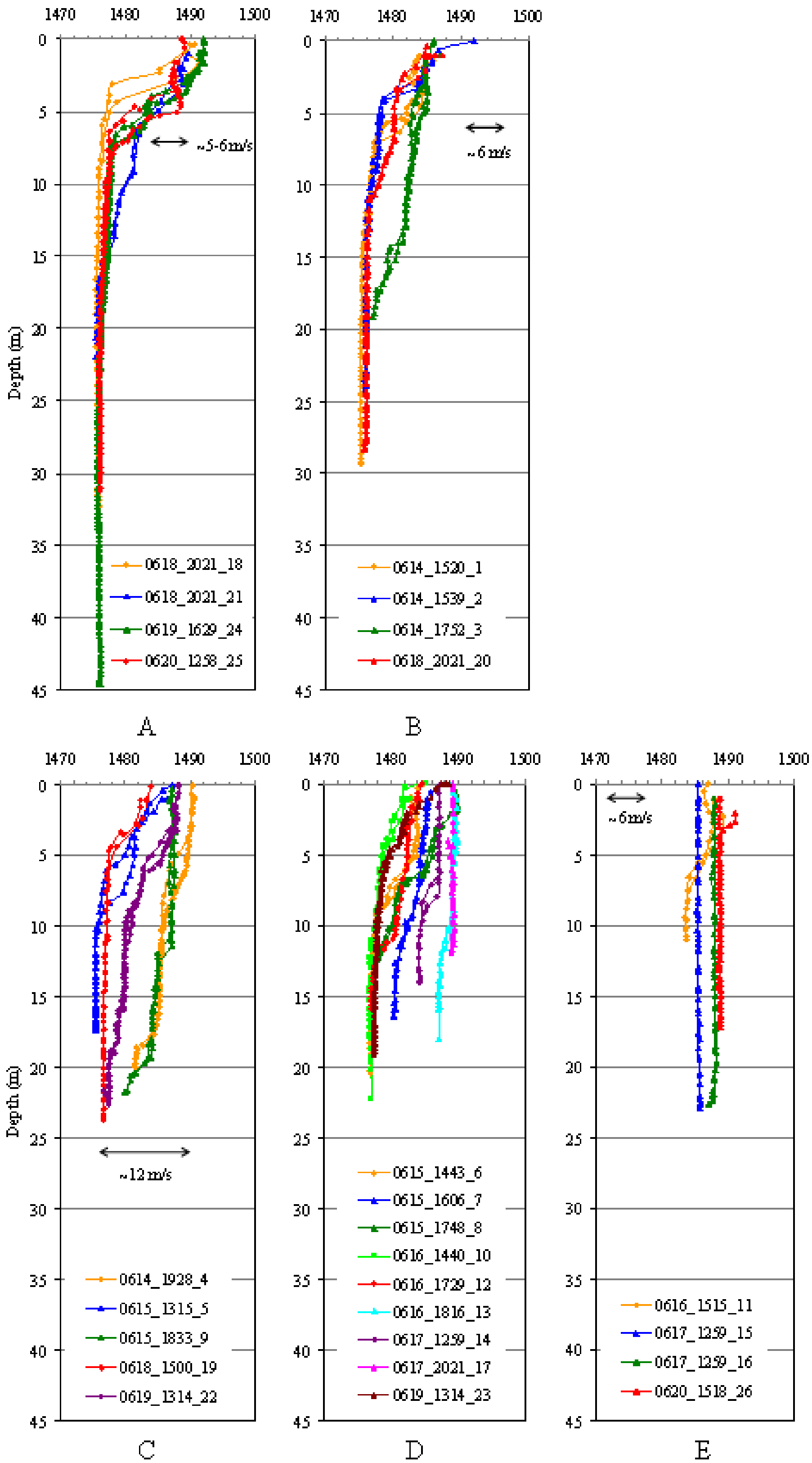


Figure 13 - Sound velocity profiles taken during the survey. Profiles are grouped by area

6.0 Water Level Correctors

Tidal measurements were continuously recorded throughout the survey by the Aanderaa WLTS installed in Castine Harbor. Python was used to convert the raw 12-data record from engineering units to water level and temperature measurements. The data were then compared to the NOAA primary station in Bar Harbor, ME using the Modified Range Ratio Method as outlined in the NOAA Special Publication NOS CO-OPS2 "Computational Techniques for Tidal Datums Handbook" in order to determine the level of MLLW at Castine. The resulting tidal record was applied to the echo soundings during post-processing in CARIS. An offset of approximately 20 cm was observed in the tidal data at approximately 6:00 am UTC on the June 19, 2008. This brief offset did not affect the rest of the tidal data (Refer to *Separates section V. Incidents Report* for a full-description).

B4. Data Processing

1.0 Multibeam Echo Sounder Processing

1.1 Processing Workflow

The multibeam data processing for this survey followed the general CARIS HIPS and SIPS workflow shown below (Figure 14).

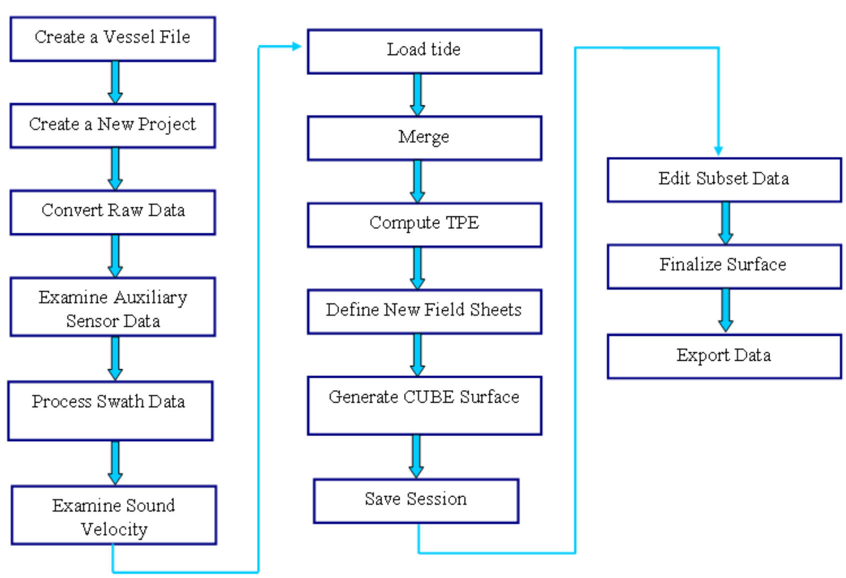


Figure 14 - CARIS HIPS and SIPS data processing workflow

1.2 Vessel Configuration File

Offsets measured from the R/V Coastal Surveyor were used to create a CARIS vessel configuration file (or HIPS Vessel File (.hvf)) within the CARIS Vessel Editor. Measured sensor offsets and calculated patch test offsets were applied to the data on-the-fly via SIS. The apply option for all offset values in the vessel file, with the exception of a few correctors applied in post-processing, was set to “no.” The static draft measurements recorded during each sound velocity cast were entered into the vessel configuration file in the waterline table. Sensor manufacturer and model information, including specifications and standard deviation values, were also entered into the vessel configuration file in order to accurately compute the Total Propagated Error (TPE) (Table 12 - Standard deviation).

1.3 Correctors Applied in Post-processing

The final static draft measurement recorded on 6/20/08 at 15:14 UTC required a correction value of -0.053 m, which was entered into the waterline table in the HVF and applied to the data (refer to *Separates section V. Survey Incident Report* for a more detailed explanation). Residual roll biases of -0.15° and 0.30° for the port and starboard transducers, respectively, were observed after the initial gridding of the data, and were applied in the HVF.

1.4 Data Conversion and CUBE Processing

All survey lines were converted into CARIS line files and imported into the CARIS project created for this survey. Although not all survey lines were examined in detail, each group inspected approximately 3 – 4 of the lines collected during their survey days in order to determine if any issues were present. Auxiliary sensor data from the POS/MV were examined for survey lines 0342 to 0346, collected by group 3 on 6/19/2008. Attitude and navigation data looked clean, with no apparent issues. The processed tide record from the tide gauge installed at Castine Harbor was loaded and merged with all survey lines.

Table 12 - Standard deviation

Standard Deviation			Comments
	Vessel	**Coastal Surveyor**	
	Sonar System	**EM3002D**	
	Positioning System	**POS/MV Model 320**	
Motion Sensor	Motion Gyro (°)	0.020	Applanix POS/MV Instrument Specifications (RTK) 2 m baseline)
	Heave% Amp	5.000	
	Heave (m)	0.050	
	Roll (°)	0.010	
	Pitch (°)	0.010	
	Position Nav (m)	0.100	
Latency	Timing Trans (s)	0.010	PPS signals typically have 0.01 second standard deviation
	Nav Timing (s)	0.010	
	Gyro Timing (s)	0.010	
	Heave Timing (s)	0.010	
	Pitch Timing (s)	0.010	
	Roll Timing (s)	0.010	
Vessel Offsets	Offset X (m)	0.001	
	Offset Y (m)	0.052	
	Offset Z (m)	0.025	
Motion Sensor	Vessel Speed (m/s)	0.030	Applanix POS/MV Instrument Specifications
Waterline	Loading	0.010	On board Draft Tube measurements
	Draft (m)	0.010	
	DeltaDraft (m)	0.012	Based on 2006 value as used Val Schmidt's dynamic draft model
IMU Alignment	IMU alignStdev gyro	0.010	Determined point at which change in input showed no observable offset in data in CARIS calibration procedure
	IMU align roll/pitch	0.040	
Tides	Tide Meas (m)	0.050	Aanderaa Instrument Specifications (0.01m) + 0.04 m leveling error
	Tide Zoning (m)	0.200	To account for tidal phase and range offsets
Sound Velocity	Surface SV (m/s)	5.000	Observed variations for surface sound speed with values ranging up to ~ 5 m/s
	SV Meas (m/s)	4.000	Maximum range observed between profiles within survey sub-area (see Fig. 8)

Prior to creating the CUBE surface, the Total Propagated Error (TPE) was computed for the data. The CARIS TPE module requires user-entered estimated error values for the tide and sound velocity measurements. A tide measurement error of 0.05 m was specified, based on the 0.01 m accuracy stated by the manufacturer and an assumed

0.04 m leveling accuracy. Although tide zoning was not used in this project, a value of 0.02 m was entered in the TPE table as the tide zone error to account for tidal phase and range offsets. The surface sound velocity error of 5 m/s was based on the allowable offset between the surface sound velocity measured by the surface probe mounted at the transducer face and that measured during the sound velocity cast. The variation of measured sound speed profiles for a given area in the survey was approximately 4 m/s. This value was entered in to the TPE table as the measured sound velocity error.

Upon completion of the TPE computation, a fieldsheet covering the entire survey extent was created and a CUBE surface was generated at a grid resolution of 0.5 m. The CUBE surface showed very few areas with more than one hypothesis, and no changes were made to primary nominations. The CUBE surface showed areas of offset on the order of 20 cm to 40 cm. These offsets are not well understood but are believed to be due to a tide phase error. A CARIS tide zone file was applied to the data in an attempt to correct for some of these offsets. This method did not prove to be successful, and the zone file was later removed. Time constraints prevented further attempts to mitigate the offset issue and for the purposes of this report, the data were used as is.

1.5 Accuracy Evaluation

An evaluation of the accuracy of the survey data was conducted with a cross-check comparison between the primary survey lines and the cross lines. In order to facilitate the analysis, the survey area was divided into five sub-areas in CARIS. Two separate CUBE surfaces, a cross line surface and a primary line surface, were generated for each subarea and the XYZ data exported into Fledermaus. The Fledermaus CrossCheck application was used to compute surface differences and statistics for the areas (see Figure 15). The initial comparison was conducted without filtering the surface. A second comparison was then run after applying a 5-m filter to the surface. All areas, with the exception of Area E located in the Narrows at the northern extent of the survey, met IHO Special Order specifications (Table 13). For a full description of the cross-check comparison, please refer to *Section IV. Cross Line Comparisons*, in the *Separates* document.

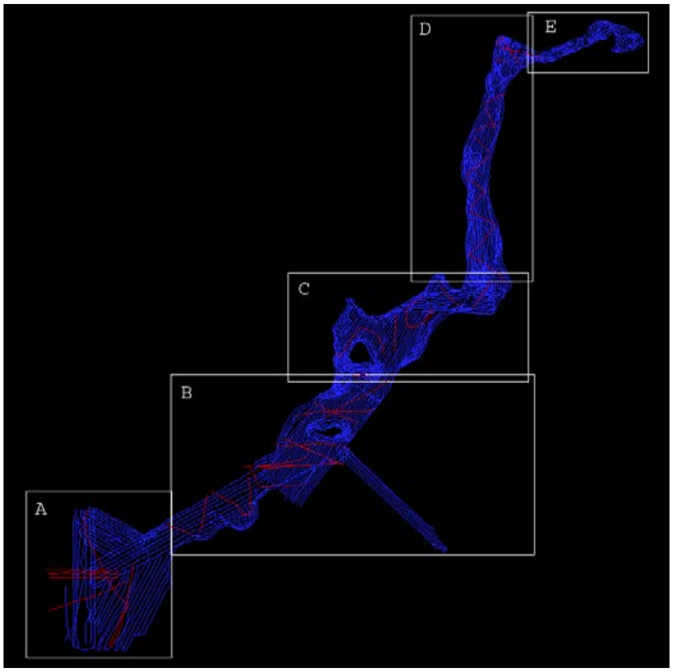


Figure 15. Image from CARIS with both cross lines (red) and main survey lines (blue).

Table 13 - Results of the cross-check analysis with and without outliers

Area A		
	With Outliers	Without Outliers
Mean Difference	1.71	-0.0293
Order Fulfilled	None	Special Order

Area B		
	With Outliers	Without Outliers
Mean Difference	0.1592	-0.0393
Order Fulfilled	Order 1	Special Order

Area C		
	With Outliers	Without Outliers
Mean Difference	-0.1135	-0.1135
Order Fulfilled	Special Order	Special Order

Area D		
	With Outliers	Without Outliers
Mean Difference	-0.03	-0.03
Order Fulfilled	Special Order	Special Order

Area E		
	With Outliers	Without Outliers
Mean Difference	0.1211	0.1211
Order Fulfilled	Order 1	Order 1

1.6 Uncertainty and Standard Deviation Analysis

CARIS TPE was used to calculate a vertical uncertainty value for each sounding in our dataset prior to creating the CUBE surface (Figure 16). The uncertainty values ranged from approximately 0.40 m to 0.70 m, with the maximum values occurring at the western edge of the survey in the deeper waters just west of Castine harbor.

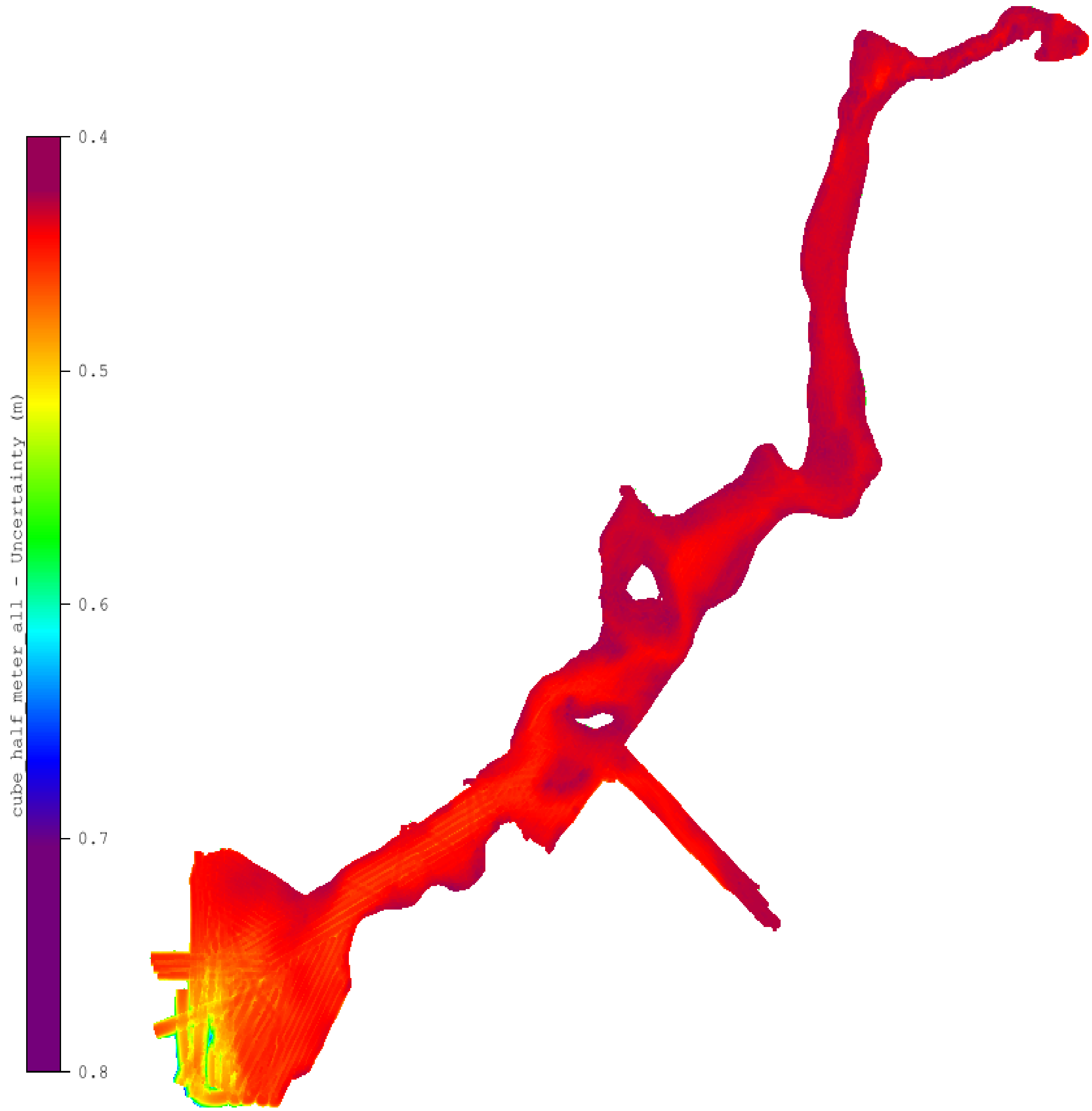


Figure 16: Uncertainty surface of survey calculated in CARIS

The standard deviations of the soundings within each grid node were also computed by CARIS during the CUBE surface creation (Figure 17). Standard deviation (std) values ranged between 0 and 1.117. Problem lines and areas are typically associated with high standard deviation values.

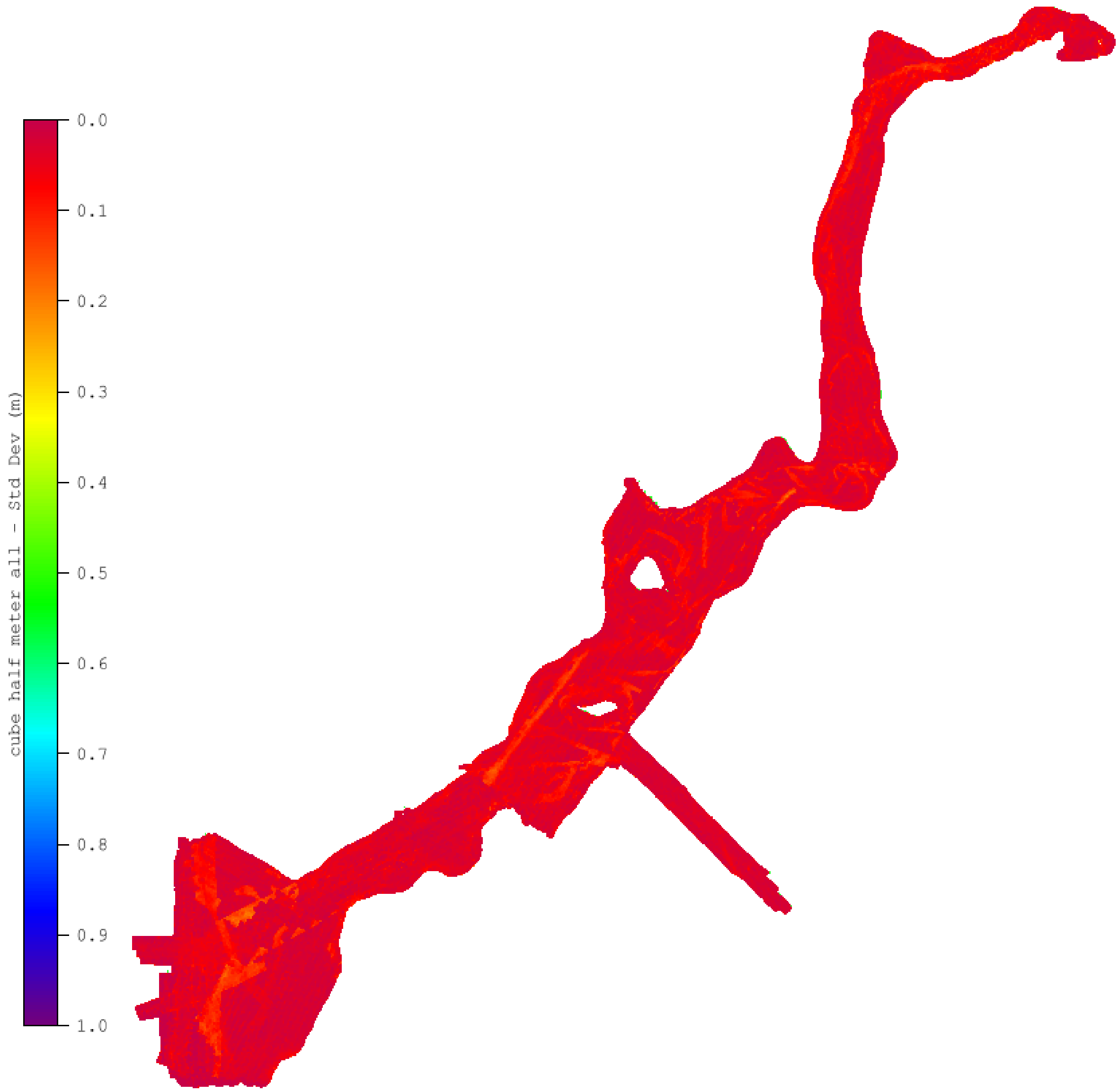


Figure 17: CUBE standard deviation surface

C. VERTICAL AND HORIZONTAL CONTROL

C1. Vertical Control

The vertical datum for this survey is Mean Lower Low Water (MLLW). A NOAA operational tide station at Bar Harbor, Maine (44°23'30"N 68°12'18"W, ID# 8413320), was used as the primary station. A secondary tide gauge was installed in Castine harbor from a fixed pier (44°23'11.04"N 68°47'55.032"W) 37 days prior to the survey. The equivalent 19-year MLLW datum for the Castine harbor tide dataset was computed using the Modified Range Ratio Method (with the methodology used described in detail in *Appendix IV.5*).

A backup tide gauge was installed along the Bagaduce River (44°23'32.028" N 68°46'19.848"W), but was non-operational during the survey due to a technical fault in the pressure sensor. Tidal corrections for data processing were based on tidal data acquired from the Castine Harbor tide station.

The data stream from the Aanderaa tide gauge located in Castine, ME provides a 12-second tide record and is comprised of 5 columns: station ID number, raw water level value, raw temperature value, station name, and UTC time stamp. The example below is from June 09, 2008:

635 117 385,rmemma,1213020781.05

The raw water level value is converted to meters using the following equation:

$$\text{Water Level(m)}=(A_m + B_m * N + C_m * N^2 + D_m * N^3)$$

where
$A_m = -1.008E-01$
$B_m = 5.125E-03$
$C_m = 7.402E-08$
$D_m = 0$
N = 12-bit raw water level value

The coefficients A_m, B_m, C_m, and D_m were determined by calibrating the tide gauge and correcting for density and gravity. The calibration is performed in freshwater with a density of 1 g/cm^3 and uses the international standard for gravity of 9.80665 m/s^2.

Python was used to code a conversion of the raw pressure sensor data into water level measurements. A copy of the full code is included in *Appendix IV.6.*

The tide gauge was leveled using fixed survey points, which included two undocumented Coast and Geodetic Survey benchmarks (see *Appendix IV.3. Tide Gauge Leveling of Castine Tide Gauge*). A second GPS base station was set up above BM-A and an OPUS solution position for this location was obtained which allowed the tide gauge data to be referenced to the geoid (see Figure 18).

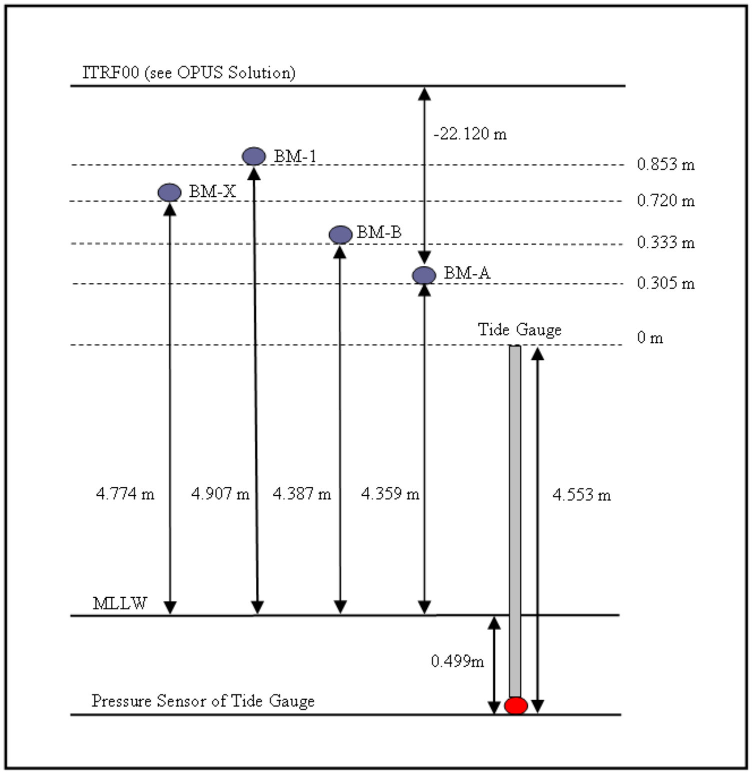


Figure 18: Tide gauge leveling

C.2 Horizontal Control

The World Geodetic System of 1984 (WGS84) was used as the horizontal datum for this survey. The horizontal positioning was given by a POS/MV in conjunction with an IMU, which was controlled using Real Time Kinematic (RTK) corrections. The RTK base station was set up on the roof of Curtis Hall dormitory on the Maine Maritime Academy campus in Castine, Maine. The base station position was determined by collecting GPS satellite observations for approximately three hours and sending the data to the National Geodetic Survey (NGS) using the Online Position User Service (OPUS). The final position of the station was 44°23’16.68”N 68°48’12.93”W with a height of 20.601m. The horizontal accuracy at the RTK base station was 0.012m and the vertical accuracy was 0.038m.

D. RESULTS AND RECOMMENDATIONS

The final chart, summarizing the results of the current status of the processed multibeam data is shown in Figure 19.

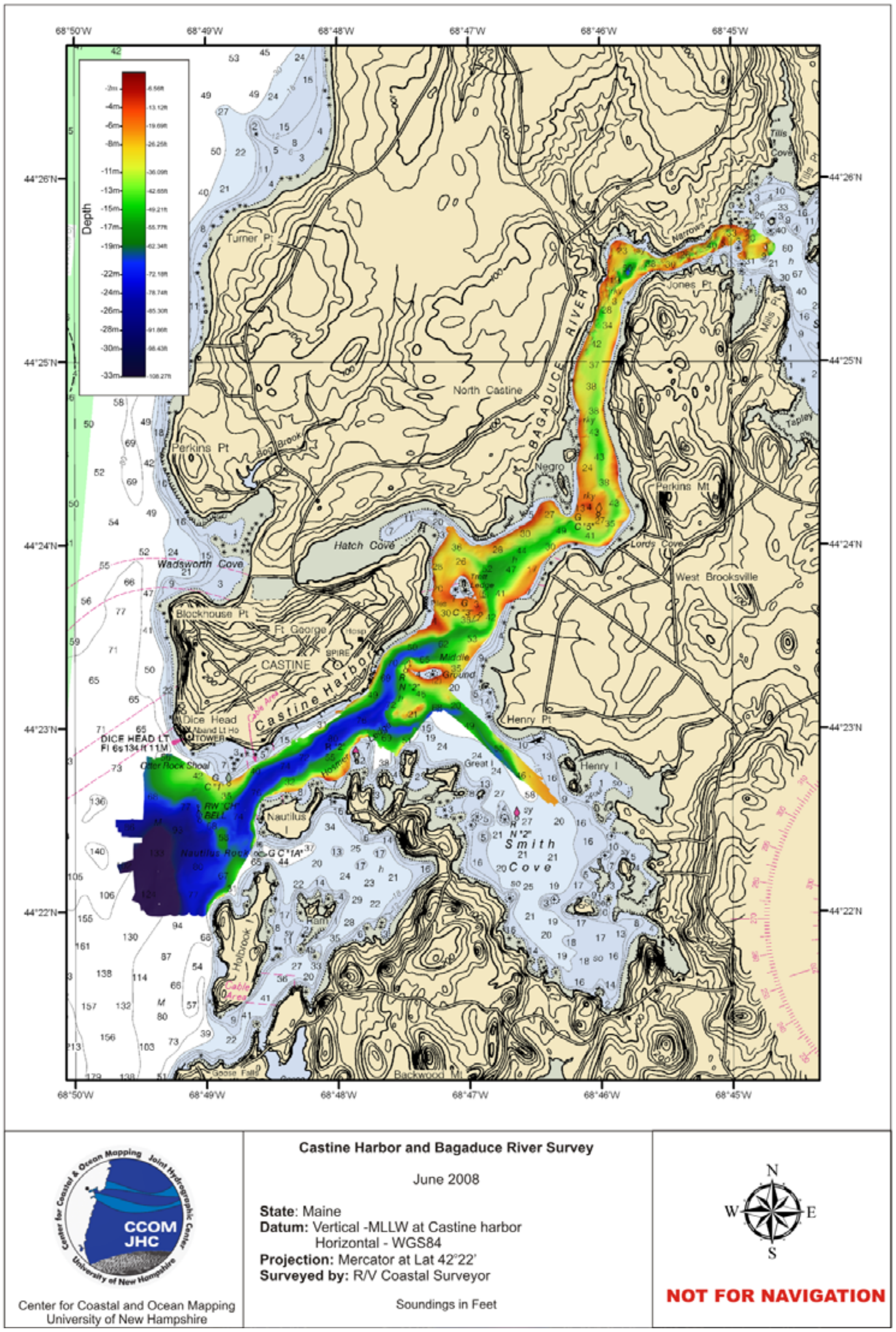


Figure 19: Final progress sketch of survey

D1. Chart Comparison

The chart comparison was carried out with NOAA chart 13309. The data from this survey were too dense to compare in their entirety, so the dataset was down-sampled to 1:50,000 using Matlab. The nautical chart and the CARIS gridded soundings were put together into ArcGIS. Three different areas were selected for analysis: the western extent of the survey, the Middle Grounds, and the Narrows. Soundings in the western extent of the survey are almost the same excepting a few locations (Figure 20). It appears that there are offsets between this survey and the chart on the order of about 2 to 3 feet. However, the value of depth soundings from the existing chart is consistently lower than the current survey soundings. For the comparison in the Middle Grounds, the majority of deeper soundings tend to agree (Figure 21). The shoals areas, however, show some major offsets in the order of 10 to 15 feet. The data on the NOAA chart in this area were collected in the early 1880’s, therefore, it is possible that the offsets are real. The final comparison was made in the Narrows (Figure 22). In general, there is an agreement between charted soundings and the ones from this survey. The average sounding offset in this area is about 1 to 2 feet.

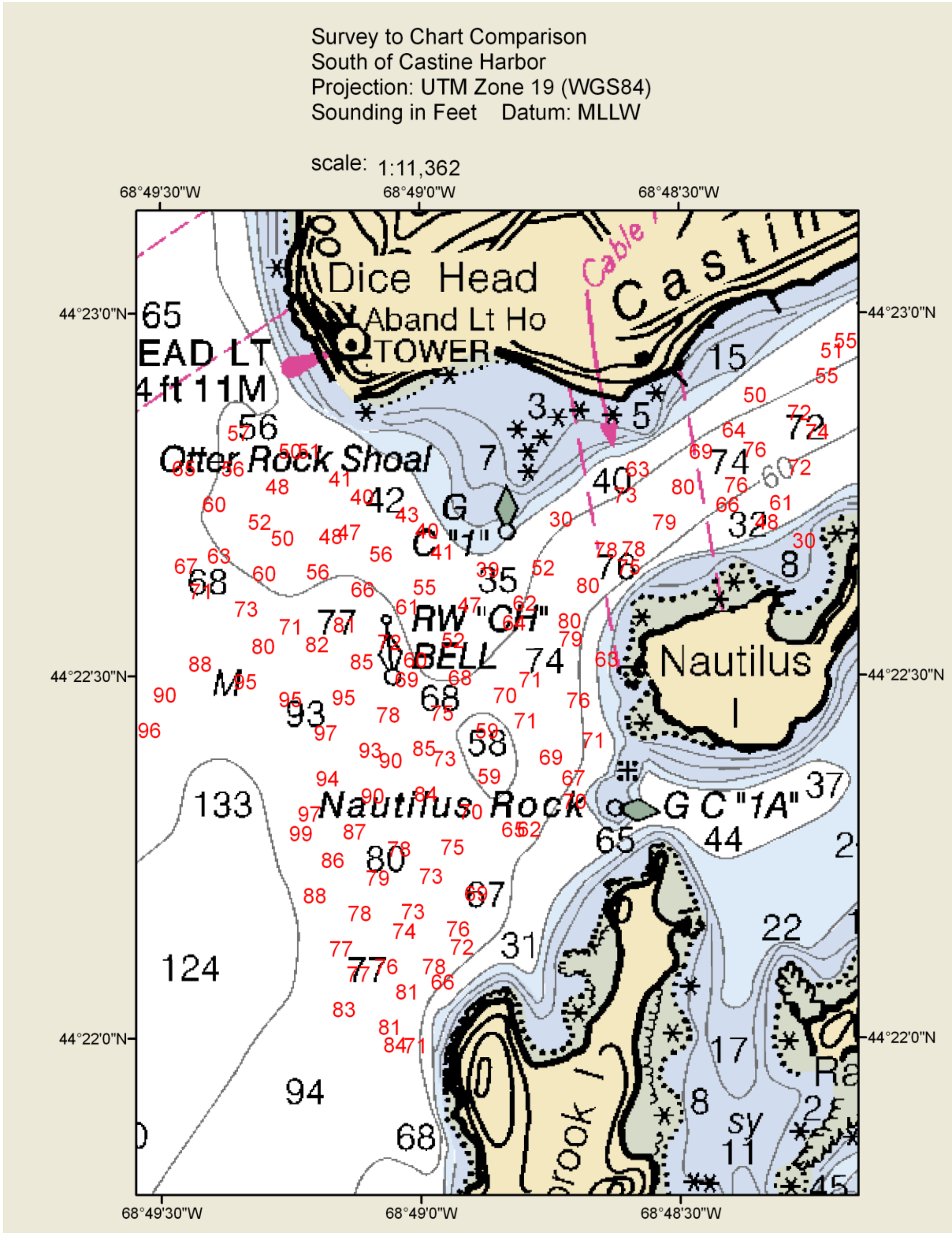


Figure 20: Chart (13309) comparison for western edge of survey

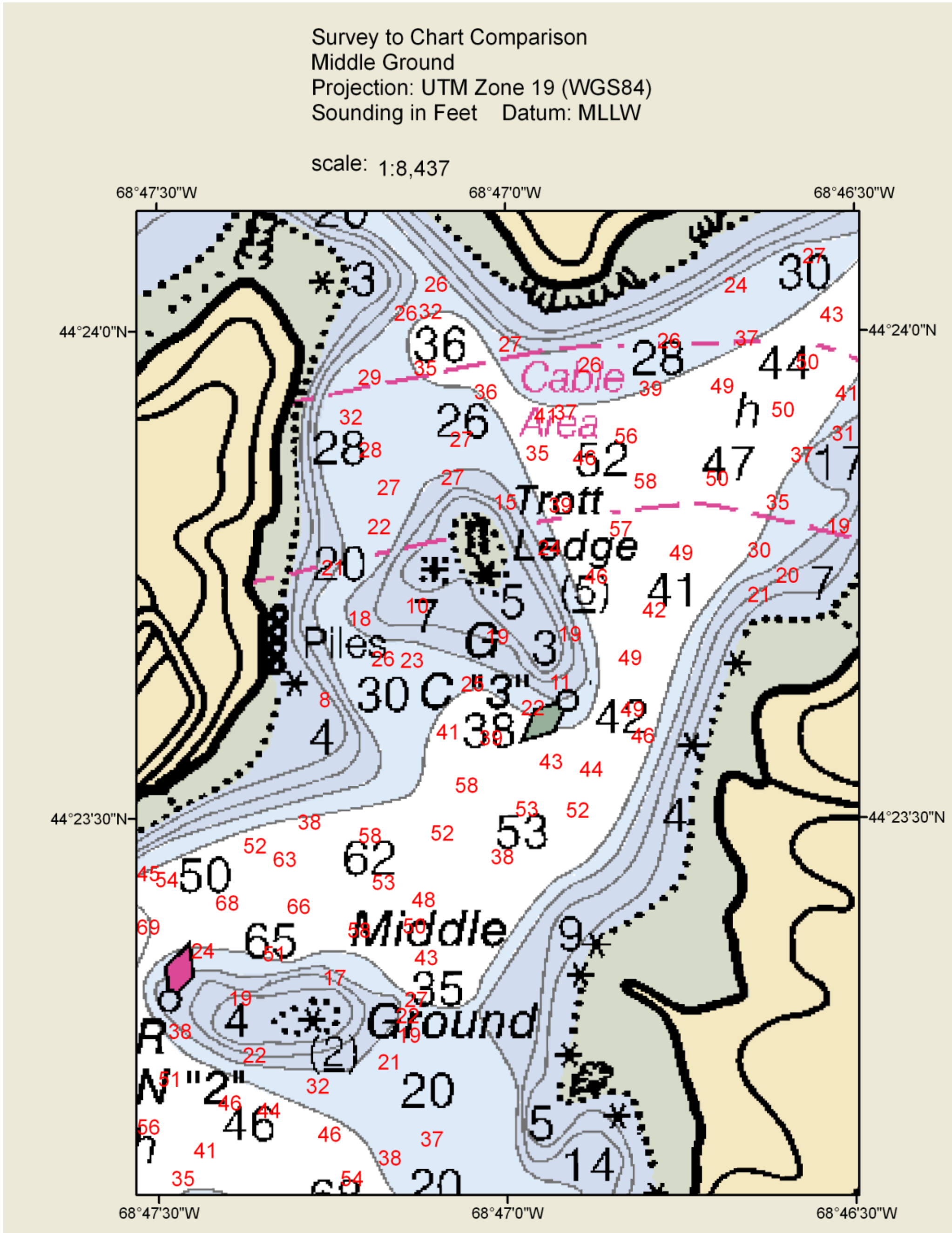


Figure 21: Chart (13309) comparison for the Middle Grounds

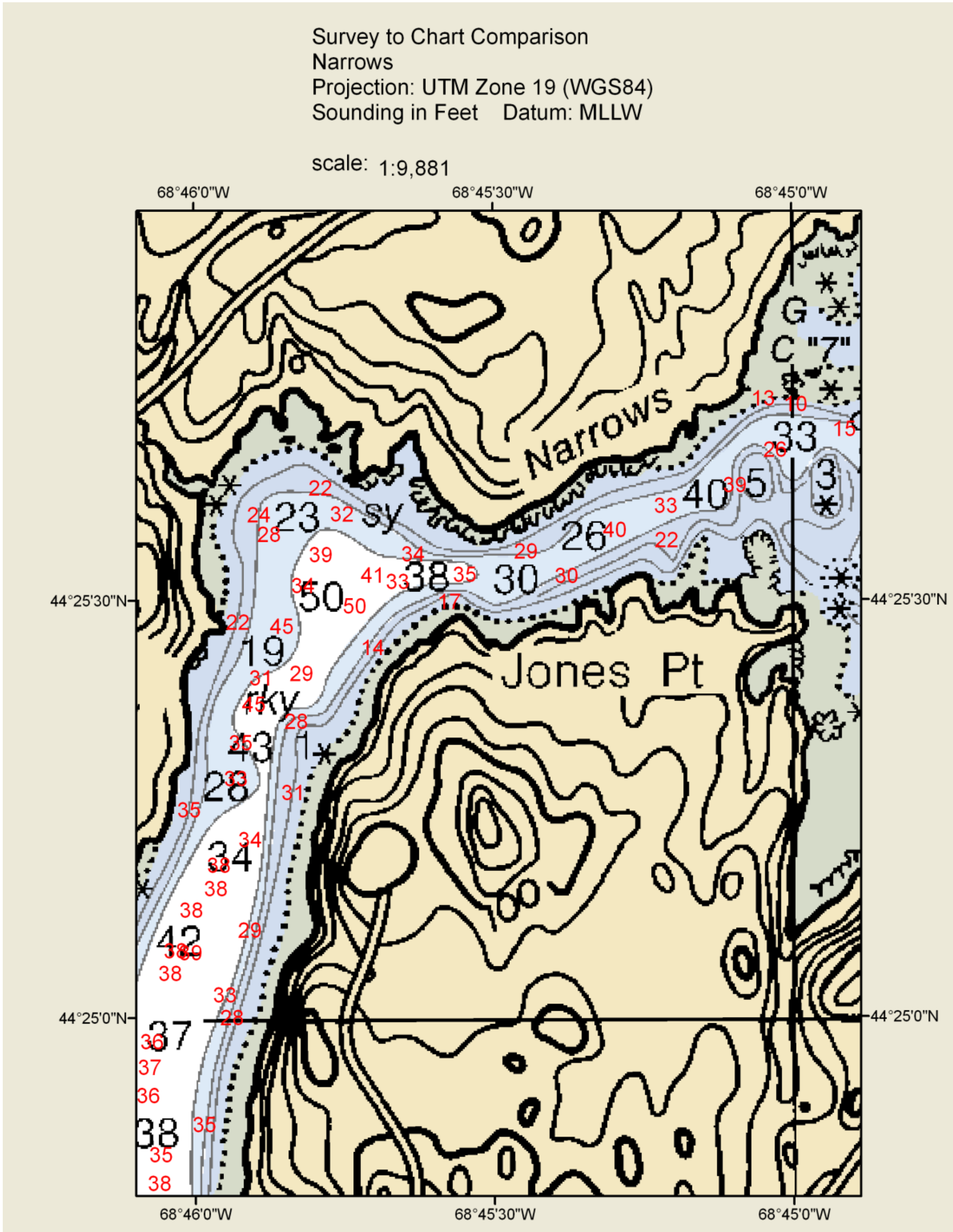


Figure 22: Chart (13309) comparison for the Narrows

D2 Concluding Remarks

The hydrographic survey of Castine Harbor and the Bagaduce River in Maine resulted in the collection of ~165 nm of multibeam data. Although the survey was largely successful, a number of the problems experienced were largely a result of being away from home-based logistical support. In addition, not having sufficient technical support and training in the use of the equipment resulted in the loss of an additional tide gauge in the north of the area.

The tidal data proved to be a particularly difficult issue to deal with, largely due to the sheer volume of data acquired. This issue took more time to sort out than initially anticipated, and as a result delayed the start of multibeam data processing. The lack of a computer network and sufficient machines for processing were also an issue, and further impeded data processing. The fact that the multibeam data were not sufficiently processed prior to the end of the survey was one of the greatest issues faced during this course.

A vertical offset of approximately 20 – 40 cm in some of the survey lines indicates a potentially serious tidal error that still needs to be sorted out. In order to determine if the offsets are indeed due to tide, the data will to be referenced to the WGS84 ellipsoid and reprocessed using a zero tide correction. Another serious error that still needs to be addressed involves the erroneous Z offset values between the transducers and the IMU that were entered into SIS. A measurement of this Z value made on 7/3/2008 has indicated that this blunder has resulted in a systematic error of approximately 0.15 m throughout the survey. This offset must be accounted for during final data processing.

APPENDIX I

TIDE NOTE AND GRAPHICS

III. Final Progress Sketch and Survey Outline

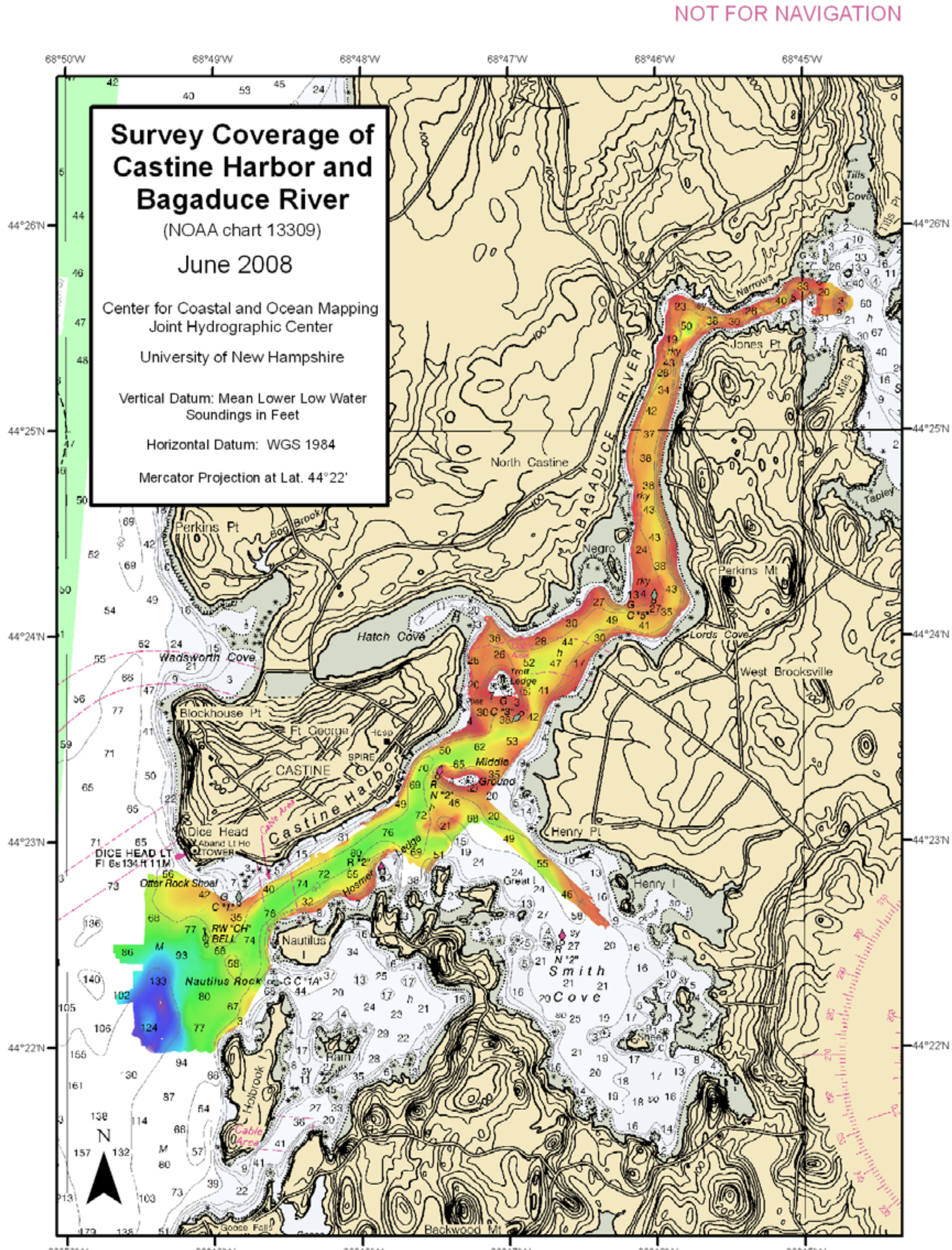


Figure 1. Summary chart showing surveyed area projected in NOAA Nautical Chart 13309.

IV. Tides and Water Levels

IV. 1 Times of Hydrographic Survey

The survey day start and end times are shown below in Table 1.

Table 1. Days and Times (UTC) for the survey

Year_Day	Start Time	End Time
2008_166	14:44:36	20:40:42
2008_167	13:20:22	20:26:34
2008_168	14:25:08	20:15:16
2008_169	13:12:52	20:29:22
2008_170	13:52:03	20:15:39
2008_171	13:32:39	19:55:00
2008_172	12:45:41	20:09:14

IV.2. Tide Station at Castine

Tidal data were collected from a tide gauge station on a fixed pier in Castine harbor at 44°23’10.94”N, 68° 47’48.19”W. The tide gauge station equipment is described in detail in the descriptive report. See DR for more details.

IV.3. Tide Gauge Leveling of Castine Tide Gauge

The tide gauge at Castine harbor was leveled using four survey fixed points in the vicinity of the tide gauge, two of which were unidentified US Coast & Geodetic Survey benchmarks (Figure IV-1 and IV-2).

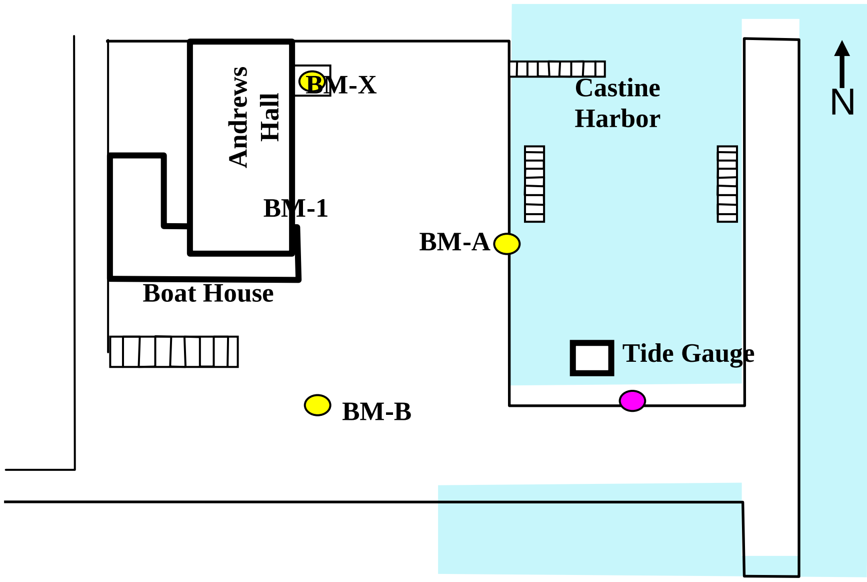
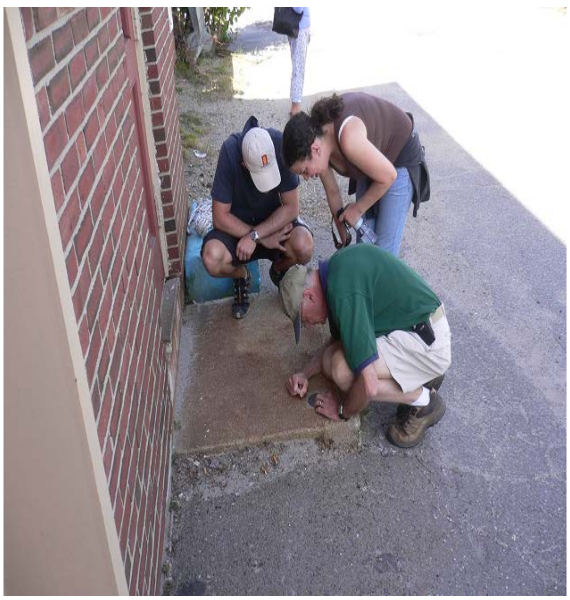


Figure 2. Tide Gauge and Benchmarks in Castine harbor.

Table 2. Benchmarks from Castine harbor.

DESCRIPTION OF BENCH MARK	DESCRIPTION OF BENCH MARK
1. **B. M. No.** BM-1	1. **B. M. No.** BM-X
2. **Established by:** U.S. COAST & GEODETIC SURVEY. **Date:** 1970	2. **Established by:** U.S. COAST & GEODETIC SURVEY. **Date:** 1970
3. **Recovered by:** Andy Armstrong **Date:** 6/13/2008	3. **Recovered by:** Andy Armstrong **Date:** 6/13/2008
4. **Type of mark:** Bench mark disc	4. **Type of mark:** Bench mark disc
5. **How stamped:** Stamped brass disc engraved with identification No.1	5. **How stamped:** Stamped brass disc with no engraved identification, defined as BM-X.
6. **Location and detailed description:** The bench mark set in the concrete slab outside classroom doors of Andrews Hall, Maine Maritime Academy (see Figure IV-I above). The location of the bench mark is not available.	6. **Location and detailed description:** The bench mark is located in front of the east door of Andrews Hall, Maine Maritime Academy (see Figure IV-I above). The location of the bench mark is not available.

BENCH MARK 1 (BM-1)



BENCH MARK X (BM-X)

BM-1

BM-2

Figure 3. Images of benchmarks used for leveling exercise.

LEVELS | **LEVELS**

Station: Castine, ME

Year: 2008 **Month:** June **Day:** 15th | **Observer:** Roxy Rodman: Jashimn

	meters	Remarks				meters	Remarks	
Elev.	10.000	Forward Levelling			**Elev.**	10.724	Backward Levelling	
B.S. +	1.867	Staff on Tide gauge			B.S. +	1.06	Staff on BM X	
H.I.	11.867				H.I.	11.784		
F.S. -	1.564	Staff on BM A			F.S. -	1.375		
Elev.	10.303				**Elev.**	10.409		
B.S. +	1.574	Staff on BM A			B.S. +	1.322		
H.I.	11.877				H.I.	11.731		
F.S. -	1.544	Staff on BM B			F.S. -	0.871	Staff on BM 1	
Elev.	10.333				**Elev.**	10.860		
B.S. +	1.740	Staff on BM B	*		B.S. +	1.201	Staff on BM 1	*
H.I.	12.073		*		H.I.	12.061		*
F.S. -	1.219	Staff on BM 1	*		F.S. -	1.72	Staff on BM B	*
Elev.	10.854		*		**Elev.**	10.341		*
B.S. +	0.852	Staff on BM 1			B.S. +	1.589	Staff on BM B	
H.I.	11.706				H.I.	11.930		
F.S. -	1.295				F.S. -	1.616	Staff on BM A	
Elev.	10.411				**Elev.**	10.314		
B.S. +	1.355				B.S. +	1.564	Staff on BM A	
H.I.	11.766				H.I.	11.878		
F.S. -	1.042	Staff on BM X			F.S. -	1.87	Staff on Tide gauge	
Elev.	10.724				**Elev.**	10.008		

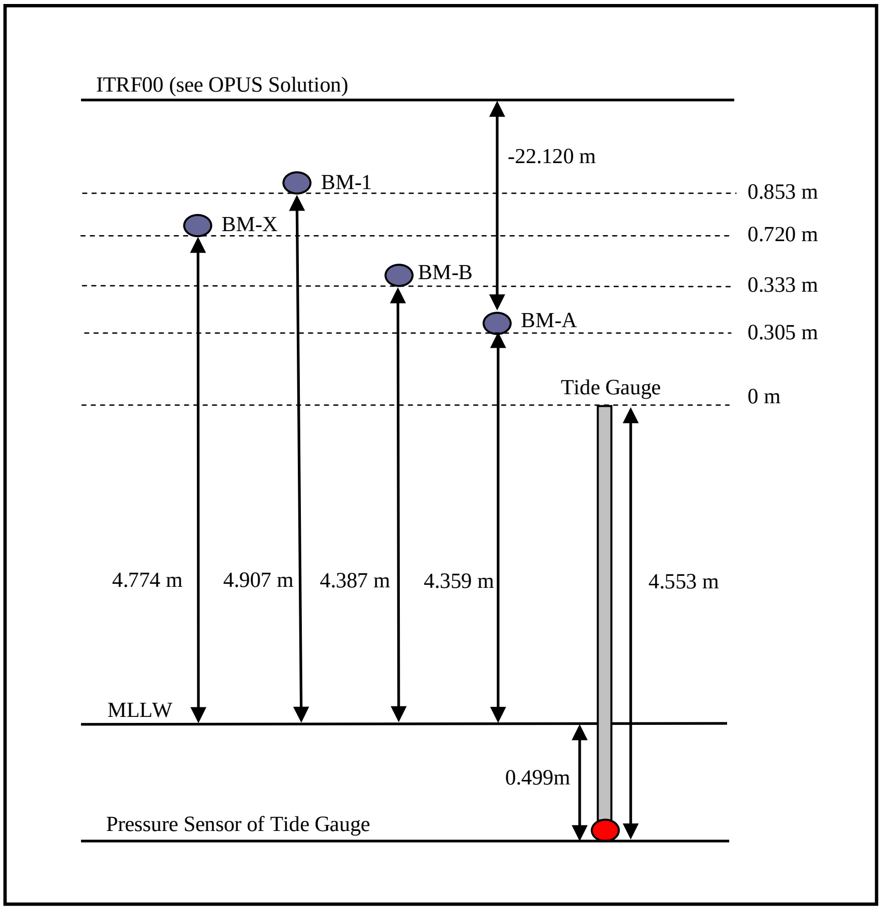
*** BM-B to BM-1 were re-surveyed as the initial survey values produced a 4.0 cm discrepancy in the height between the forward and backward run. The values above include only re-surveyed data.**

ELEVATION		
B.M. Numbers	**Forward Run (m)**	**Backward Run (m)**
Tide Gauge	10	10.008
BM-A	10.303	10.314
BM-B	10.333	10.341
BM-1	10.854	10.860
BM-X	10.724	10.724

DIFFERENCE OF ELEVATION			
Designation of Section	**Forward Run**	**Backward Run**	**Mean**
Tide Gauge to BM-A	0.303	-0.306	0.305
BM-A to BM-B	0.030	-0.027	0.028
BM-B to BM-1	0.521	-0.519	0.520
BM-1 to BM-X	-0.130	0.136	0.133

The tide gauge sensor is 14 ft 11& 1/4 inches (4.553 m) below from the top of the PVC pipe of the stilling well
The location of the tide gauge pressure sensor is 0.499 m below MLLW (see 19-year tidal datum transformation)

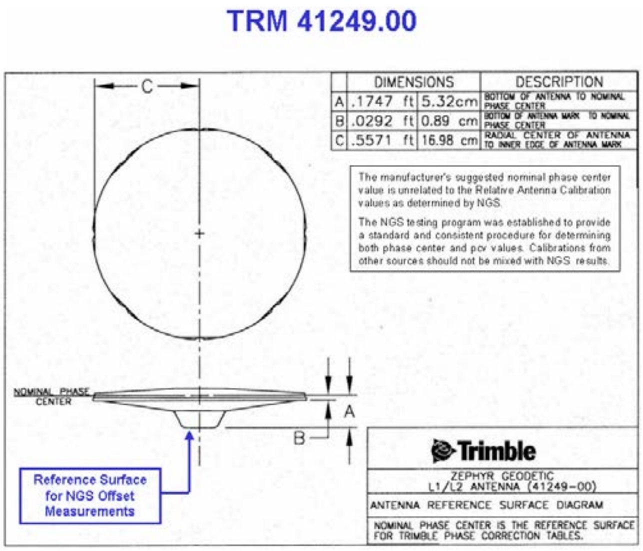
Elevations of Benchmarks above tide staff, sensor and MLLW (m)			
	Above the tide gauge stilling well (m)	Above the pressure sensor (in m)	Above MLLW Zero of the Gauge (m)
	A	B = A + 4.553 m	C = B - 0.499
BM-A	0.305	4.858	4.359
BM-B	0.333	4.886	4.387
BM-1	0.853	5.406	4.907
BM-X	0.720	5.273	4.774



IV.4. Location of BM-A: OPUS solution: 82761670.dat 000378431

NOTE: Antenna offsets supplied by the user were zero. Coordinates returned will be for the antenna reference point (ARP).

The vertical antennae offset above metal protrusion near the MMA dock (BM-A) was 1.418 m. This measured offset needs to be applied in any future datum transformations.



Reference Surface for GPS antenna. Height measurement (1.418 m) was taken vertically from top of metal spike (BM-A) to top of metal plate of tripod mount prior to mounting the antennae. Height measured using a Trimble Measuring Rod.

http://www.ngs.noaa.gov/ANTCAL/diagrams/TRM41249.00.gif

NGS OPUS SOLUTION REPORT
========================

All computed coordinate accuracies are listed as peak-to-peak values. For additional information: www.ngs.noaa.gov/OPUS/Using_OPUS.html#accuracy

USER: s.dijkstra@unh.edu DATE: June 18, 2008
RINEX FILE: 8276167r.08o TIME: 17:25:02 UTC

SOFTWARE: page5 0612.06 master2.pl START: 2008/06/15 17:34:00
EPHEMERIS: igr14840.eph [rapid] STOP: 2008/06/16 16:31:00
NAV FILE: brdc1670.08n OBS USED: 54190 / 55045 : 98%
ANT NAME: TRM41249.00 NONE # FIXED AMB: 154 / 160 : 96%
ARP HEIGHT: 0.0 OVERALL RMS: 0.018(m)

REF FRAME:	**NAD_83 (CORS96) (EPOCH:2002.0000)**		**ITRF00 (EPOCH:2008.4568)**	
X:	1651240.617 (m)	0.006 (m)	1651239.871 (m)	0.006 (m)
Y:	-4256449.434 (m)	0.013 (m)	-4256448.013 (m)	0.013 (m)
Z:	4438875.321 (m)	0.008 (m)	4438875.277 (m)	0.008 (m)
LAT:	44 23 11.68144	0.006 (m)	44 23 11.71656	0.006 (m)
E LON:	291 12 11.48591	0.006 (m)	291 12 11.47771	0.006 (m)
W LON:	68 47 48.51409	0.006 (m)	68 47 48.52229	0.006 (m)
EL HGT:	-20.949 (m)	0.014 (m)	-22.120(m)	0.014 (m)

ORTHO HGT: 4.003 (m) 0.032 (m) [NAVD88 (Computed using GEOID03)]

	UTM COORDINATES	**STATE PLANE COORDINATES**
	UTM (Zone 19)	**SPC (1801 ME E)**
Northing (Y) [meters]	4914830.760	80026.204
Easting (X) [meters]	516184.475	276351.519
Convergence [degrees]	0.14213126	-0.20761798
Point Scale	0.99960322	0.99990688
Combined Factor	0.99960650	0.99991016

US NATIONAL GRID DESIGNATOR: 19TEK1618414831(NAD 83)

<u>BASE STATIONS USED</u>

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE (m)
DJ7831	BRU5 BRUNSWICK 5 CORS ARP	N435323.306	W0695647.662	107289.1
DK4177	PNB5 PENOBSCOT 5 CORS ARP	N442706.177	W0684620.162	7497.6
AH5044	BARH BAR HARBOR CORS ARP	N442342.137	W0681318.080	45833.8

<u>NEAREST NGS PUBLISHED CONTROL POINT</u>

PE2112	Castine Orthodox Church Spire	N442320.918	W0684759.443	374.1

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

IV.5. Equivalent 19-Year Datum for Castine Station

The equivalent 19-year datum for the tide gauge in Castine harbor was computed using the Modified Range Ratio Method as outlined in the NOAA Special Publication NOS CO-OPS2 "Computational Techniques for Tidal Datums Handbook". The observed water level data from Castine harbor and the verified tide data for the primary station at Bar Harbor (retrieved from http://www.tidesandcurrents.noaa.gov) were recorded from 18:00 on 8 May to 24:00 on 31 May 2008 (UTC time) and verified using data from 17 May to 31 May 2008. Bar Harbor, ME (Station ID: 8413320) is located at 44° 23.5' N, 68° 12.3' W and was established on 16 August 1947 with a Present Installation from 9 June 1999. The new tidal epoch is from 1983-2001.

http://www.co-ops.nos.noaa.gov/station_info.shtml?stn=8413320%20Bar%20Harbor,%20ME

Two different methods were used to extract the Higher Highs (HH), Lower Highs (LH), Lower Lows (LL), and Higher Lows (HL) from the Castine harbor tide gauge dataset. The two methods were used to verify the computed 19-year equivalent MLLW datum for Castine.

- The first method manually picked the HH, LH, LL and HL peaks from the graphed tide dataset. The peaks were selected using the time at the start of each peak crest, although this should really have been done using the peak midpoint if phase offset were to be considered.
- The second method used MATLAB code to pick tidal peaks from a smoothed 6-minute average of the data.

These high and low peaks picked using the two different methods were used in the computation of the 19-year equivalent tidal datum. The computed MLLW datums for Castine varied only by a couple of mm (see Tables 3 & 4) and the MLLW datum of 0.499 m was used in the tide file exported utilized in CARIS Hips and Sips.

The terminology used in following computations of the 19-year equivalent tidal datums for Castine (a) using Bar Harbour (b) as the primary station (see tables below) are summarised here.

Diurnal High Water Inequality	DHQ
Diurnal Low Water Inequality	DLQ
Mean High Water	MHW
Mean Low Water	MLW
Great Diurnal range	Gt
Mean range	Mn
Diurnal Tide Level	DTL
Mean Tide Level	MTL
Mean Range Ratio	Mn_{ratio}
Diurnal High Water Inequality Ratio	DHQ_{ratio}
Diurnal Low Water Inequality Ratio	DLQ_{ratio}
Great Diurnal Ratio	Gt_{ratio})

NOTE: Difference are symbolized using Δ (e.g. Diurnal Low Water Inequality is ΔDLQ)

Table 3. Data used and the results of the 19-year equivalent tidal datums for Castine using manual picked highs and lows of Method 1.

Castine				Bar Harbor							
HHW_a	LHW_a	HLW_a	LLW_a	HHW_b	LHW_b	HLW_b	LLW_b	ΔHHW	ΔLHW	ΔHLW	ΔLLW
4.38	4.06	0.64	0.17	5.057	4.755	1.21	0.73	-0.677	-0.695	-0.56	-0.57
4.36	3.89	0.73	0.47	5.023	4.545	1.303	1.011	-0.663	-0.655	-0.541	-0.573
4.24	3.88	1.04	0.65	4.911	4.538	1.619	1.206	-0.671	-0.658	-0.556	-0.579
4.16	3.89	0.98	0.74	4.776	4.556	1.545	1.271	-0.616	-0.666	-0.531	-0.565
3.86	3.82	0.87	0.81	4.521	4.454	1.487	1.364	-0.661	-0.634	-0.554	-0.617
3.87	3.73	0.88	0.82	4.51	4.394	1.448	1.408	-0.64	-0.664	-0.588	-0.568
3.85	3.73	0.80	0.73	4.498	4.378	1.412	1.325	-0.648	-0.648	-0.595	-0.612
3.85	3.69	0.80	0.81	4.523	4.354	1.372	1.388	-0.673	-0.664	-0.578	-0.572
3.95	3.76	0.92	0.84	4.612	4.465	1.484	1.418	-0.662	-0.705	-0.578	-0.564
4.07	3.65	1.07	0.81	4.747	4.323	1.643	1.384	-0.677	-0.673	-0.574	-0.573
4.05	3.74	1.09	0.71	4.731	4.411	1.655	1.268	-0.681	-0.671	-0.558	-0.565
4.01	3.61	1.19	0.78	4.704	4.28	1.76	1.311	-0.694	-0.67	-0.531	-0.57
4.04	3.62	1.13	0.76	4.696	4.312	1.687	1.307	-0.656	-0.692	-0.547	-0.557
3.94	3.58	1.20	0.77	4.577	4.266	1.769	1.341	-0.637	-0.686	-0.571	-0.569
3.93	3.49	1.24	0.77	4.598	4.215	1.79	1.343	-0.668	-0.725	-0.573	-0.55
3.83	3.47	1.24	0.77	4.5	4.144	1.8	1.341	-0.67	-0.674	-0.571	-0.56
3.72	3.37	1.18	0.80	4.398	4.044	1.735	1.349	-0.678	-0.674	-0.549	-0.555
3.67	3.41	1.14	0.80	4.327	4.067	1.707	1.381	-0.657	-0.657	-0.581	-0.567
3.64	3.41	1.12	0.77	4.289	4.082	1.7	1.324	-0.649	-0.672	-0.554	-0.58
3.42	3.42	1.01	0.78	4.104	4.097	1.577	1.355	-0.684	-0.677	-0.575	-0.567
3.60	3.47	0.93	0.67	4.29	4.138	1.507	1.233	-0.69	-0.668	-0.563	-0.577
3.80	3.44	0.74	0.65	4.454	4.116	1.297	1.195	-0.654	-0.676	-0.545	-0.557

	HHW_a	LHW_a	HLW_a	LLW_a	HHW_b	LHW_b	HLW_b	LLW_b	ΔHHW	ΔLHW	ΔHLW	ΔLLW
Sum	86.240	80.130	21.940	15.880	100.846	94.934	34.507	28.253	-14.606	-14.804	-12.373	-12.567
Mean	3.920	3.642	0.997	0.722	4.584	4.315	1.569	1.284	-0.664	-0.673	-0.562	-0.571

$DHQ_a = 0.5 \times (HHW_a - LHW_a)$	0.139
$DLQ_a = 0.5 \times (HLW_a - LLW_a)$	0.138
$HW_a = (HHW_a + LHW_a)/2$	3.781
$Lw_a = (HLW_a + LLW_a)/2$	0.860
$Gt_a = HHW_a - LLW_a$	3.198
$Mn_a = Hw_a - Lw_a$	2.922
$DTL_a = (HHW_a + LLW_a)/2$	2.321
$MTL_a = (Hw_a + Lw_a)/2$	2.320

$DHQ_b = 0.5 \times (HHW_b - LHW_b)$	0.134
$DLQ_b = 0.5 \times (HLW_b - LLW_b)$	0.142
$Hw_b = (HHW_b + LHW_b)/2$	4.450
$Lw_b = (HLWb + LLW_b)/2$	1.426
$Gt_b = HHW_b - LLW_b$	3.300
$Mn_b = Hw_b - Lw_b$	3.023
$DTL_b = (HHW_b + LLW_b)/2$	2.934
$MTL_b = (Hw_b + Lw_b)/2$	2.938

$\Delta DHQ = 0.5 \times (\Delta HHW - \Delta LHW)$	0.005
$\Delta DLQ = 0.5 \times (\Delta HLW - \Delta LLW)$	-0.004
$\Delta Hw = (\Delta HHW + \Delta LHW)/2$	-0.668
$\Delta Lw = (\Delta HLW + \Delta LLW)/2$	-0.567
$\Delta Gt = \Delta HHW - \Delta LLW$	-0.093
$\Delta Mn = \Delta HW - \Delta LW$	-0.102
$\Delta DTL = (\Delta HHW + \Delta LLW)/2$	-0.618
$\Delta MTL = (\Delta HW + \Delta LW)/2$	-0.618

From NOAA Tables for Bar Harbor

MHHW	4.524
MHW	4.394
DTL	2.791
MTL	2.784
MSL	2.786
MLW	1.174
MLLW	1.058
GT	3.465
MN	3.22
DHQ	0.13
DLQ	0.115
HWI	3.29
LWI	9.51
NAVD	2.879
Maximum	5.999
Max Date	19780207
Max Time	0:00
Minimum	0.283
Min Date	19840120
Min Time	18:12

Ratios

$Mn_{ratio} = Mn_a/(Mn_a - \Delta Mn)$	0.966
$DHQ_{ratio} = DHQ_a/(DHQ_a - \Delta DHQ)$	1.033
$DLQ_{ratio} = DLQ_a/(DLQ_a - \Delta DLQ)$	0.969
$Gt_{ratio} = Gt_a/(Gt_a - \Delta Gt)$	0.969

Corrected

$MTL_{corrected\ for\ A} = MTL_{accepted\ for\ B} + \Delta MTL$	2.166
$DTL_{corrected\ for\ A} = DTL_{accepted\ for\ B} + \Delta DTL$	2.173
$Mn_{corrected\ for\ A} = Mn_{accepted\ for\ B} \times Mn_{ratio}$	3.112
$GT_{corrected\ for\ A} = GT_{accepted\ for\ B}$ x Gtratio	3.358

$\mathbf{MLLW_a} = DTL_{corrected\ for\ A} - 0.5 \times Gt_{corrected\ for\ A}$	**0.499**
$MHHW_a = MLLW_a + Gt_{corrected\ for\ A}$	3.857
$MLW_a = MTL_{corrected\ for\ A} - 0.5 \times Mn_{corrected\ for\ A}$	0.610
$MHW_a = MLW_a + Mn_{corrected\ for\ A}$	3.722

Table 4. Data used and the results of the Modified Range Ratio Method determination of the 19-year equivalent tidal datums for Castine using the smoothed 6-minute averaged data for the Castine Gauge computed by the MATLAB code (included below) of Method 2.

Castine				
	HHW_a	**LHW_a**	**HLW_a**	**LLW_a**
18-May	3.95	3.76	1.0405	0.8023
19-May	4.0623	3.6452	1.0852	0.8325
20-May	4.05	3.7393	1.163	0.8114
21-May	4.007	3.6084	1.125	0.7055
22-May	4.0389	3.6136	1.1936	0.7709
23-May	3.94	3.58	1.24	0.75
24-May	3.9293	3.4975	1.23	0.77
25-May	3.83	3.463	1.1707	0.77
26-May	3.72	3.3643	1.14	0.7616
27-May	3.67	3.41	1.1257	0.8002
28-May	3.6395	3.4095	1.0107	0.8025
29-May	3.4127	3.4123	0.93	0.7607
30-May	3.6	3.4686	0.74	0.7739
31-May	3.7882	3.44	0.7207	0.6725
		3.572		0.65

Bar Harbor			
HHW_b	**LHW_b**	**HLW_b**	**LLW_b**
4.612	4.465	1.643	1.388
4.747	4.323	1.655	1.418
4.731	4.411	1.76	1.384
4.704	4.28	1.687	1.268
4.696	4.312	1.769	1.311
4.577	4.266	1.79	1.307
4.598	4.215	1.8	1.341
4.5	4.144	1.735	1.343
4.398	4.044	1.707	1.341
4.327	4.067	1.7	1.349
4.289	4.082	1.577	1.381
4.104	4.097	1.507	1.324
4.29	4.138	1.297	1.355
4.454	4.116	1.329	1.233
	4.253		1.195

ΔHHW	**ΔLHW**	**ΔHLW**	**ΔLLW**
-0.662	-0.705	-0.6025	-0.5857
-0.6847	-0.6778	-0.5698	-0.5855
-0.681	-0.6717	-0.597	-0.5726
-0.697	-0.6716	-0.562	-0.5625
-0.6571	-0.6984	-0.5754	-0.5401
-0.637	-0.686	-0.55	-0.557
-0.6687	-0.7175	-0.57	-0.571
-0.67	-0.681	-0.5643	-0.573
-0.678	-0.6797	-0.567	-0.5794
-0.657	-0.657	-0.5743	-0.5488
-0.6495	-0.6725	-0.5663	-0.5785
-0.6913	-0.6847	-0.577	-0.5633
-0.69	-0.6694	-0.557	-0.5811
-0.6658	-0.676	-0.6083	-0.5605
	-0.681		-0.545

	HHW_a	**LHW_a**	**HLW_a**	**LLW_a**
Sum	53.638	52.984	14.915	11.434
Mean	3.831	3.532	1.065	0.762

HHW_b	**LHW_b**	**HLW_b**	**LLW_b**
63.027	63.213	22.956	19.938
4.502	4.214	1.640	1.329

ΔHHW	**ΔLHW**	**ΔHLW**	**ΔLLW**
-9.389	-9.548	-8.041	-8.504
-0.671	-0.682	-0.574	-0.567

$DHQ_a = 0.5 \times (HHW_a - LHW_a)$	0.149516
$DLQ_a = 0.5 \times (HLW_a - LLW_a)$	0.151549
$HW_a = (HHW_a + LHW_a)/2$	3.681763
$Lw_a = (HLW_a + LLW_a)/2$	0.913815
$Gt_a = HHW_a - LLW_a$	3.069
$Mn_a = Hw_a - Lw_a$	2.767947
$DTL_a = (HHW_a + LLW_a)/2$	2.296773
$MTL_a = (Hw_a + Lw_a)/2$	2.297789

$DHQ_b = 0.5 \times (HHW_b - LHW_b)$	0.143864
$DLQ_b = 0.5 \times (HLW_b - LLW_b)$	0.155257
$Hw_b = (HHW_b + LHW_b)/2$	4.358064
$Lw_b = (HLWb + LLW_b)/2$	1.484457
$Gt_b = HHW_b - LLW_b$	3.173
$Mn_b = Hw_b - Lw_b$	2.873607
$DTL_b = (HHW_b + LLW_b)/2$	2.915564
$MTL_b = (Hw_b + Lw_b)/2$	2.921261

$\Delta DHQ = 0.5 \times (\Delta HHW - \Delta LHW)$	0.005686
$\Delta DLQ = 0.5 \times (\Delta HLW - \Delta LLW)$	-0.003708
$\Delta Hw = (\Delta HHW + \Delta LHW)/2$	-0.676336
$\Delta Lw = (\Delta HLW + \Delta LLW)/2$	-0.570642
$\Delta Gt = \Delta HHW - \Delta LLW$	-0.104
$\Delta Mn = \Delta HW - \Delta LW$	-0.105694
$\Delta DTL = (\Delta HHW + \Delta LLW)/2$	-0.618792
$\Delta MTL = (\Delta HW + \Delta LW)/2$	-0.623489

From NOAA Tables for Bar Harbor

MHHW	4.524
MHW	4.394
DTL	2.791
MTL	2.784
MSL	2.786
MLW	1.174
MLLW	1.058
GT	3.465
MN	3.22
DHQ	0.13
DLQ	0.115
HWI	3.29
LWI	9.51
NAVD	2.879
Maximum	5.999
Max Date	19780207
Max Time	0:00
Minimum	0.283
Min Date	19840120
Min Time	18:12

Ratios

$Mn_{ratio} = Mn_a/(Mn_a - \Delta Mn)$	0.963219
$DHQ_{ratio} = DHQ_a/(DHQ_a - \Delta DHQ)$	1.039531
$DLQ_{ratio} = DLQ_a/(DLQ_a - \Delta DLQ)$	0.976115
$Gt_{ratio} = Gt_a/(Gt_a - \Delta Gt)$	0.96731

Corrected

$MTL_{\text{corrected for A}} = MTL_{\text{accepted for B}} + \Delta MTL$	2.160511
$DTL_{\text{corrected for A}} = DTL_{\text{accepted for B}} + \Delta DTL$	2.172208
$Mn_{\text{corrected for A}} = Mn_{\text{accepted for B}} \times Mn_{ratio}$	3.101567
$GT_{\text{corrected for A}} = GT_{\text{accepted for B}} \times Gtratio$	3.351729

$\mathbf{MLLW_a} = DTL_{\text{corrected for A}} - 0.5 \times Gt_{\text{corrected for A}}$	**0.49634**
$MHHW_a = MLLW_a + Gt_{\text{corrected for A}}$	3.848073
$MLW_a = MTL_{\text{corrected for A}} - 0.5 \times Mn_{\text{corrected for A}}$	0.609728
$MHW_a = MLW_a + Mn_{\text{corrected for A}}$	3.711295

The ~20 cm offset noticed in the tide data at ~6.00 am UTC on the morning of the 19th July (Separate V.5 Survey Incident Report) needed to be understood in order to ensure that this tide record shift resulted in no offset of the tidal datum. A second Modified Range Ratio Method computation of the equivalent 19-year datum for Castine was done for the period 19-23 June. The calculated MLLW for the Castine harbor tide gauge of **0.452854 m** was very similar to that determined for the period prior to the offset of **0.49634 m** obtained using NOAA verified tidal data from Bar Harbor for May 2008

	Castine				**Bar Harbor**							
	HHW_a	**LHW_a**	**HLW_a**	**LLW_a**	**HHW_b**	**LHW_b**	**HLW_b**	**LLW_b**	**ΔHHW**	**ΔLHW**	**ΔHLW**	**ΔLLW**
19 June	3.91	3.477	1.0502	0.6614	4.59	4.14	1.64	1.27	-0.6785	-0.6612	-0.5933	-0.6078
20 June	3.8914	3.47	0.97	0.5873	4.54	4.14	1.60	1.21	-0.6531	-0.665	-0.6318	-0.6275
21 June	3.8243	3.43	0.9391	0.5523	4.49	4.11	1.58	1.16	-0.6702	-0.6798	-0.6409	-0.6065
22 June	3.8164	3.47	0.97	0.5575	4.47	4.14	1.53	1.16	-0.6531	-0.6732	-0.5612	-0.5982
23 June	3.7689	3.52		0.5925	4.44	4.19		1.19	-0.6686	-0.6725	0	-0.595

	HHW_a	**LHW_a**	**HLW_a**	**LLW_a**	**HHW_b**	**LHW_b**	**HLW_b**	**LLW_b**	**ΔHHW**	**ΔLHW**	**ΔHLW**	**ΔLLW**
Sum	19.211	17.367	3.929	2.951	22.535	20.719	6.357	5.986	-3.324	-3.352	-2.427	-3.035
Mean	3.842	3.473	0.982	0.590	4.507	4.144	1.589	1.197	-0.665	-0.670	-0.485	-0.607

$DHQ_a = 0.5 \times (HHW_a - LHW_a)$	0.1844
$DLQ_a = 0.5 \times (HLW_a - LLW_a)$	0.1960625
$HW_a = (HHW_a + LHW_a)/2$	3.6578
$Lw_a = (HLW_a + LLW_a)/2$	0.7862625
$Gt_a = HHW_a - LLW_a$	3.252
$Mn_a = Hw_a - Lw_a$	2.8715375
$DTL_a = (HHW_a + LLW_a)/2$	2.2162
$MTL_a = (Hw_a + Lw_a)/2$	2.2220313

$DHQ_b = 0.5 \times (HHW_b - LHW_b)$	0.18158
$DLQ_b = 0.5 \times (HLW_b - LLW_b)$	0.1959625
$Hw_b = (HHW_b + LHW_b)/2$	4.32532
$Lw_b = (HLWb + LLW_b)/2$	1.3931625
$Gt_b = HHW_b - LLW_b$	3.310
$Mn_b = Hw_b - Lw_b$	2.9321575
$DTL_b = (HHW_b + LLW_b)/2$	2.85205
$MTL_b = (Hw_b + Lw_b)/2$	2.8592413

$\Delta DHQ = 0.5 \times (\Delta HHW - \Delta LHW)$	0.00282
$\Delta DLQ = 0.5 \times (\Delta HLW - \Delta LLW)$	0.06078
$\Delta Hw = (\Delta HHW + \Delta LHW)/2$	-0.66752
$\Delta Lw = (\Delta HLW + \Delta LLW)/2$	-0.54622
$\Delta Gt = \Delta HHW - \Delta LLW$	-0.058
$\Delta Mn = \Delta HW - \Delta LW$	-0.1213
$\Delta DTL = (\Delta HHW + \Delta LLW)/2$	-0.63585
$\Delta MTL = (\Delta HW + \Delta LW)/2$	-0.60687

From NOAA Tables for Bar Harbor

MHHW	4.524
MHW	4.394
DTL	2.791
MTL	2.784
MSL	2.786
MLW	1.174
MLLW	1.058
GT	3.465
MN	3.22
DHQ	0.13
DLQ	0.115
HWI	3.29
LWI	9.51
NAVD	2.879
Maximum	5.999
Max Date	19780207
Max Time	0:00
Minimum	0.283
Min Date	19840120
Min Time	18:12

Ratios

$Mn_{ratio} = Mn_a/(Mn_a - \Delta Mn)$	0.9594699
$DHQ_{ratio} = DHQ_a/(DHQ_a - \Delta DHQ)$	1.0155303
$DLQ_{ratio} = DLQ_a/(DLQ_a - \Delta DLQ)$	1.4492821
$Gt_{ratio} = Gt_a/(Gt_a - \Delta Gt)$	0.9825664

Corrected

$MTL_{corrected\ for\ A} = MTL_{accepted\ for\ B} + \Delta MTL$	2.17713
$DTL_{corrected\ for\ A} = DTL_{accepted\ for\ B} + \Delta DTL$	2.15515
$Mn_{corrected\ for\ A} = Mn_{accepted\ for\ B} \times Mn_{ratio}$	3.0894931
$GT_{corrected\ for\ A} = GT_{accepted\ for\ B}$ x Gtratio	3.4045926

$\mathbf{MLLW_a} = DTL_{corrected\ for\ A} - 0.5 \times Gt_{corrected\ for\ A}$	**0.452854**
$MHHW_a = MLLW_a + Gt_{corrected\ for\ A}$	3.8574463
$MLW_a = MTL_{corrected\ for\ A} - 0.5 \times Mn_{corrected\ for\ A}$	0.6323835
$MHW_a = MLW_a + Mn_{corrected\ for\ A}$	3.7218765

APPENDIX II

SUPPLEMENTAL SURVEY RECORDS AND CORRESPONDENCE

(No supplemental Correspondence)

APPENDIX III

FEATURES REPORT

(NO AWOIS ITEMS, DTONS, WRECKS, OR MARITIME BOUNDARIES)

APPROVAL PAGE

W00273

Data meet or exceed current specifications as certified by the OCS survey acceptance review process. Descriptive Report and survey data except where noted are adequate to supersede prior surveys and nautical charts in the common area.

The following products will be sent to NGDC for archive

- W00273_DR.pdf
- Collection of depth varied resolution BAGS
- Processed survey data and records
- W00273_GeoImage.pdf

The survey evaluation and verification has been conducted according to current OCS Specifications, and the survey has been approved for dissemination and usage of updating NOAA's suite of nautical charts.

Approved: ______________________________

Lieutenant Matthew Jaskoski, NOAA
Chief, Atlantic Hydrographic Branch