Data Acquisition & Processing Report

Type of Survey: Benthic Habitat and Hydrographic

Project No. NF-06-03, S-I911-NF-06

Time Frame: March 21 – April 2, 2006

Localities

Buck Island, St. Croix, U.S.Virgin Islands

La Parguera, Puerto Rico

2006

Chief Scientist

Timothy A. Battista

Lead Hydrograher

Mike L. Stecher

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NOAA Ship NANCY FOSTER

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Table of Contents

Appendices

I. Background

In June 1998, the U.S. Coral Reef Task Force (USCRTF) was established by Presidential Executive Order 13089. The USCRTF mission is to lead, coordinate, and strengthen U.S. government actions to better preserve and protect coral reef systems. The National Oceanic and Atmospheric Administration's (NOAA) Center for Coastal Monitoring and Assessment (CCMA) Biogeography Team is supporting the USCRTF mandate. The Biogeography Team conducted the third year of an ongoing scientific research mission on board the NOAA ship NANCY FOSTER from March 21 to April 2, 2006. The purpose of this cruise is to support the benthic characterization of coral reef habitat in the U.S. Virgin Islands and Puerto Rico.

II. Area

This is a joint mission with the National Park Service (NPS), the National Marine Fisheries Service (NMFS), and the U.S. Virgin Islands and Puerto Rican territorial governments. The mission explored and surveyed and mapped moderate depth bathymetry (30 – 1000 meters) with the NANCY FOSTER's Simrad EM1002 multibeam system for natural resource management and seafloor characterization. Multibeam bathymetry and backscatter was collected along with Remotely Operated Vehicle (ROV) underwater video. Priority areas for 2006 included the deep water portion of the Buck Island Reef National Monument north of St. Croix and the La Parguera region along the southwestern coast of Puerto Rico. Additional multibeam data was collected to merge with pre-existing shallow water bathymetry from previous CCMA cruises in the Buck Island vicinity. Multibeam data was collected to conform to IHO Order 1 (<100m) and Order 2 (>100m) accuracy standards. The two figures below identify the priority survey areas for 2006. The coordinates bounding the area south west of Puerto Rico are 17°54'N - 67°09'W to the northwest, and 17°51'N - 66°54'W to the southeast and encompass approximately 65 square kilometers, or 26 square miles. The coordinates bounding the area north of St. Croix are17°50'N - 64°47'W to the northwest and 17°46'N - 64°26'W to the southeast and encompass approximately 80 square kilometers, or 31 square miles.

Fig 1: 2006 Priority Project Areas - Puerto Rico

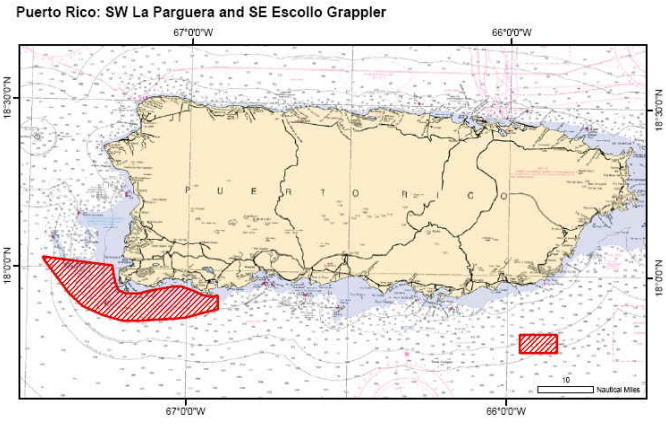
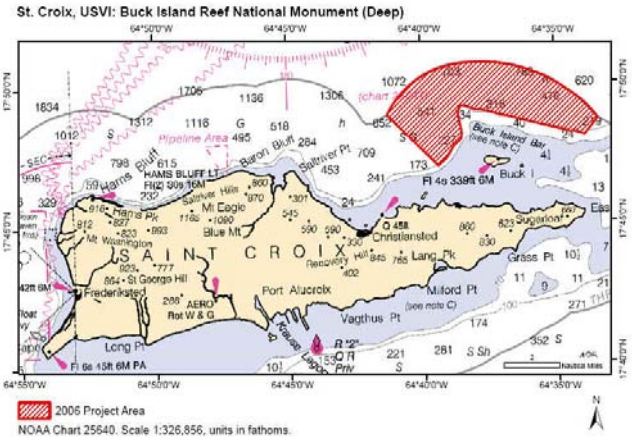


Fig 2: 2006 Priority Project Areas - St. Croix



III. Equipment

Vessel

The NOAA Ship NANCY FOSTER (R352) is 57 meters in length, has a beam of 12 meters and draws approximately 3 meters of water. During the Charleston, South Carolina drydock period in November of 2005, numerous survey hardware and software installations were implemented by NOAA's Aviation and Marine Operations division (NMAO) to make multibeam data acquisition a more integral component of the ship's research support. NMAO funded the permanent installation of a Simrad EM1002 multibeam sonar, an Applanix POS/MV positioning system and other ancillary sensors and support equipment. A Sea Acceptance Test (SAT) was performed prior to the NF-06-03 cruise by representatives from Kongsberg and the Office of Coast Survey. For more details on the performance review of the multibeam system please refer to the Hydrographic Systems Readiness Review (HSRR) for the NOAA Ship Nancy Foster, 2006. The NF-06-03 cruise was the first to implement the Nancy Foster's multibeam system during a research cruise.

Sonar System

The Simrad EM1002 multibeam echosounder is permanently hull-mounted between two fiberglass hydrodynamic fittings starboard of the keel line, aft of the bow. The EM1002 is a 95-kHz system with a 150° swath consisting of 111 individually formed, electronically roll-stabilized 2° beams, at a maximum ping rate of 10Hz, depending on water depth. The EM1002 has three different automatically adjusted pulse lengths to maximize coverage in deeper waters at 0.2, 0.7 and 2 milliseconds respectively. A combination of phase and amplitude detection is used, resulting in measurement accuracy practically independent of beam angle. The system is compensated in real-time for sound velocity changes at the transducer array, to assist in the electronic beam steering capabilities of the EM1002.

Fig 3: EM1002 transducer fairing

Fig 4: EM1002 transducer

The EM1002 sonar system is controlled with a UNIX based operator system (SUN Solaris 8) that utilizes the Common Desktop Environment and Kongsberg's MERLIN V 5.2.2 acquisition and control program. Before surveying commenced and periodically thereafter, the EM1002 system self-test (BIST test) was performed to confirm the sonar's operating status. Sonar errors were not observed during the survey. As per advice from the Kongsberg representative during the SAT, the automatic and default parameters were used to control the sonar during data acquisition. The EM1002 backscatter default options were verified with Adel Sterling and the Hawaii Mapping Resource Group who have extensive experience aquiring backscatter imagery with the EM1002 system onboard the R/V KILO MOANA. The equidistant beam spacing mode was chosen to give a uniform distribution of soundings on the seafloor. The ping rate was set by the system and was automatically adjusted according to the depth below the transducer. Only limited runtime parameters changed during the survey including the maximum port and starboard angles, which did not exceed 55°. Sound velocity profiles were acquired approximately every four hours throughout the survey. See *Appendix A* for the EM1002 Runtime & Installation Parameters Reports. Versions of all hardware and software used for this survey can be found in *Appendix B.*

Motion Reference Unit

The Applanix Model POS/MV Model 320 V4 (POS) is a GPS-aided inertial measurement unit (IMU) that generates attitude data in three axes. Measurements of roll, pitch and heading are all accurate to $\pm$ 0.02° or better, regardless of the vessel latitude. Heave measurements supplied by POS maintain an accuracy of 5% of the measured vertical displacement or $\pm$ 5cm (whichever is the larger) for periods of 20 seconds or less. The accuracy and stability of measurements delivered by the system remain unaffected by vessel turns, changes of speed, wave-induced motion, or other dynamic maneuvers. The IMU is located on the Hold Deck in the Forepeak Void; refer to Appendix H for vessel diagram. Position and motion data were supplied from the POS system via serial communications to the Processing Unit (PU). Com Port 2 was configured to supply motion data at an update frequency of 100 Hz to the EM1002 sonar for real-time motion compensation. The heave bandwidth was set to 18.0 seconds with a dampening ration of .707. Roll, pitch, and heave positive sense were port up, bow up, and heave up respectively. The multipath was set to low, due to the ideal placement of the two GPS antennae. The POS/MV software settings are documented in *Appendix C.*

Fig 5: Inertial Measurement Unit

Positioning System

The POS/MV Model 320 V4 obtains its positions from two identical dual frequency Trimble Zephyr GPS antennae. An ancillary Trimble DSM 132 DGPS system provided an RTCM data stream to the POS. The two POS antenna are located above the bridge deck on the starboard side; refer to Appendix H for vessel diagram. The DSM 132 received differential beacon transmittals from the U.S Coast Guard Continually Operating Reference Station (CORS) station Port Isabel, Puerto Rico frequency 295.0 kHz. The POS also provided the pulse per second (PPS) strobe that EM1002 uses to continually synchronize the internal system clock to UTC time. The POS computes GPS heading by performing carrier phase differential measurements between the two GPS antennae. Position updates were supplied from the POS/MV to the PU of the EM1002 system via serial communications at a frequency of 10 Hz.

Fig 6: GPS Antenna configuration

Sound Velocity

The NANCY FOSTER is equipped with a hull-mounted SBE 45 thermosalinograph (TSG), near the EM1002 transducer. The TSG measures near-surface conductivity and temperature in order to calculate sound velocity in real-time. The data from the TSG streamed to the EM1002's MERLIN acquisition and control software to aid in electronic beam steering. The primary instrument for determining sound velocity throughout the entire water column was a Seabird Electronics SBE-911 CTD instrument. An auxiliary SBE-19 was used for calibration verification and could be deployed in the event of a primary system failure. Sound velocity casts were deployed approximately every four hours during survey operations. Sound velocity casts were processed with NOAA's Velocwin V8.80 software. Processed casts were converted to Simrad format (*.asvp) and uploaded to the MERLIN acquisition and control software. The NANCY FOSTER's hydraulic winch was rigged through the block of a J-Frame davit, which provided a consistent rate of descent for acquisition of the sound velocity data. Calibration reports from SEA-BIRD Electronics are documented in *Appendix D.*

Acquisition System

The Kongsberg MERLIN V5.2.2 acquisition and control system is based on the Sun Microsystems Solaris 8 UNIX operating system. The MERLIN system integrated the auxiliary sensors with the sounding data from the PU to create "datagrams". The datagrams combine the positioning, attitude, sound velocity and sounding data. The data was logged in the *.all format. Coastal Oceanographics Hypack Max V.4.3A provided the navigation information to the helms display and was used to create line plans for the surveyed areas. Coverage BASE surfaces were created from 3m to 10m resolutions, depending on depth, in CARIS's 6.0 HIPS and SIPS (SP1 HF1-18) during data

acquisition to verify coverage. The BASE surfaces were then exported in GEOTIFF format to the HYPACK PC to create holiday line plans and additional lines.

IV. Quality Control

The Simrad raw multibeam format (*.ALL) combines positioning data, attitude data, sound velocity correctors, sonar offset values, and is corrected for the outer beam angle offset. The HIPS Conversion Wizard uses the Simrad format to convert the multibeam data into HDCS data files. During the conversion process a depth limit of 1000m was applied to reject any soundings that exceeded the depth rating of the EM1002. The Vessel configuration used for both survey areas data conversion was the R352_MB.hvf file. This file included the patch test results, dynamic draft, waterline and the Total Propagated Error (TPE) values (HVF & TPE Report, *Appendix E*). The Buck Island data was projected to the North American Datum of 1983, Universal Transmercator Zone 20, Northern Hemisphere (NAD83 UTM20N) and the La Parguera data was projected in NAD83 UTM19N. All the acquired data was converted and preliminary processing occurred in the field.

Preliminary data processing consisted of: Application of zoned preliminary tides, navigation editing, attitude editing, swath data editing and subset editing. Navigation edits included reviewing for time jumps greater than 0.2 seconds and removing data in vessel turns. Attitude data was reviewed for gaps, and none were identified. Swath filtering occurred prior to editing and was used to eliminate large outliers in the water column with a depth filter, minimum and maximum filter depths varied by survey area. If the there was adequate coverage from neighboring swaths, then across track filters were used to limit the swath's outer beams. During processing of the data, the Swath Edit mode removed remaining fliers, as well as down-slope beams where the survey lines crossed over the reef escarpment providing unreliable soundings.

The Hips Subset Editor was the second phase of editing. Subset editing enabled the hydrographer to evaluate each swath against its neighboring swath while identifying potential tidal and motion artifacts. The verification of features from adjacent lines as well as feature alignment also confirms the sensor offsets. BASE surface were created to identify systematic errors or artifacts within the data set that could be further investigated with the swath or subset editor. The Bathymetry Associated with Statistical Error (BASE) surfaces created from the merged and TPE calculated soundings are georeferenced images of a multi-attributed, weighted mean surface. The BASE surface uses a combination of range, uncertainty and swath angle weights to assign nodes depth values for creating the seabed surface. The BASE surface images were reviewed with multiple resolutions, sun angles, sun azimuths and vertical exaggerations. The BASE surface routine produced images identifying depth, shoal-biased depth, deep-biased depths, mean depths, standard deviation, sounding density, and depth uncertainty. During acquisition in the field, editing steps were expedited to create BASE surface to confirm adequate multibeam coverage for each survey area and to identify ROV transects. The contract Lead Hydrographer completed final processing of the datasets after the completion of field operations. Refer to *Appendix F* for a multibeam processing flow chart. The

following two images depict the areas surveyed by the Depth BASE surface. Grey-scale areas near Buck Island are from the 2004 and 2005 surveys.

Fig 7: Completed 2006 bathymetry coverage, shown as 10m grid, La Parguera, SW Puerto Rico.

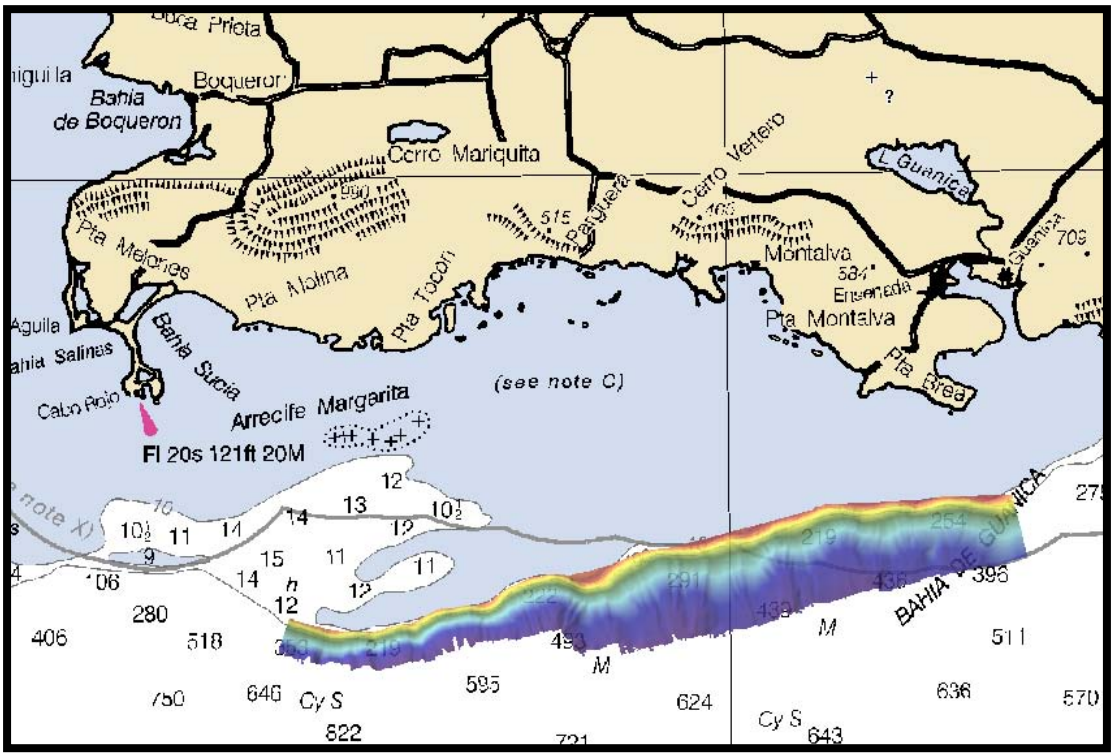


Fig 8: Completed 2006 bathymetry coverage, shown as 10m grid, Buck Island, St Croix

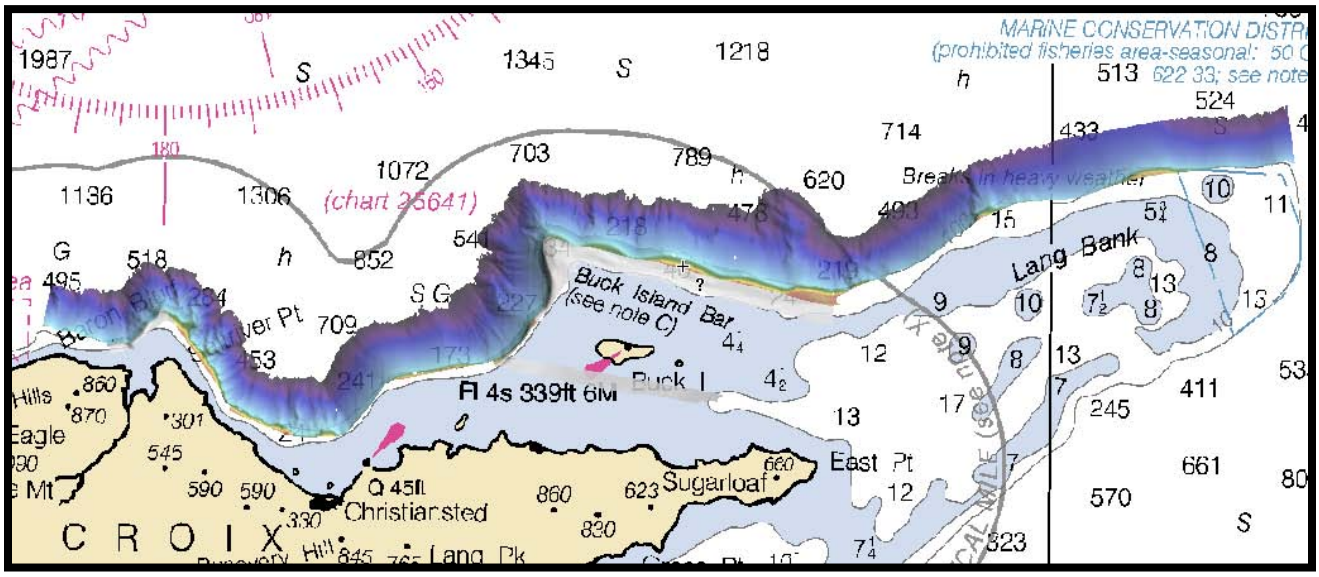


Image resolutions were built to measure the success of achieving multibeam coverage for the survey areas according to section 5.2.3 in the NOAA Specs and Deliverables:

Table 1: BASE Surface Resolutions and Depth Ranges

Resolution (meters)	Depth Ranges (meters)
2m	29m to 60m
3m (resolution mapped in field)	29m to 60m
5m	59m to 150m
10m	Deeper than 149m

Multiple BASE surfaces were created for each survey area to demonstrate multibeam coverage according to the previously mentioned section 5.2.3. Final BASE surfaces were generated by weighting the sounding's grazing angle with the seabed. The Hips Export Wizard produced 24-bit sun-illuminated geo-referenced images of the BASE depth surfaces and ASCII XYZ text exports, at resolutions in accordance with the depth limits for each survey area. A final analysis was performed on reference surfaces with the Hips Quality Control Report and is discussed in the Assessment of IHO Compliance section on page 16 and in Appendix K.

V. Corrections to Echo Soundings

Instrument corrections

An initial leadline confidence check was measured against the multibeam echosounder prior to the start of field operations on March 21, 2006 at the Frederiksted Pier, St. Croix. The purpose of this check was to verify the system during static conditions by confirming that the digital depths being recorded reflected the actual depths. A sound velocity cast was performed at the site and uploaded to the EM1002. The leadline was performed approximately 3 meters starboard of the EM1002. The sonar's MERLIN acquisition system was logging data while the leadline was performed. The CARIS Swath Editor was then used to verify the EM1002 depth soundings. Soundings were queried approximately 3 meters to starboard of the nadir beam with values ranging from 11.3m to 11.5m. The average of four leadline depths returned a value of 11.41m. No instrument correction was applied because of insufficient evidence of systematic error.

Sensor Offsets

On the February 7th, 2006 the NOAA Ship NANCY FOSTER had her sensor offsets surveyed by the Power & Control Systems Group of L3 Communications. The IMU, GPS antennas, EM1002 transducer and the center of motion were surveyed with respect to the RP of the vessel. The values obtained from the survey are documented in *Appendix G & H*. These offsets were entered into the MERLIN acquisition software, POS/MV software and into the TPE section of the Vessel Configuration File during the

SAT trials in March of 2006. These values were also checked and verified prior to data acquisition for this cruise. The offsets used for the positioning system and sonar are documented in the POS/MV Configuration Report and the EM1002 Installation Parameters report (*Appendix A & C*).

Static and Dynamic Draft Corrections

Static draft values were obtained from visual observations of the Projection Draft marks on the starboard side of the NANCY FOSTER. The static draft correction recorded on March 21, 2006 was 12.1ft while tied up at Frederiksted Pier, St. Croix. Subtracting the initial draft value of 12.1 from the fixed offset (1.68m) for the Reference Point to the EM1002 gives the final draft reading of -2.01m, which was entered into the MELIN software and confirmed with the leadline procedure previously discussed. On April 2nd 2006, while tied up at the USCG base in Puerto Rico, the static draft was recorded at 11.4ft. Over the fourteen days underway, a total of 0.7 tenths of a foot of draft was lost to water and fuel consumption. This information was entered into the R352_MB vessel configuration file under "waterline height", as 0.015m per day of draft change.

The dynamic draft survey was performed during the Sea Acceptance Test (SAT) offshore of Charleston, South Carolina in March of 2006. Representatives from the NOAA Aviation and Marine Operations (NMAO) performed the survey and evaluated the results. The dynamic draft was determined using the reference surface method as per the NOS Field Procedures Manual. Results of the dynamic draft survey were entered into the CARIS vessel configuration file, R352_MB.hvf. Refer to *Appendix I* for further information on draft corrections.

System Alignment and Calibrations

System Alignment and calibration procedures are fully documented in *Appendix I*, the NF-06-03 Multibeam Calibration Procedures & Patch Test Report. The calculated patch test values for roll, pitch and yaw were entered into the R352_MB vessel configuration file.

Tide Corrections

Existing water level stations were used in conjunction with height and time correctors in a CARIS tide zone definition file (ZDF). Preliminary tides, adjusted to MLLW, and ZDFs were supplied by NOAA CO-OPS prior to the commencement of survey operations for both areas. Verified six-minute interval water level and final tide zone correctors were applied while post processing the data. During the computation of the TPE, survey specific parameters including the estimated tidal errors, were applied. These values were supplied by CO-OPS. The estimated tidal error contribution to the total survey error budget in the vicinity of La Parguera is 0.02 meters at the 95% confidence level, and includes the estimated gauge measurement error of ~0.012m and a tidal zoning error of 0.0 m. The estimated tidal error contribution to the total survey error budget in the vicinity of Buck Island is 0.110 meters at the 95% confidence level and

includes the estimated gauge measurement error of ~0.012m and a tidal zoning error of ~0.03 m. The tidal datum computation error for both project areas was 0.0m. The Tide Requirements and Tide Note for Hydrographic Survey, developed by NOAA CO-OPS will be submitted as *Appendix J.*

VI. Statement of Accuracy and Suitability for Charting

Assessment of horizontal control

Positioning equipment and methods

The horizontal datums for this project is the North American Datum of 1983 Universal Transmercator Zone 19 and 20, Northern Hemisphere (NAD83 UTM19N & 20N). Differential GPS (DGPS) corrected positions were supplied to both the POS/MV and HYPACK systems. Both systems have visual alarms to notify the operator if the DGPS fix is lost or if HDOP values of 4.0 are exceeded; none were observed. Differential corrections were received from U.S. Coast Guard Continually Operating Reference Station (CORS) Isabel, Puerto Rico at a frequency of 295.0 kHz with the Trimble DMS 132 receiver.

Quality control

A position check between two independent DGPS systems was observed and recorded with HYPACK on March 19, 2006 while docked at the Frederiksted Pier, St. Croix pier. The Trimble DMS 132 was logged as a raw DGPS positions with no offsets applied. The POS/MV DGPS data was logged with the offsets positioning the vessel at the Reference Point (RP). Both system's DGPS data were collected for at least one minute. The distance measured between the two averaged DGPS positions was approximately 7.0m. The distance calculated from the PacOrd survey was 7.15m. The consistent positioning between the two systems falls well within DGPS positioning standards.

Statement of accuracy and compliance with HSSDM

Based on a combination of the positioning system confidence check, real-time tolerance monitoring and seafloor feature alignment, the Hydrographer feels that the Horizontal Control should be considered adequate for the purposes of this survey.

Assessment of vertical control

Water level measuring equipment and methods

The Vertical Datum for this survey was Mean Lower-Low Water (MLLW). The National Water Level Observation Network (NWLON) primary tide stations at, Magueyes Island, Puerto Rico (975-9110) and Lime Tree Bay, St.Croix (975-1401) served as the primary sources for water level reducers for this survey. Six-minute predicted tides were obtained from the CO-OPS home page (www.co-ops.nos.noaa.gov) and were applied during acquisition. Verified smooth tides were applied during post-processing.

Tides Zoning

The tidal zoning data, time and height corrections were provided by NOAA CO-OPS (refer to *Appendix J*). The hydrographer applied final approved (smooth) tides to the survey data during processing. The verified tides were time and height corrected with the file I911NF2006CORF.zdf that was provided by CO-OPS.

Statement of accuracy and compliance with HSSDM

The hydrographer believes that the zoning of tide correctors between the two primary tide stations is adequate for the purpose and location of the survey.

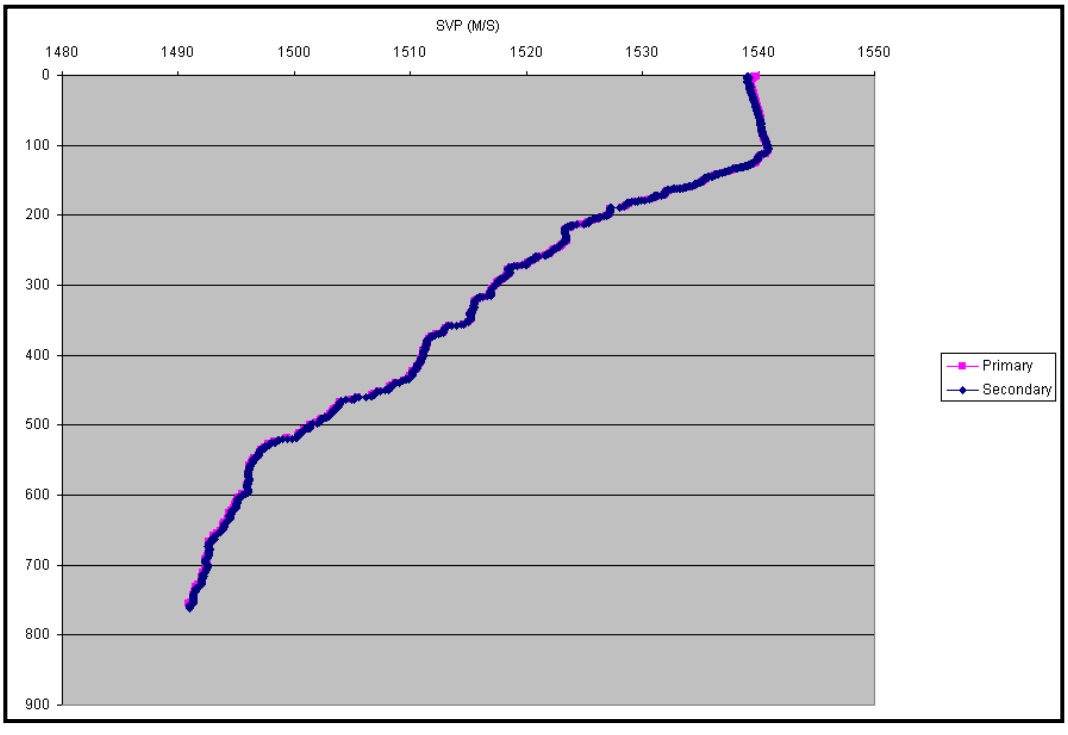
Assessment of sensors

Ancillary sensors

Sound velocity profiles were acquired using the NANCY FOSTER'S SeaBird Electronics SBE911 Conductivity, Temperature, and Depth (CTD) profiler (S/N 9P32146-0731). A back-up SBE 19 (S/N 192472-0285) was used to verify the calibration coefficients of the primary sound velocity profiler. Raw CTD data was processed using NOAA's Velocwin V8.8 software, which generated the sound velocity profiles required for real-time corrections in the MERLIN acquisition system. Casts were recorded to the full depth of the area being surveyed.

The speed of sound through the water was determined by a minimum of one cast every four hours during multibeam acquisition. In general the CTD casts showed the water column to be well mixed both spatially and temporally. Periodic comparisons between recent cast data were observed during the survey using Excel software. The primary CTD was calibrated against the backup unit prior to the commencement of survey operations. Each unit had been calibrated prior to use for this survey; refer to Appendix D for the SBE calibration reports.

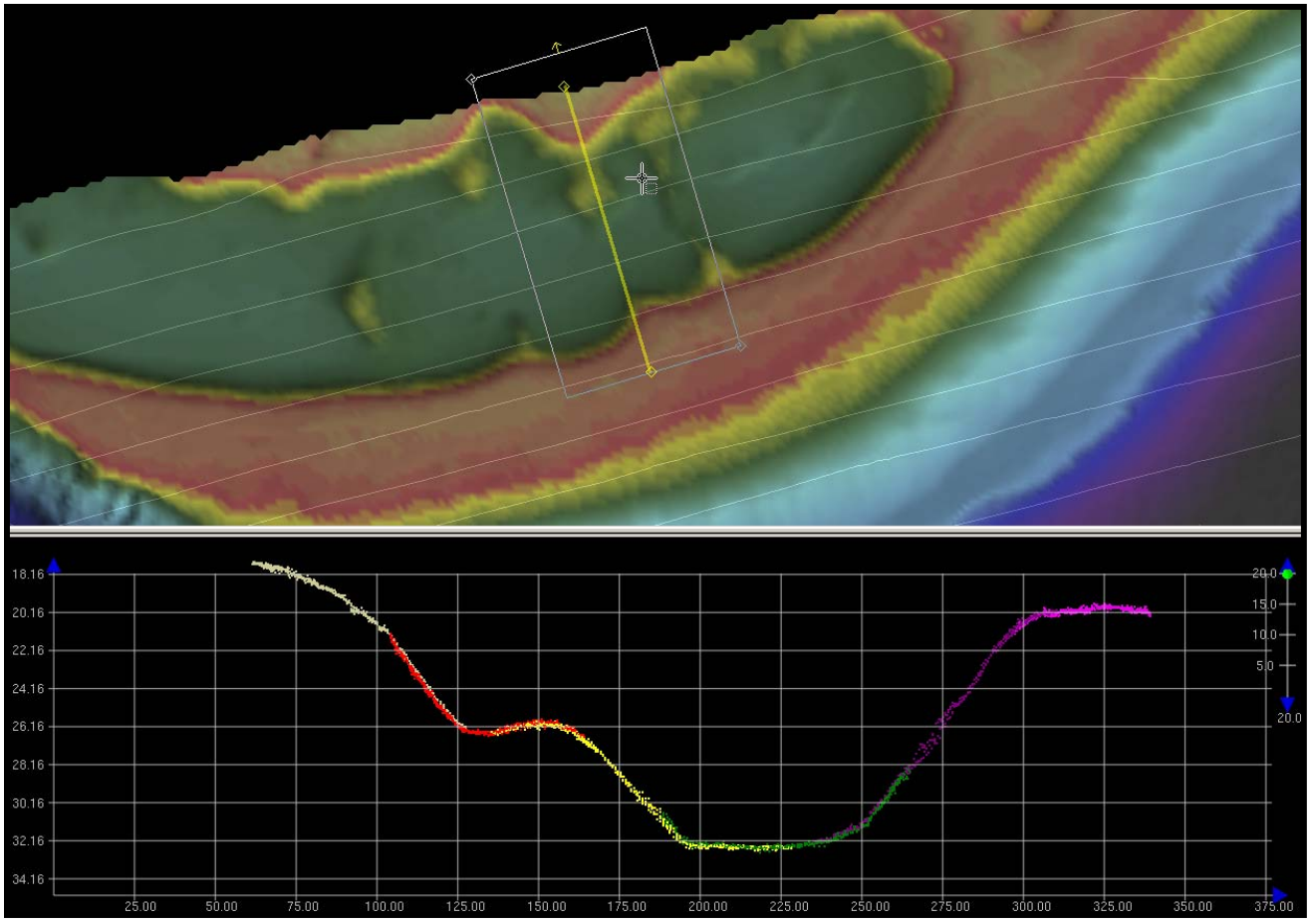
Fig 9: SVP Comparison



Assessment of Patch Test and Results

The Hydrographer believes that the values of the latency, pitch, roll and gyro offsets in both a shallow water and deep water setting, coupled with a thorough review of the patch test lines in Caris HIPS HDCS editor, adequately meet the requirements for the patch test. The Hydrographer is confident in the values derived from the patch test for sensor alignment. The following image represents an area of feature alignment that was collected with six lines of multibeam data.

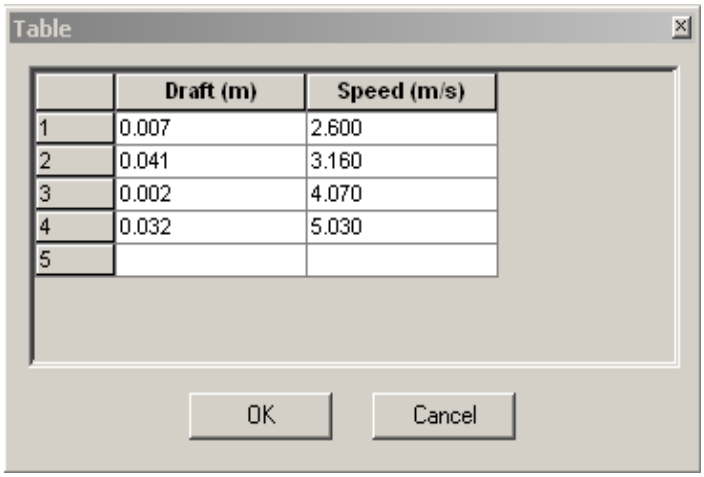
Fig 10: Features mapped with the EM1002 multibeam

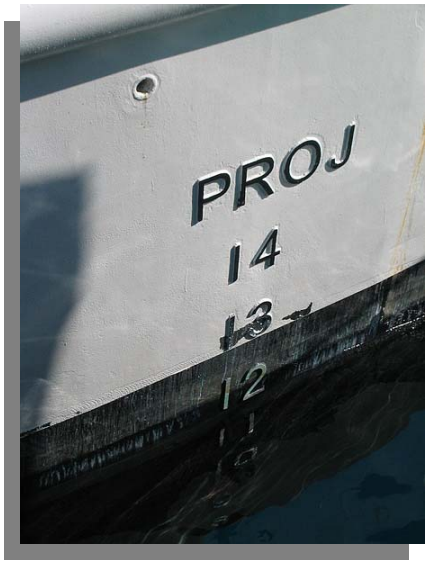


Assessment of Dynamic and Static Draft

Dynamic draft values for the NANCY FOSTER were performed during the Sea Acceptance Test (SAT) offshore of Charleston, South Carolina in March of 2006. Representatives from the NOAA Aviation and Marine Operations (NMAO) performed the survey and evaluated the results. Four-RPM levels were used to determine the dynamic draft: 790, 1000, 1300 and 1600. The observed changes in draft were negligible, with a maximum corrector of 0.041m. The values of the dynamic draft were entered into the R352_MB.hvf and were applied during the merge process in CARIS.

Table 2: CARIS Dynamic Draft Table





Static draft (waterline) observations were made from the pier the day of departure from St. Croix under full load and from the pier at the end of the cruise in Puerto Rico. Subtracting the RP from the projection draft markings on the starboard side of the NANCY FOSTER gave the draft to be used in the MERLIN software (-2.01m). A total loss of .213m was observed during the cruise, this value was divided into the 13 days of underway time (0.015m/day) and entered into the R352_MB.hvf vessel configuration file. The initial draft value was verified with a lead line observation while tied up at Frederiksted Pier, St. Croix. Appendix D includes detailed information regarding the dynamic, static and leadline values. The Lead Hydrographer feels that the dynamic and static draft corrections are adequate for this survey.

Fig 12: Projection Draft markings

Assessment of Horizontal and Vertical offsets

Sensor Offsets

The Power & Control Systems Group (PacOrd) surveyed the offsets to a maximum error of +/-5cm, with most of the critical offsets measured to within +/-0.5cm. Maximum errors of the angles surveyed did not exceed +/-1.0°. During the SAT, Chuck Hoeing (Kongsberg Rep), Nick Forfinski from NMAO and the Lead Hydrographer verified the sensor offset inputs for the EM1002, POS/MV and the CARIS R352_MB vessel configuration file. For the NF-06-03 cruise the Lead Hydrographer and Jay Lazar (Lead Hydrographer '04-'05 cruises) consulted and also verified all offsets entered into each program. Refer to the 2006 Hydrographic Systems Readiness Review (HSSR) for the NANCY FOSTER for more information.

Assessment of Sensor Calibrations

Each sensor associated with this survey underwent one form of calibration prior to commencement of survey operations. The multibeam sonar and offsets were calibrated with a leadline and position check while docked at the Frederiksted Pier, St. Croix pier. This data was digitally recorded to verify that the proper offsets and draft corrections were being applied to the multibeam data. The offsets to these systems were accurately measured during the PacOrd offset survey and verified by the Lead Hydrographer as well as participating hydrographers. The position checked well within DGPS position standards of +/-10meters. The CTD was calibrated against the backup unit and both received calibrations by the manufacturer within the previous year. The calibration for all systems including mounting angle offsets for the sonar system (Patch Test), occurred during the SAT trials, and were confirmed again with the documented NF-03-06 cruise calibration procedures. Based on these results the Lead Hydrographer feels that all the systems are adequately calibrated for the purpose of this survey.

Assessment of Object Detection

The EM1002 system's sonar ping rates are controlled automatically and are dependent on water depths. During acquisition, outer beam overlap was planned at 10%. The goals of the survey were to meet object detection requirements that satisfy IHO Order 1 in waters shoaler than 100m and IHO Order 2 deeper than 100m.

Bottom Coverage and Line Spacing

The survey lines are typically planned parallel to the general contours of the survey area. Line spacing was determined by depth using 10% overlap with 45° cutoff angles, port and starboard, for the majority of the areas surveyed. While surveying the shelf areas a 55° swath limit was used for the port and starboard beams to maximize coverage. Holiday lines were planned according to BASE surfaces created in the field. The resolutions for creating holiday plans were 3m for the shelf regions and 10m for depths generally greater than 100m. Preliminary review of the data in the field by the

Lead Hydrographer determined that the bottom coverage and line spacing were considered adequate for the purposes of this survey. During final evaluation of the 3m BASE surface during post processing, several small areas of holidays were identified in the La Parguera shelf regions from insignificant overlap from neighboring swaths. The largest is located at 17°53'08.3N and 67°00'45.17W and is approximatly 80m long and 8m wide. In addition, final mapping requirements were requested at the 2m resolution for depths shoaler than 60m. This change in resolution resulted in areas of inadequate coverage, mostly along the shelf/reef breaks, and along the outer swaths between some lines. It is recommended for overall coverage in the shelf areas that the 3m BASE surface be used for coverage estimates.

Table 3: Line Planning specs

LINE PLANNING SPECS NF-03-06			L=2 d tan (a/2) * (1-s)	a = Multibeam Swath Angle s = Swath Sidelap	d = Water Depth (ft)	
Depth (Fath)	Depth (M)	Depth (ft)	Swath Angle (Degrees)	Swath Overlap (%)	Line Spacing (ft)	Line Spacing (M)
5	9.1	30.0	55	10	77.1	23.5
10	18.3	60.0	55	10	154.2	47.0
15	27.4	90.0	55	10	231.4	70.5
20	36.6	120.0	55	10	308.5	94.0
25	45.7	150.0	55	10	385.6	117.5
30	54.9	180.0	55	10	462.7	141.0
40	73.2	240.0	55	10	617.0	188.0
50	91.4	300.0	55	10	771.2	235.1
75	137.2	450.0	55	10	1156.8	352.6
100	182.9	600.0	55	10	1542.4	470.1
125	228.6	750.0	45	10	1350.0	411.5
150	274.3	900.0	45	10	1620.0	493.8
175	320.0	1050.0	45	10	1890.0	576.1
200	365.8	1200.0	45	10	2160.0	658.4
250	457.2	1500.0	45	10	2700.0	823.0
300	548.6	1800.0	45	10	3240.0	987.5
350	640.1	2100.0	45	10	3780.0	1152.1
400	731.5	2400.0	45	10	4320.0	1316.7
450	823.0	2700.0	45	10	4860.0	1481.3
500	914.4	3000.0	45	10	5400.0	1645.9
550	1005.8	3300.0	45	10	5940.0	1810.5
600	1097.3	3600.0	45	10	6480.0	1975.1
650	1188.7	3900.0	45	10	7020.0	2139.7
700	1280.2	4200.0	45	10	7560.0	2304.3

Survey operations were primarily conducted at a vessel speed of approximately 4.5 knots for deep water and approximately 6 knots for the shallow shelf regions of Buck Island and La Parguera. The Field Operations Officer (FOO) of the NOAA ship THOMAS JEFFERSON, which also operates an EM1002 echosounder, supplied speed and ping rate tables for the EM1002. This table was designed to meet the requirement of the NOAA Specs and Deliverables section 5.2.2: "The hydrographer shall ensure that the vessel speed is adjusted so than no less than 3.2 beam foot prints, center-to-center, fall within 3 m, or a distance equal to 10 percent of the depth, whichever is greater, in the along track direction". Vessel speeds were adjusted to follow this table and to meet project requirements. Additionally, survey speeds were decreased during periods of heavy seas. In the opinion of the Lead Hydrographer, the vessel speeds and the sonar parameters used in this survey adequately ensonified the seafloor.

Assessment of IHO Compliance and Quality Control Report

Crosslines totaling approximately 6% of mainscheme were surveyed for both the Buck Island and La Parguera regions. The CARIS generated Quality Control Report compares the crosslines for each project against the 5m Depth BASE surface. The graphs in *Appendix K* are a cumulative representation of the IHO compliance of all the crosslines run for each region against the BASE surface. The results of the QC report are based on individual HDCS soundings from the crosslines, to a BASE surface created from the mainscheme data. Comparing HDCS crossline data to a mainscheme BASE surface may introduce, or reduce, errors, depending on results of comparisons between surfaces and individual soundings. During the acquisition of the crosslines in the La Parguera region, the Captain of the ship was testing the NANCY FOSTER's single beam system. The single beam frequency created "cross talk" interference with the EM1002 data, and significantly impacted the quality of the data. The impact of this is clearly visible in the IHO compliance graphs with a reduced percentile of beam above the 95% error required to meet IHO1 and IHO 2 specifications. The time constraints for the end of the cruise made re-running the lines not a practical option. As of the date of this document creation, the Rob Hare error model has not been created for the NANCY FOSTER. This report will be updated when the model becomes available.

VII. Summary Of Submitted Data:

The following documentation and data will accompany this survey upon completion:

Data

- Raw multibeam sonar sounding files in ALL format
- Processed multibeam sounding files in CARIS HDCS format
- Raw and processed sound velocity data files
- Predicted tides correctors (created from NOAA NWLON Gauges Magueyes Island, Puerto Rico (975-9110) and Lime Tree Bay (975-1401)
- Verified tide correctors created from NOAA NWLON Gauges Magueyes Island, Puerto Rico (975-9110) and Lime Tree Bay (975-1401)
- Tidal zoning prepared by NOAA CO-OPS
- XYZ files
- Sun-Illuminated GeoTiffs
- CARIS Hydrographic Vessel File (HVF)
- CARIS Session Files
- CARIS Fieldsheets

Approval Sheet (Separate Signed Document Verifying DAPR information)
APPROVAL

As Lead Hydrographer, I have ensured that standard field surveying and processing procedures were followed during this project in accordance with the Hydrographic Manual, Fourth Edition; Hydrographic Survey Guidelines; Field Procedures Manual, and the NOS Hydrographic Surveys Specifications and Deliverables Manual, as updated for 2003.

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

Approved and Forwarded: _____

APPENDIX A:

EM1002 Installation and Runtime Parameters

EM1002 installation parameters NOAA SHIP NANCY FOSTER Cruise# S-1911-NF-06

```
Software:
---------
SPTX : 1.0.6 991014
SPRX : 1.0.6 991014
BSP  : 1.5.5 050809
PU   : 2.2.1 031031
Hull Unit Included: No

Motion Sensor:
----------------
Source = Attitude Sensor, Port 2
Starboard Pos. = 0.00
Forward Pos.   = 0.00
DownwardPos.   = 0.00
Sensor Delay   = 0
Roll Offset    = 0.00
PitchOffset    = 0.00
Heading Offset = 0.00
Roll Ref. Plane= Pitch-Roll Axis Plane

Waterlevel:
-------------
Downward Pos.  = -2.01

Transducer:
--------------
Forward Pos.   = 0.81
Starboard Pos. = 1.86
Downward Pos.  = 1.68
Heading Re Bow = 0.03
Roll           = -0.01
Pitch          = 0.05

Heading:
--------
Source          = Attitude Sensor
Offset          = 0.00
Format          = NMEA HDT
1PPS            = In Use
Clock Offset (s)= 0

# Serial port no. 1
--------------------
Port will read: GGA ZDA
Baud Rate   = 19200 baud
Data Bits   = 8 bits
Stop Bits   = 1 bits
Parity      = None

# Serial port no. 2
--------------------
Port will read: Attitude
Baud Rate   = 19200 baud
Data Bits   = 8 bits
Stop Bits   = 1 bits
Parity      = None

# Serial port no. 3
--------------------
Port will read: None
Baud Rate   = 9600 baud
Data Bits   = 8 bits
Stop Bits   = 1 bits
Parity      = None

# Serial port no. 4
--------------------
```

```
Port will read: None
Baud Rate   = 9600 baud
Data Bits   = 8 bits
Stop Bits   = 1 bits
Parity      = None

# Ethernet
--------------------
Port will read: None

# Clock Synchronization:
-----------------------
Sync. To: External Clock

Active Pos. Sys. on Port 1

# Positioning System on Port 1
-------------------------------
Motion Correction = Enabled
Geoid         = WGS_84
Forward Pos.  = 0.00
Starboard Pos.= 0.00
Downward Pos .= 0.00
Pos.Delay     = 0.0
Time To Use   = From Datagram

# Positioning System on Port 3
-------------------------------
Motion Correction = Disabled
Geoid         = WGS_84
Forward Pos.  = 0.00
Starboard Pos.= 0.00
Downward Pos .= 0.00
Pos.Delay     = 0.0
Time To Use   = From System

# Positioning System on Port 4
-------------------------------
Motion Correction = Disabled
Geoid         = WGS_84
Forward Pos.  = 0.00
Starboard Pos.= 0.00
Downward Pos .= 0.00
Pos.Delay     = 0.0
Time To Use   = From System

# Positioning System on Ethernet
-------------------------------
Motion Correction = Disabled
Geoid         = WGS_84
Forward Pos.  = 0.00
Starboard Pos.= 0.00
Downward Pos .= 0.00
Pos.Delay     = 0.0
Time To Use   = From System
```

EM1002 runtime parameters NOAA SHIP NANCY FOSTER
Cruise# S-1911-NF-06

```
# Sounder Main:
---------------
Sounder Mode          = Off
Ping Mode             = Auto

# Sounder Depth is supposed to be within:
-----------------------------------------
Min. Depth             = 1 m
Max. Depth             = 1200 m

# Sector / Beams:
-----------------
Max Port Angle         = 45 deg
Max Starboard Angle    = 45 deg
Max Port Coverage      = 600 deg
Max Starboard Coverage = 600 m

Beam Spacing           = Equidistant
Angular Coverare       = Automatic

Tracking               = Auto

Depth To Normal Incidence    = 60m
Normal Incidence Backscatter = -25dB
Oblique Backscatter          = -25dB

# Sound Speed:
--------------
Sound Speed Profile    = 00011_06069183.98.asvp
Tx Sound Speed         = 1538.7 m/s
Sound Sensor Offset    = 0.0 m
Sound Speed Source     = Probe

# Seabed Imaging:
-----------------
TVG Law Crossover Angle= 25 deg.

# Gain:
------
Absorbtion Coeff.      = 30.00 dB
Range Gate             = Normal

# Filtering:
------------
Slope Filter           = Active
Sector Tracking Filter = Active

# Manual Control:
-----------------
Tx Power               = -10 dB
Fixed Gain             = 30 dB

# Simulator:
------------
Min. Depth             = 50 m
Max. Depth             = 50 m
Slant X                = 0 deg
Slant Y                = 0 deg
```

APPENDIX B:

Hydrographic Hardware/Software Inventory

Hydrographic Systems Inventory Cruise# NF-06-03				HARDWARE
Equipment type	Manufacturer	Model	Serial #	Firmware
Transducer	Kongsberg/Simrad	EM1002	288	N/A
Transceiver Unit	Kongsberg/Simrad	EM1002	303	N/A
Inertial GPS PCS	Applanix	POS/MV 320 V4	2249	N/A
IMU	Applanix	LN 200	447	N/A
DGPS	Trimble	DSM 132	224096283	3.0
Acquisition PC	Sun MicroSystems	Solaris 8	TT32220431	N/A
SVP	SBE	SBE 911	9P32146-0731	N/A
SVP	SBE	SBE 19	O285	N/A

Hydrographic Systems Inventory Cruise# NF-06-03			SOFTWARE
Equipment type	Manufacturer	Model	Software Version
Inertial GPS PCS	Applanix	POS/MV 320 V4	3.2
Navigation	Coastal Oceanographics	N/A	4.3A
Acquisition	Kongsberg/Simrad	MERLIN	5.2 V2
Processing	NOAA	Velocwin	8.8
Processing	CARIS	HIPS & SIPS	6.0 SP1 HF 1-18

APPENDIX C:

POS/MV 320 V4 Configuration Report

Input/Output Ports Set-up

COM1
Baud Rate=19200
Parity=None
Data Bits=8 Bits
Stop Bits=1 Bit
Flow Control=None
Output Select=NMEA

NMEA Output=GGA,ZDA,VTG Update Rate=10 Hz Talker ID=IN
Roll Positive Sense=Port UpPitch Positive Sense=Bow UpHeave Positive Sense=Heave Up
Input Select=None

COM2
Baud Rate=19200
Parity=None
Data Bits=8 Bits
Stop Bits=1 Bit
Flow Control
Output Select=Binary

Binary Output Update Rate=100 Hz Frame=Sensor 1 Formula Select=SIMRAD 1000 (Tate-Bryant) Roll Positive Sense=Port UpPitch Positive Sense=Bow UpHeave Positive Sense=Heave Up Input Select=None

COM3
Baud Rate=19200
Parity=None
Data Bits=8 Bits
Stop Bits=1 Bit
Flow Control=None
Output Select=None
Input Select=Base 1 GPS
Base GPS Input

Input Type=RTCM 1 or 9Line=Serial

Ethernet Logging ControlLogging Group Select=111,113 Logging Control
Output Rate (groups 1, 102, 103)=20 Hz

Ethernet Realtime Output ControlOutput Group Select=1,22,3,7,10,111,113 Output Control
Output Rate (groups 1,102, 103)=2 Hz

Events Event 1=Positive Edge Trigger
Event 2=Positive Edge Trigger

GAMS Parameter Setup
Two Antenna Separation (m)=2.253Heading Calibration Threshold (deg)=0.700Heading Correction (deg)=0.000 Baseline Vector

X Component (m)=-2.253 Y Component (m)=0.027 Z Component (m)=0.011

Heave Filter
Heave Bandwith (sec)=18.000
Damping Ratio=0.707

Lever Arms & Mounting AnglesLever Arms & Mounting Angles
Ref. to IMU Lever Arm X (m)=0.737 Y (m)=0.001 Z (m)=-0.125
IMU Frame w.r.t. Ref. Frame X (deg)= -0.009 Y (deg)=-0.006 Z (deg)=0.057
Ref. to Primary GPS Lever Arm X (m)=6.571 Y (m)=-4.740 Z (m)=-16.308
Ref. to Vessel Lever Arm X (m)=0.000 Y (m)=0.000 Z (m)=0.000
Ref. to Centre of Rotation Lever Arm X (m)=-12.295 Y (m)=0.000 Z (m)=-1.965
Sensor Mounting
Ref. to Aux. 1 GPS Lever Arm X (m)=0.000 Y (m)=0.000 Z (m)=0.000
Ref. to Aux. 2 GPS Lever Arm X (m)=0.000 Y (m)=0.000 Z (m)=0.000
Ref. to Sensor 1 Lever Arm X (m)=0.000 Y (m)=0.000 Z (m)=0.000
Sensor 1 Frame w.r.t. Ref. Frame
X (deg)=0.000
Y (deg)=0.000
Z (deg)=0.000
Ref. to Sensor 2 Lever Arm
X (m)=0.000
Y (m)=0.000
Z (m)=0.000
Sensor 2 Frame w.r.t. Ref. Frame
X (deg)=0.000
Y (deg)=0.000
Z (deg)=0.000

Tags, Multipath & AutoStart
Time Tag 1=UTC Time
Time Tag 2=GPS Time
AutoStart=Enabled
Multipath=Low

Statistics POS Version= MV-320,VER4,S/N2249,HW2.7-7,SW03.22-Feb08/06,ICD03.17,OS425B14,IMU2,PGPS13,SGPS13,RTK-0,THV-0,DPW-0
GPS Receivers Primary Receiver=BD950;SN:4520A58693,v.00211,channels:24 Secondary Receiver=BD950:SN:4520A58705,v.00211,channels:24

Statistics
Total Hours=1238.4
Total Runs=31
Average Run (hours)=39.9
Longest Run (hours)=623.0
Current Run (hours)=111.8

Navigator ConfigurationFrame Contol=User Frame Auxiliary GPS Position=NormalPrimary GPS

Measurement=NormalGAMS=unchecked Disable GAMS Solution

POS Internet Address POS Internate Address=010.048.002.012 Subnet Mask=255.000.00.000

Gps Receiver ConfigurationPrimary GPS Receiver Primary GPS GPS Output Rate=1 Hz

GPS 1 Port
Baud Rate=9600
Parity=None
Data Bits=8 Bits
Stop Bits=1 Bit

Auto Configuration
Enabled
Secondary GPS Receiver
Secondary GPS
GPS Output Rate=1 Hz
GPS 2 Port
Baud Rate=9600

Parity=None Data Bits=8 Bits Stop Bits=1 Bit
Auto Configuratiion
Enabled

User Parameter Accuracy
RMS Accuracy
Attitude (deg)=0.050
Headinig (deg)=0.050
Position (m)=2.000
Velocity (m/s)=0.500

APPENDIX D:

SBE Calibration Reports

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0731
CALIBRATION DATE: 28-Nov-05

SBE9plus PRESSURE CALIBRATION DATA
10000 psia S/N 89936

DIGIQUARTZ COEFFICIENTS:

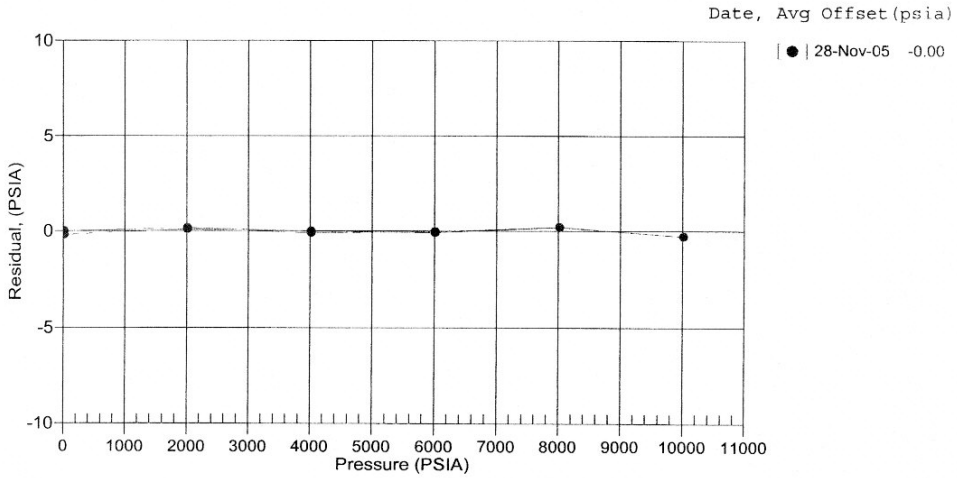
C1 = -4.767972e+004
C2 = -5.006157e-001
C3 = 1.084620e-002
D1 = 3.613800e-002
D2 = 0.000000e+000
T1 = 3.031386e+001
T2 = -5.277072e-004
T3 = 3.790810e-006
T4 = 6.671000e-010
T5 = 0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.30208e-002
AD590B = -9.65521e+000
Slope = 1.00003
Offset = 0.0170 (dbars)

PRESSURE (PSIA)	INST OUTPUT(Hz)	INST TEMP(C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.687	33002.25	17.9	14.658	14.682	-0.005
2015.057	33686.17	18.0	2015.137	2015.219	0.162
4015.411	34354.35	18.0	4015.262	4015.400	-0.011
6015.659	35007.84	18.1	6015.382	6015.578	-0.081
8016.122	35647.65	18.1	8016.069	8016.322	0.200
10016.954	36274.20	18.1	10016.373	10016.683	-0.271
8016.052	35647.65	18.2	8016.007	8016.260	0.208
6015.286	35007.79	18.2	6015.062	6015.258	-0.028
4015.240	34354.34	18.2	4015.012	4015.150	-0.090
2014.934	33686.20	18.2	2014.948	2015.030	0.096
14.682	33002.32	18.3	14.478	14.503	-0.179

Residual = corrected instrument pressure - reference pressure



SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4175
CALIBRATION DATE: 18-Nov-05

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS

g = 4.39920964e-003
h = 6.44548622e-004
i = 2.30059501e-005
j = 2.09050383e-006
f0 = 1000.0

ITS-68 COEFFICIENTS

a = 3.68121923e-003
b = 5.99863609e-004
c = 1.57790803e-005
d = 2.09200441e-006
f0 = 3179.379

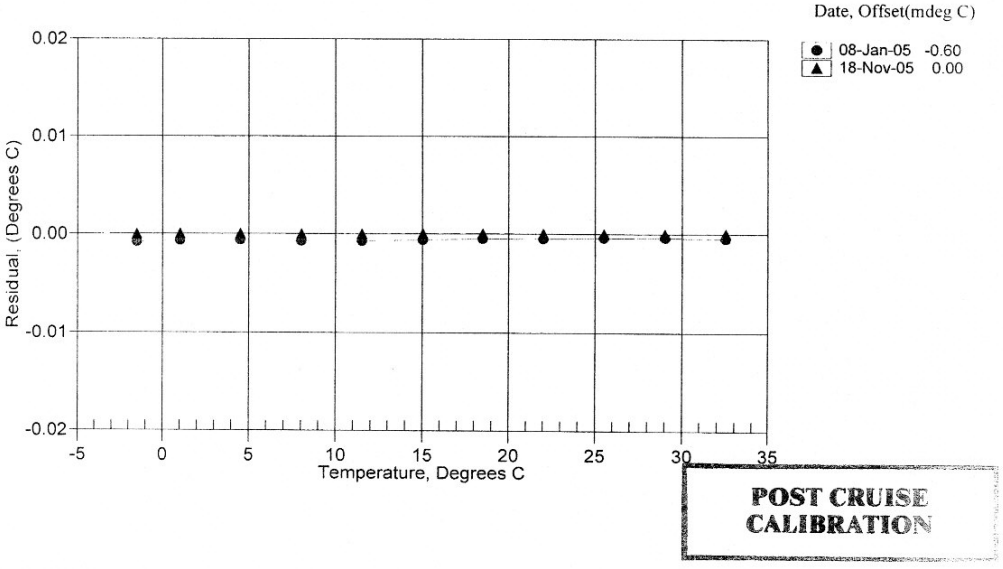
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5005	3179.379	-1.5005	-0.00001
0.9996	3362.706	0.9996	0.00002
4.4996	3632.034	4.4996	0.00001
7.9996	3916.539	7.9996	-0.00003
11.4996	4216.638	11.4996	-0.00001
14.9996	4532.727	14.9996	0.00001
18.4996	4865.194	18.4996	0.00003
21.9996	5214.409	21.9996	0.00001
25.4996	5580.739	25.4996	-0.00002
28.9996	5964.533	28.9996	-0.00003
32.4996	6366.131	32.4996	0.00002

Temperature ITS-90 = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature ITS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



POST CRUISE CALIBRATION

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2767
CALIBRATION DATE: 18-Nov-05

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

g = -1.01807883e+001
h = 1.55538498e+000
i = -1.41895967e-003
j = 2.05900222e-004
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 6.35690683e-006
b = 1.55212901e+000
c = -1.01752988e+001
d = -8.69789130e-005
m = 5.2
CPcor = -9.5700e-008 (nominal)

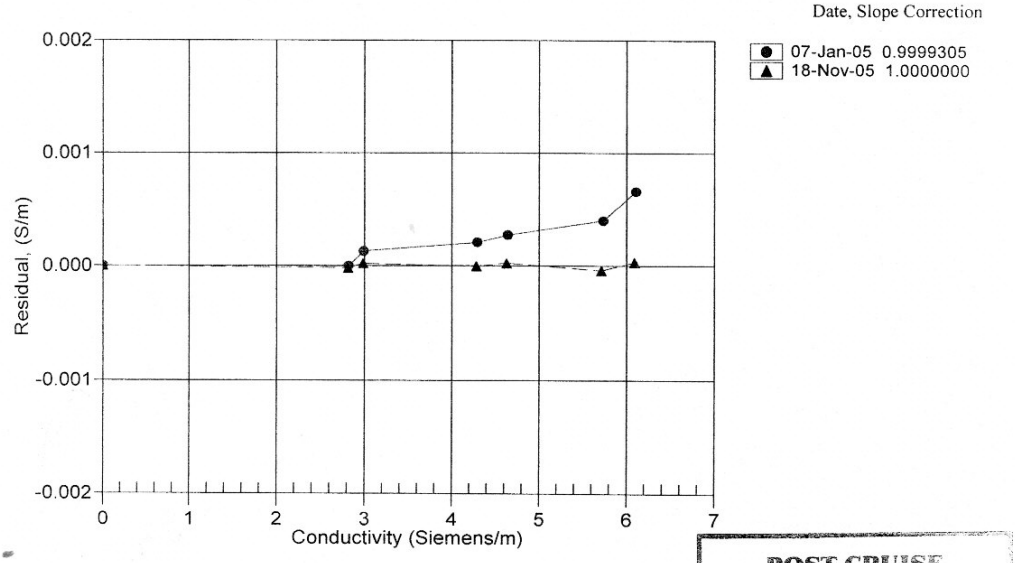
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.56030	0.00000	0.00000
-1.0001	34.8847	2.80956	4.96387	2.80954	-0.00002
1.0018	34.8852	2.98145	5.07402	2.98147	0.00002
14.9999	34.8853	4.27917	5.83837	4.27916	-0.00001
18.4999	34.8840	4.62637	6.02634	4.62639	0.00002
28.9999	34.8815	5.71178	6.57899	5.71174	-0.00004
32.4999	34.8746	6.08499	6.75850	6.08502	0.00003

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



POST CRUISE CALIBRATION

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 06-Dec-05

SBE19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS

g = 4.12533706e-003
h = 5.76088078e-004
i = -1.71029034e-007
j = -2.89832532e-006
f0 = 1000.0

ITS-68 COEFFICIENTS

a = 3.64763850e-003
b = 5.70491163e-004
c = 7.08541505e-006
d = -2.89821095e-006
f0 = 2297.672

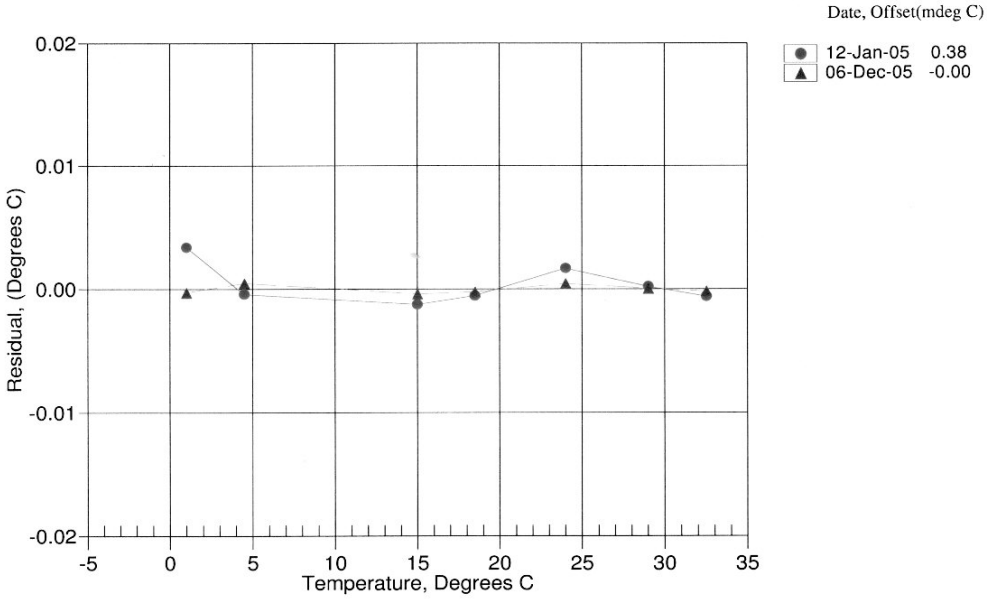
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2297.672	0.9997	-0.00027
4.5000	2490.830	4.5005	0.00049
15.0000	3139.237	14.9996	-0.00038
18.5000	3379.673	18.4998	-0.00020
23.9999	3783.445	24.0003	0.00045
29.0000	4179.021	29.0001	0.00007
32.5000	4472.721	32.4998	-0.00017

Temperature ITS-90 = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature ITS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 08-Dec-05

SBE19 PRESSURE CALIBRATION DATA
5000 psia S/N 133807 TCV: -121

QUADRATIC COEFFICIENTS:

PA0 = 2.492695e+003
PA1 = -6.505116e-001
PA2 = -5.432016e-008

STRAIGHT LINE FIT:

M = -6.505347e-001
B = 2.492368e+003

PRESSURE PSIA	INST OUTPUT(N)	COMPUTED PSIA	ERROR %FS	LINEAR PSIA	ERROR %FS
14.79	3807.4	15.16	0.01	15.53	0.01
1014.94	2271.8	1014.60	-0.01	1014.50	-0.01
2014.90	736.1	2013.84	-0.02	2013.53	-0.03
3014.97	-802.6	3014.77	-0.00	3014.49	-0.01
4015.01	-2340.3	4014.79	-0.00	4014.81	-0.00
5015.07	-3878.4	5014.82	-0.01	5015.40	0.01
4014.91	-2340.8	4015.12	0.00	4015.14	0.00
3014.75	-804.9	3016.27	0.03	3016.00	0.02
2014.97	734.8	2014.70	-0.01	2014.38	-0.01
1014.74	2271.0	1015.10	0.01	1015.00	0.01
14.79	3808.1	14.68	-0.00	15.05	0.01

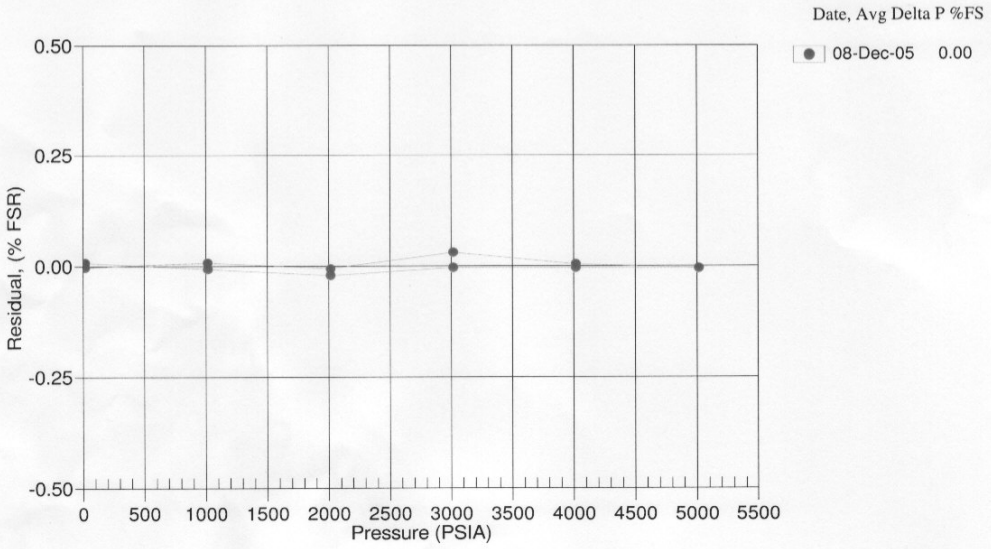
Straight Line Fit:

Pressure (psia) = M * N + B (N = binary output)

Quadratic Fit:

pressure (psia) = PA0 + PA1 * N + PA2 * N^2

Residual = (instrument pressure - true pressure) * 100 / Full Scale Range



SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 06-Dec-05

SBE19 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

g = -4.06615658e+000
h = 4.84869087e-001
i = 1.33004184e-003
j = -2.71256107e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 1.35181566e-002
b = 4.68318054e-001
c = -4.05092941e+000
d = -1.02668100e-004
m = 2.3
CPcor = -9.5700e-008 (nominal)

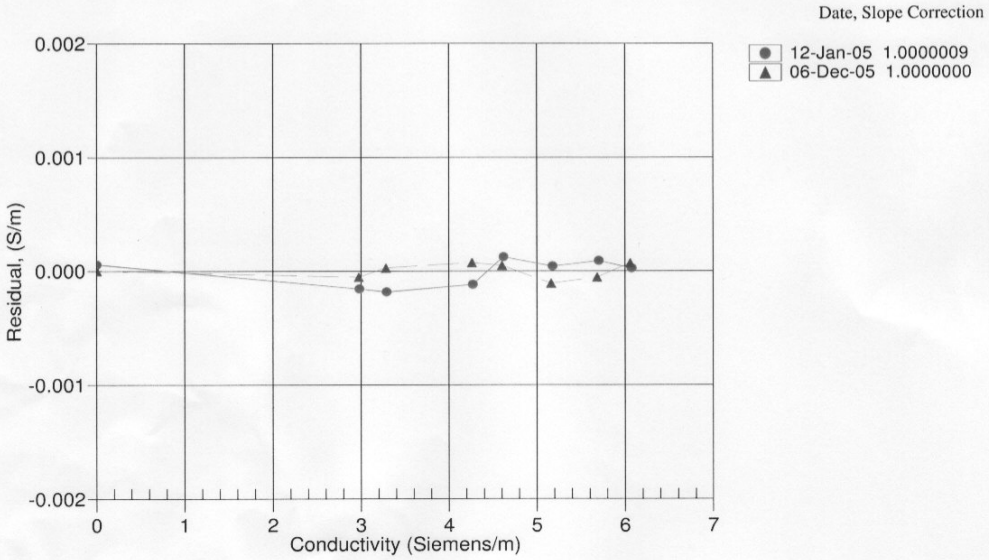
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREO (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88516	0.00000	0.00000
1.0000	34.7472	2.97062	8.26817	2.97057	-0.00005
4.5000	34.7271	3.27714	8.63260	3.27716	0.00003
15.0000	34.6842	4.25712	9.70465	4.25719	0.00007
18.5000	34.6754	4.60169	10.05398	4.60174	0.00005
23.9999	34.6662	5.15875	10.59387	5.15864	-0.00011
29.0000	34.6616	5.67983	11.07488	5.67977	-0.00006
32.5000	34.6607	6.05192	11.40582	6.05199	0.00007

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



APPENDIX E:

R352_MB. hvf & TPE Report

Vessel Name: R352_MB.hvf
Vessel created: April 28, 2006

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2006-064 00:00

Transduer #1:

Pitch Offset: 0.900
Roll Offset: -0.110
Azimuth Offset: -0.200

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer:
Model: em1002
Serial Number:

Navigation Sensor:

Time Stamp: 2006-064 00:00

Comments
Latency 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer:
Model:
Serial Number:

Gyro Sensor:

Time Stamp: 2006-064 00:00

Comments (null)
Latency 0.000

Entry 0) Draft: 0.000 Speed: 0.000

Heave Sensor:

Time Stamp: 2006-064 00:00

Comments Caris TechNote - SV Corrections for Simrad.pdf 072303
Apply No
Latency 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

Pitch Sensor:

Time Stamp: 2003-111 00:00

Comments Caris TechNote - SV Corrections for Simrad.pdf 072303
Apply No
Latency 0.000
Pitch offset: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

Roll Sensor:

Time Stamp: 2006-064 00:00

Comments Caris TechNote - SV Corrections for Simrad.pdf 072303
Apply No
Latency 0.000
Roll offset: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

Draft Sensor:

Time Stamp: 2006-064 00:00

Apply Yes
Comments (null)
Entry 1) Draft: 0.007 Speed: 5.054
Entry 2) Draft: 0.041 Speed: 6.143
Entry 3) Draft: 0.002 Speed: 7.911
Entry 4) Draft: 0.032 Speed: 9.778

TPE

Time Stamp: 2006-064 00:01

Comments
Offsets

Motion sensing unit to the transducer 1
X Head 1 1.855
Y Head 1 0.074
Z Head 1 1.801

Motion sensing unit to the transducer 2
X Head 2 0.000
Y Head 2 0.000
Z Head 2 0.000
Navigation antenna to the transducer 1
X Head 1 5.760
Y Head 1 6.596
Z Head 1 17.984
Navigation antenna to the transducer 2
X Head 2 0.000
Y Head 2 0.000
Z Head 2 0.000

Roll offset of transducer number 1 -0.014
Roll offset of transducer number 2 0.000

Heave Error: 0.060 or 5.000'' of heave amplitude.
Measurement errors: 0.020
Motion sensing unit alignment errors
Gyro:0.000 Pitch:0.000 Roll:0.000
Gyro measurement error: 0.020
Roll measurement error: 0.020
Pitch measurement error: 0.020
Navigation measurement error: 4.000
Transducer timing error: 0.000
Navigation timing error: 0.000
Gyro timing error: 0.010
Heave timing error: 0.010
PitchTimingStdDev: 0.010
Roll timing error: 0.010
Sound Velocity speed measurement error: 0.500
Surface sound speed measurement error: 0.500
Tide measurement error: 0.012
Tide zoning error: 0.100
Speed over ground measurement error: 0.250
Dynamic loading measurement error: 0.000
Static draft measurement error: 0.030
Delta draft measurement error: 0.000

Svp Sensor:

Time Stamp: 2006-064 00:00

Comments (null)
Svp #1:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.811
DeltaY: 1.856
DeltaZ: 1.676

SVP #2:

Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset: 0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

WaterLine:

Time Stamp: 2006-064 00:00

Comments
Apply No
WaterLine 0.000

Time Stamp: 2006-080 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-081 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-082 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-083 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-084 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-085 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-086 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-087 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-088 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-089 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-090 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-091 00:00

Comments
Apply Yes
WaterLine 0.010

Time Stamp: 2006-092 00:00

Comments
Apply Yes
WaterLine 0.010

Total Propagated Error (TPE) Report

NOAA Ship NANCY FOSTER 2006

Caris HIPS 6.0 has an error model that derives from a sounding's source errors the total propagated error (TPE) for that sounding. The sources of the estimates of the various errors vary from manufacturers' specifications, to theoretical values, to field tested empirical observations. The error estimates (one sigma) are entered into the TPE sensor section of an HVF.

Below is a table listing various source errors and their estimate, followed by a detailed discussion describing each error estimate.

Error Source	Error Estimate
Heave % Amplitude	5.0
Heave	0.05
Gyro	0.02
Roll	0.02
Pitch	0.02
Navigation	4.0
Timing Transducer	unknown
Navigation Timing	unknown
Gyro Timing	0.01
Heave Timing	0.01
Pitch Timing	0.01
Roll Timing	0.01
Sound Velocity Measured	0.5
Surface	0.5
Tide Measured	0.012
Tide Zoning	0.0 & .03
Offset X	0.02
Offset Y	0.02
Offset Z	0.02
Vessel Speed	0.25
Loading	unknown
Draft	0.03
Delta Draft	unknown

Detailed Discussion of Error Estimates

Heave % Amplitude

Error: 5.0

Definition: *Heave % Amplitude* is an additional heave standard deviation component that is the percentage of the instantaneous heave.

Discussion: See *Heave* discussion below.

Heave

Error: 0.05

Definition: *Heave* is the measurement for standard deviation of the heave data in meters.

Discussion: The POS/MV heave error is given as 0.05 meters + 5% of heave; however, the Caris error model implementation uses *Heave* or *Heave % Amplitude*, whichever is greater (see *Heave* discussion below). Thus a value of 0.06 for *Heave* is used as a compromise

Gyro

Error: 0.02

Definition: *Gyro* is the measurement standard deviation of the heading data in degrees.

Discussion: *Gyro* is based on POS/MV manufacturer specifications

Roll

Error: 0.02

Definition: *Roll* is the measurement standard deviation of the roll data in degrees.

Discussion: *Roll* is based on POS/MV manufacturer specifications.

Pitch

Error: 0.02

Definition: *Gyro* is the measurement standard deviation of the heading data in degrees.

Discussion: *Pitch* is based on POS/MV manufacturer specifications.

Navigation

Error: 4.0

Definition: *Navigation* is the standard deviation associated with the measurement of positions for the vessel in meters.

Discussion: *Navigation* is based on POS/MV manufacturer specifications.

Timing Transducer

Error: 0.0

Definition: *Timing Transducer* is the standard deviation of transducer time stamp measurements.

Discussion: *Timing Transducer* is not known and is currently being researched.

Navigation Timing

Error: 0.0

Definition: *Navigation Timing* is the standard deviation of navigation time stamp measurements.

Discussion: *Navigation Timing* is not known and is currently being researched.

Gyro Timing

Error: 0.01

Definition: *Gyro Timing* is the standard deviation of gyro time stamp measurements.

Discussion: *Gyro Timing* is based on POS/MV manufacturer specifications.

Heave Timing

Error: 0.01

Definition: *Heave Timing* is the standard deviation of heave time stamp measurements.

Discussion: *Heave Timing* is based on POS/MV manufacturer specifications.

Pitch Timing

Error: 0.01

Definition: *Pitch Timing* is the standard deviation of pitch time stamp measurements.

Discussion: *Pitch Timing* is based on POS/MV manufacturer specifications.

Roll Timing

Error: 0.01

Definition: *Roll Timing* is the standard deviation of roll time stamp measurements.

Discussion: *Roll Timing* is based on POS/MV manufacturer specifications.

Sound Velocity Measured

Error: 0.05
Definition: *Sound Velocity Measured* is the standard deviation of the measurement of sound velocity readings in meters/second.
Discussion: *Sound Velocity Measured* is based on SEACAT manufacturer specifications.

Surface

Error: 0.05
Definition: *Surface* is the standard deviation of the measurement of surface sound speed readings in meters/second.
Discussion: This value is currently being researched. In the meantime, NOAA Ship NANCY FOSTER will use 0.05, which is what NOAA Ship THOMAS JEFFERSON used for its Simrad SSVS.

Tide Measured

Error: .012
Definition: *Tide Measured* is the standard deviation of the measured tide values in meters.
Discussion: *Tide Measured* is based on CO-OPS calculations.

Tide Zoning

Error: Buck Island 0.03, La Parguera 0.00
Definition: *Tide Zoning* is the standard deviation of the tide values associated with zoning in meters.
Discussion: *Tide Zoning* is based on general CO-OPS calculations.

Offset X

Error: 0.02
Definition: *Offset X* is the standard deviation of the measured X offsets of the vessel.
Discussion: *Offset X* is the accuracy limit of whatever survey method was used to survey the vessel.

Offset Y

Error: 0.02
Definition: *Offset Y* is the standard deviation of the measured X offsets of the vessel.
Discussion: *Offset Y* is the accuracy limit of whatever survey method was used to survey the vessel.

Offset Z

Error: 0.02
Definition: *Offset Z* is the standard deviation of the measured X offsets of the vessel.

Discussion: *Offset Z* is the accuracy limit of whatever survey method was used to survey the vessel.

Vessel Speed

Error: 0.25

Definition: *Vessel Speed* is the standard deviation for the vessel speed measurements in meters/second.

Discussion: *Vessel Speed* requires further research. In the meantime, NANCY FOSTER is using what THOMAS JEFERSON used in 2005.

Loading

Error: 0

Definition: *Loading* is the measurement standard deviation of the vertical changes during the survey because of fuel consumption, etc. *Loading* corresponds to the Caris waterline measurement error.

Discussion: *Loading* is not currently used. Further investigation is required.

Draft

Error: 0.03

Definition: *Draft* is the standard deviation of the vessel draft measurements in meters.

Discussion: *Draft* is the accuracy limit of the draft measuring method.

Delta Draft

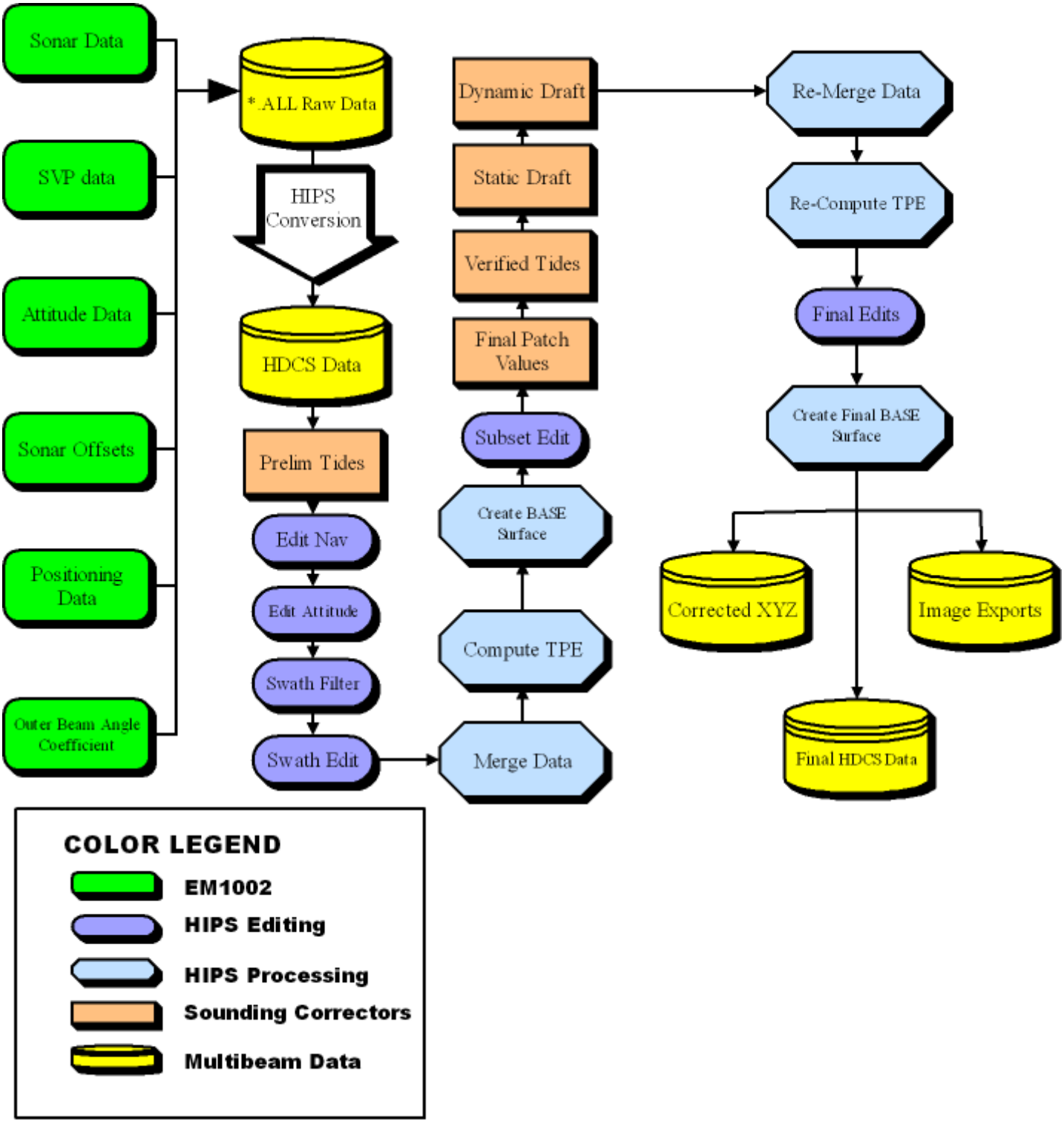
Error: 0

Definition: *Delta Draft* is the standard deviation of the dynamic vessel draft measurements in meters.

Discussion: *Delta Draft* is not currently used. Further investigation is required.

APPENDIX F:

CARIS Processing Flow Chart


Sonar Data
SVP data
Attitude Data
Sonar Offsets
Positioning Data
Outer Beam Angle Coefficient
* .ALL Raw Data
HIPS Conversion
HDCS Data
Prelim Tides
Edit Nav
Edit Attitude
Swath Filter
Swath Edit
Merge Data
Compute TPE
Create BASE Surface
Subset Edit
Final Patch Values
Verified Tides
Static Draft
Dynamic Draft
Re-Merge Data
Re-Compute TPE
Final Edits
Create Final BASE Surface
Corrected XYZ
Image Exports
Final HDCS Data
COLOR LEGEND
EM1002
HIPS Editing
HIPS Processing
Sounding Correctors
Multibeam Data

APPENDIX G:

NOAA Ship NANCY FOSTER Static Offset Report

L3 communications
Power & Control Systems Group
PacOrd

2/8/2006

Subj : NOAA SHIP Nancy Foster Survey

Ref: (a) SW225-AO-MMA-010/OP762/ALIGN THEORY, Theory of Combat System Alignment
(b) Table 1 of ITEM NO. 501

Encl: (1) Foundation Leveling Data Sheets

PacOrd personnel accomplished the survey of the equipment listed in table 1 of work item # 501 on board the NOAA SHIP Nancy Foster.

The granite blocks Roll and Pitch planes were set to the ship's gravity plane. The granite block was then used as the reference for all readings requiring a comparison to the ship's gravity plane.

The ship's centerline was transferred up from the keel, to the granite block 0°-180° reference line through an access cut into the hull of the ship. The granite block reference lines were then used as the reference for all readings requiring centerline reference.

The IMU foundation had to be removed, drilled and tapped for the new style IMU and reset.

The 12KHZ Transducer pitch angle exceeds the ±0.25° allowed by four minutes (reading is +0.3166°), a waiver was received from NOAA for this condition.

All other readings are within tolerance.

The final survey data is summarized in enclosure (1).

Byron K. Dunn
CSA Engineer

3161-3 St. Johns Bluff Rd
Jacksonville, Fl 32246
(904) 641-5442 - Phone
(904) 641-9967 - Fax

communications
PacOrd

SERIAL NO. 00656.001.02-03

INSPECTION/DEFICIENCY REPORT

JOB ORDER NO.

VESSEL NAME: NOAA SHIP NANCY FOSTER

DATE SUBMITTED: 7-Feb-06

WORK ITEM NO: 501

PARAGRAPH: para. 7.5

INSPECTION DATE(S): 11/14/05-02/02/06

TITLE OF WORK ITEM: SURVEY

TYPE OF REPORT

NOTICE ☐ IDR/CFR ☒ REQ REPORT ☐ PCP ☐ INFO ONLY ☐ OTHER

BALANCE REPORT

☐ PRINTS/DWG ☐ CFM/CFE ☐ GFM/GFE ☐ CONFLICTING PRINTS/DWGS SUPPLIED

☐ PRINTS/DWGS DO NOT REFLECT EXISTING SHIPBOARD / SITE CONDITIONS; DWG. NO:

incorrect: ☐ SPECIFICATIONS ☐ COMPARTMENT ☐ LOCATION REFERENCED SYSTEM:

PROBLEM/CONDITION:

Contractor accomplished Alignment Survey.
See attached results.

RECOMMEND: ☐ ISSUE A CHANGE ORDER ☒ ACCEPT REQUIRED REPORT ☐ ACCEPT PCP ☐ ACCEPT INFO ☒ SEE ATTACHED

Recommend Supervisor accept required report.

LEAD SHOP/AFFECTED TRADES	SIGNATURE OF ORIGINATOR	PRINT NAME	DATE
PacOrd	Byron K. Dunn	Byron K. Dunn	7-Feb-06

PROGRAM MANAGER/PROJECT SUPERINTENDENT DIRECTIONS

THE ABOVE RECOMMENDATIONS NEED TO BE CONTRACTUALLY INVOKED WITHIN DAYS OF ## TO LIMIT PRODUCTION IMPACT

☐ THIS REPORT EFFECTS CRITICAL PATH ☐ CHARGED TO BASIC ☐ CHANGE TO BE ISSUED ☐ AUTHORIZED TO PROCEED

CUSTOMER /SUPSHIP FINDINGS, RECOMMENDATIONS AND/OR APPROVAL

SIGNATURE	PRINT NAME	DATE

ENCLOSURE 1

L3 communications
Power & Control Systems Group
PacOrd

PacOrd
Jacksonville Division
3161-3 St. Johns Bluff
Jacksonville, FL 32246
Phone:(904) 641-5442
Fax: (904) 641-9967

SYSTEM	All readings are in centimeters					All readings are in Degrees					
	Horiz			Vert		Heading		Pitch		Roll	
	X	Y		Z		Degrees		Degrees		Degrees	
Granite Block	0.0	0.0		0.0		0.0000	±0.1°	-0.0022	±0.0025°	0.0014	±0.0025°
IMU Foundation	73.7	0.1	±0.5cm	4.3	±0.5cm	0.0573	±0.1°	0.0061	±0.01°	0.0092	±0.01°
IMU To Surface	73.7	0.1	±0.5cm	-12.5	±0.5cm	0.0573	±0.1°	0.0061	±0.01°	0.0092	±0.01°
AFT POS/MV Antenna #2	430.9	-473.7	±0.5cm	-1628.2	±0.5cm	N/A		N/A		N/A	
FWD POS/MV Antenna #1	657.1	-474.0	±0.5cm	-1630.8	±0.5cm	N/A		N/A		N/A	
POS/MV Antenna rel. to each other	226.2	-0.3	±0.5cm	N/A	-	N/A	-	N/A	-	N/A	-
Center of Roll and Pitch	-1229.5	0.0	±5cm	-196.5	±5cm	NA	-	NA	-	NA	-
Ship' Draft Marks Aft Stbd	-3138.5	609.6	±5cm	-289.4	±2cm	NA	-	NA	-	NA	-
Ship' Draft Marks Aft Port	-3138.5	-609.6	±5cm	-289.4	±2cm	NA	-	NA	-	NA	-
Ship' Draft Marks Fwd Stbd	1071.7	350.5	±5cm	-350.4	±2cm	NA	-	NA	-	NA	-
Ship' Draft Marks Fwd Port	1071.7	-350.5	±5cm	-350.4	±2cm	NA	-	NA	-	NA	-
Port Gyro	216.5	0.0	±5cm	-1254.8	±2cm	0.0017	±0.25°	NA	-	NA	-
Stbd Gyro	216.5	43.2	±5cm	-1254.8	±2cm	0.0047	±0.25°	NA	-	NA	-
EM 1002 Multibeam Foundation (Bottom)	81.1	185.6	±1cm	153.7	±1cm	0.0286	±0.1°	0.0500	±0.025°	-0.0139	±0.025°
EM 1002 Multibeam	81.1	185.6	±1cm	167.6	±1cm	0.0286	±0.1°	0.0500	±0.1°	-0.0139	±0.1°
ADCP	-665.5	-157.8	±5cm	154.6	±2cm	45.0750	±0.25°	-0.0750	±0.25°	0.0167	±0.25°
AFT Deck Bench Mark Port	-3783.7	-527.1	±0.5cm	-386.1	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
AFT Deck Bench Mark Stbd	-3783.7	527.1	±0.5cm	-386.1	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
AFT Deck Alignment Cube	-3594.5	581.7	±0.5cm	-471.2	±0.5cm	0.0000	±0.1°	0.0555	±0.01°	-0.0083	±0.01°
Moon Pool BM	-2197.7	121.9	±0.5cm	-385.4	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Flying Bridge Port BM	469.9	-559.4	±0.5cm	-1419.9	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Flying Bridge Stbd BM	469.2	561.4	±0.5cm	-1418.6	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Flying Bridge Alignment Cube	648.3	2.5	±0.5cm	-1431.2	±0.5cm	0.0000	±0.1°	0.0333	±0.01°	-0.0333	±0.01°
Dry Lab Fwd Bench Mark	-462.6	313.5	±0.5cm	-589.0	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Dry Lab Aft Bench Mark	-993.2	313.5	±0.5cm	-589.4	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°
Dry Lab Alignment Cube	-639.3	102.9	±0.5cm	-588.7	±0.5cm	0.0000	±0.1°	0.0500	±0.01°	0.0083	±0.01°
Computer Lab Fwd Bench Mark	-600.4	-380.9	±0.5cm	-596.7	±0.5cm	0.0667	±0.1°	NA	±0.05°	NA	±0.05°
Computer Lab Aft Bench Mark	-1070.2	-380.8	±0.5cm	-597.8	±0.5cm	0.0667	±0.1°	NA	±0.05°	NA	±0.05°
Computer Lab Alignment Cube	-837.9	-162.2	±0.5cm	-569.7	±0.5cm	0.0000	±0.1°	0.0042	±0.01°	0.0167	±0.01°
IMU AFT Bench Mark	-146.9	16.6	±0.5cm	-19.7	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°

IMU FWD Bench Mark	339.0	17.4	±0.5cm	-19.5	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
IMU Alignment Cube	161.1	169.2	±0.5cm	-4.4	±0.5cm	0.0000	±0.1°	-0.0111	±0.01°	-0.0528	±0.01°	
ADCP AFT Bench Mark	-1169.8	-26.7	±0.5cm	-38.4	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
ADCP FWD Bench Mark	-148.7	-26.7	±0.5cm	-38.4	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
ADCP Alignment Cube	-668.5	-208.0	±0.5cm	18.4	±0.5cm	0.0000	±0.1°	0.0389	±0.01°	0.0444	±0.01°	
Gyro Bench Mark Fwd	216.5	22.4	±0.5cm	-1164.5	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
Gyro Bench Mark Aft	-98.5	22.4	±0.5cm	-1156.9	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
Keel Bench Mark Fwd	318.6	1.9	±0.5cm	108.3	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
Keel Bench Mark Aft	-118.3	1.9	±0.5cm	108.3	±0.5cm	0.0000	±0.1°	NA	±0.05°	NA	±0.05°	
12Khz Stbd	-634.4	-157.8	±5cm	154.6	±2cm	N/A	-	0.3167	±0.25°	-0.1167	±0.25°	
200KHZ Transducer	-236.7	-90.2	±5cm	108.3	±2cm	N/A	-	0.0917	±0.25°	-0.0333	±0.25°	
Moon Pool Adapter	-2248.7	121.3	±5cm	111.8	±2cm	N/A	-	-0.0250	±0.25°	0.1500	±0.25°	

Port Down = Positive

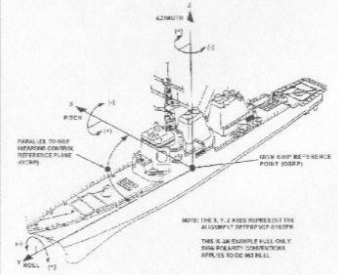
Bow Down = Positive

X dimension readings forward of Granite Block = positive, aft of Granite Block =negative

Y dimension readings starboard of Granite Block = positive, port of Granite Block =negative

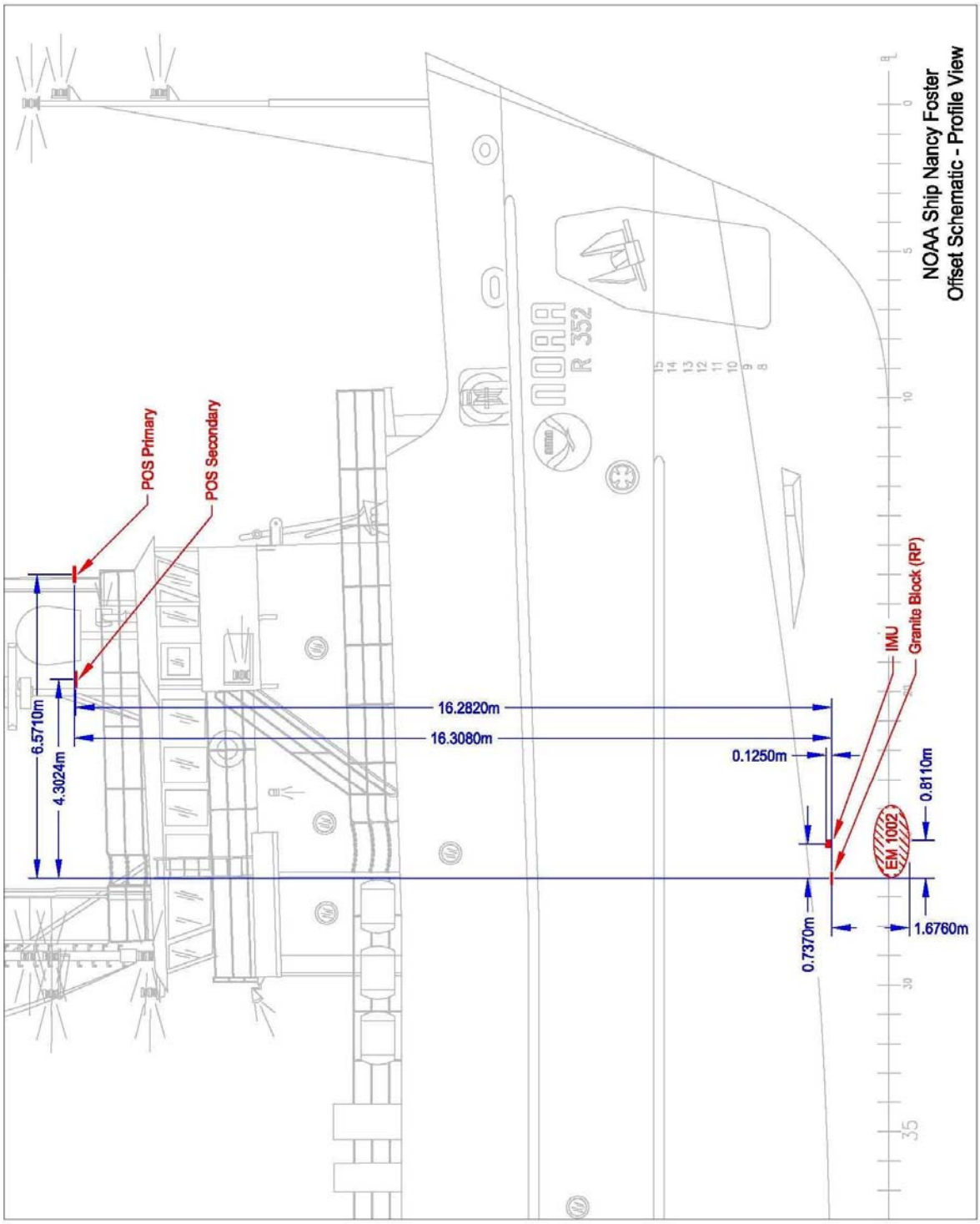
Z dimension readings lower than Granite Block = positive, higher than Granite Block =negative

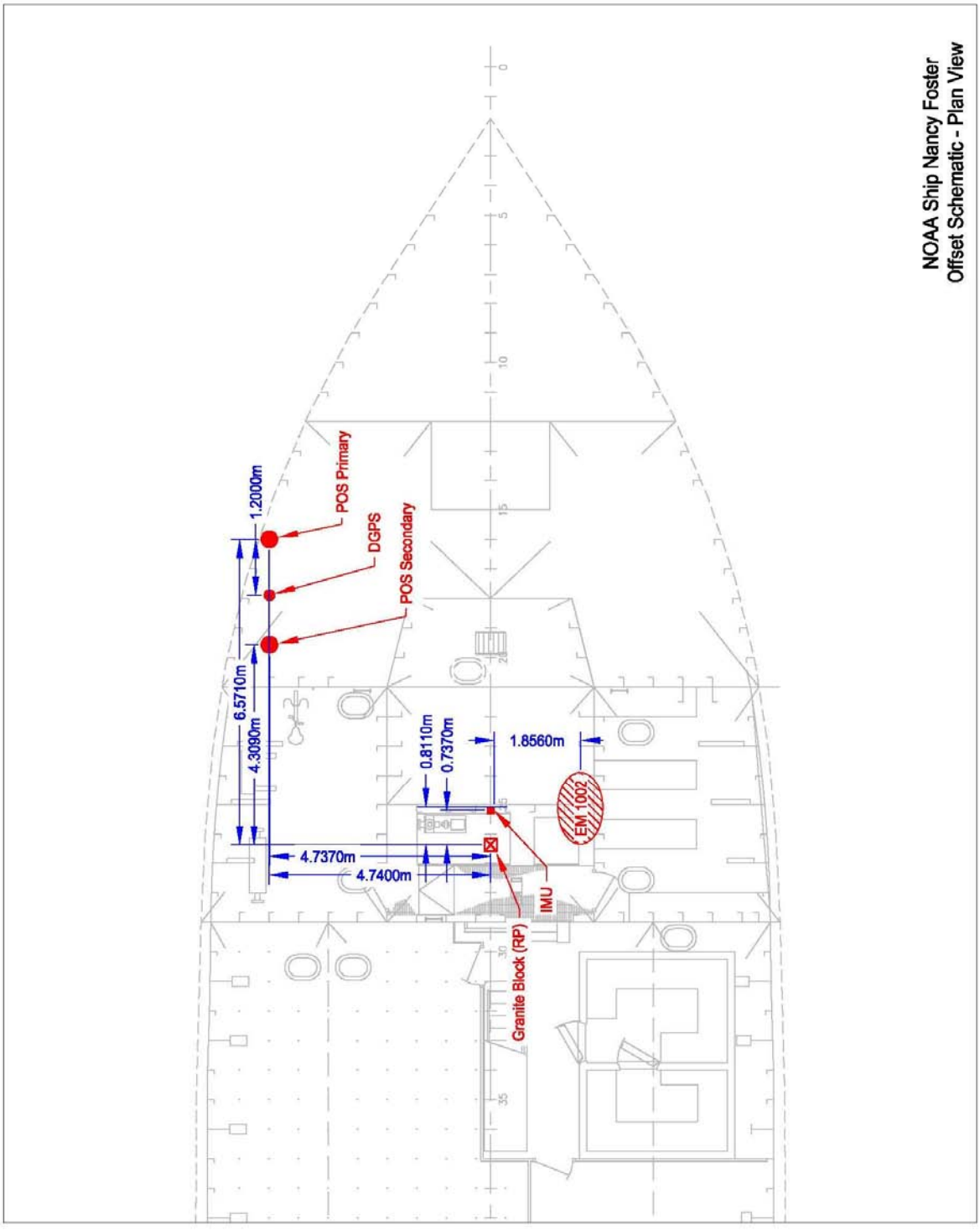
Figure 3-53. Sign Polarity Convention



APPENDIX H:

NOAA Ship NANCY FOSTER Offset Diagram


NOAA Ship Nancy Foster
Offset Schematic - Profile View
POS Primary
POS Secondary
IMU
Granite Block (RP)
6.5710m
4.3024m
16.2820m
16.3080m
0.1250m
0.8110m
EM 1002
0.7370m
1.6760m
NOAA
R 352


NOAA Ship Nancy Foster
Offset Schematic - Plan View
POS Primary
DGPS
POS Secondary
1.2000m
6.5710m
4.3090m
0.8110m
0.7370m
1.8560m
EM 1002
4.7370m
4.7400m
IMU
Granite Block (RP)

APPENDIX I:

Multibeam Calibration Procedures & Patch Test Report

Calibration Date: March 21, 2006

Ship	NOAA Ship Nancy Foster
Vessel	
Echosounder System	Simrad EM1002
Positioning System	POS/MV Model 320 M4
Attitude System	POS/MV Model 320 M4

Calibration type:

Annual		Full	X
Installation	X	Limited/Verification	
System change			
Periodic/QC			
Other:			

The following calibration report documents procedures used to measure and adjust sensor biases and offsets for multibeam echosounder systems. Calibration must be conducted A) prior to CY survey data acquisition B) after installation of echosounder, position and vessel attitude equipment C) after changes to equipment installation or acquisition systems D) whenever the Hydrographer suspects incorrect calibration results. The Hydrographer shall periodically demonstrate that calibration correctors are valid for appropriate vessels and that data quality meets survey requirements. In the event the Hydrographer determines these correctors are no longer valid, or any part of the echosounder system configuration is changed or damaged, the Hydrographer must conduct new system calibrations.

Multibeam echosounder calibrations must be designed carefully and individually in consideration of systems, vessel, location, environmental conditions and survey requirements. The calibration procedure should determine or verify system offsets and calibration correctors (residual system biases) for draft (static and dynamic), horizontal position control (DGPS), navigation timing error, heading, roll, and pitch. Standard calibration patch test procedures are described in *Field Procedures for the Calibration of Multibeam Echo-sounding Systems*, by André Godin (Documented in Chapter 17 of the Caris HIPS/SIPS 5.3 User Manual, 2003). Additional information is provided in *POS/MV Model 320 Ver 3 System Manual* (10/2003), Appendix F, Patch Test, and the NOAA Field Procedures Manual (FPM, 2003). **The patch test method only corrects very basic alignment biases**. These procedures are used to measure static navigation timing error, transducer pitch offset, transducer roll offset, and transducer azimuth offset (yaw). Dynamic and reference frame biases can be investigated using a reference surface.

Pre-calibration Survey Information

Reference Frame Survey

(IMU, sensor, GPS antenna offsets and rotation with respect to vessel reference frame)

Vessel reference frame defined with respect to:

[ ] IMU [X] Reference Position

Reference to IMU Lever Arm

X(m)	Y(m)	Z(m)
0.737	0.001	-0.125

IMU frame w.r.t vessel reference frame

X(deg)	Y(deg)	Z(deg)
-0.009	-0.006	-0.057

Reference to Sensor Lever Arm

X(m)	Y(m)	Z(m)
0.0	0.0	0.0

[X] **Measurements verified for this calibration.**
Reference Centerline Survey report
[X] **Drawing and table attached.**

[X] **Drawing and table included with project report/DAPR:** NF-06-03 DAPR

Position/Motion Sensor Calibration (for POS/MV model 320 M4)

Calibration date: February 7,2006

Reference to primary GPS Lever Arm

X(m)	Y(m)	Z(m)
6.571	-4.740	-16.308

Heave Settings: Bandwidth 18.00 Damping Period .707

Reference to Center of Rotation Lever Arm

X(m)	Y(m)	Z(m)
-12.295	0.000	-1.965

Firmware version 3.22 was used for the entire survey.

Static Draft Survey
(Vessel waterline with respect to RP)

Survey date: March, 21 2006

Prior to conducting the patch test and survey, initial confidence checks were performed to ensure an accurate measurement of water depths. While the Nancy Foster was tied up to the pier at Frederiksted, St. Croix, the survey team initially observed the static draft of the starboard PROJ draft marks at +/-3.69m(12.1ft.). The EM1002 transducer offset from the RP (0,0,0) is a fixed distance of 1.676m, which is entered into the installation parameters in the EM1002 controller software, Merlin V.5.2v2. The waterline to the RP is the elevation required to compensate for draft.

RP to EM1002 offset - WL = Elevation from WL to RP

1.68m - 3.69m = -2.01

To verify the draft and the EM1002 depths, five leadlines were performed from the 02 starboard deck, above and slightly starboard of the EM1002 while tied up alongside the pier. The leadline comprised of an eight-pound lead attached to a 100ft fiberglass tape. While the leadline's were being performed the EM1002 was acquiring multibeam data with the Merlin software. The average leadline value of 18.73m was subtracted from the 02-deck elevation of 7.32m above the WL to equal a final depth of 11.41m. The average elevation of the starboard multibeam data was 11.4m, confirming the draft setting of –2.01m in the Merlin software.

Line	Avg. Raw Z(m)	Leadline Z (m)
00001_20060321_155045	*11.3 – 11.5	11.41
* -2.01 draft, 0.00 tide, 0.00 squat Observed value averaged with starboard beams		

For the duration of the survey from March 21 to April 2, 2006, the static draft change due to fuel consumption and water discharge totaled .213m, or .015m per day. The changes observed were corrected for in the waterline table of the hydrographic vessel file R352_MB.hvf

Static Draft Correction -2.01 **(meters)**

Dynamic Draft Survey

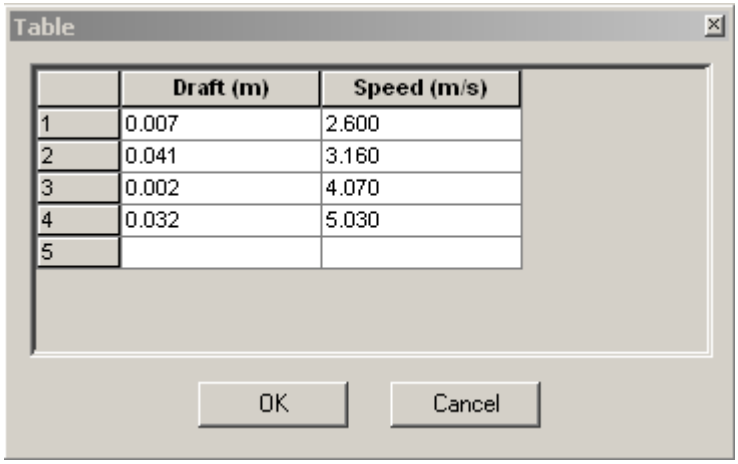
(Vessel waterline with respect to vessel reference frame and vessel speed)

The dynamic draft survey was performed during the Sea Acceptance Test (SAT) offshore of Charleston, South Carolina in March of 2006. Representatives from the NOAA Aviation and Marine Operations (NMAO) performed the survey and evaluated the results. The dynamic draft was determined using the reference surface method as per the NOS Field Procedures Manual. Results of the dynamic draft survey were entered into the CARIS vessel configuration file, R352_MB.hvf

Tabular Summery of Dynamic Draft Results

RPM	Area A		Area B		Area C		Average Speed		Average Δ Draft	
	Speed	*Δ Draft*	*Speed*	*Δ Draft*	*Speed*	*Δ Draft*	*Ave.*	*σ*	*Ave.*	*σ*
0	1.832	0.000	1.327	0.000	0.912	0.000	**1.357**	0.461	**0.000**	0.000
790	6.598	0.026	4.260	-0.026	4.346	0.022	**5.068**	1.326	**0.007**	0.029
1000	6.104	0.088	6.089	-0.078	6.261	0.115	**6.151**	0.095	**0.041**	0.105
1300	7.866	-0.015	7.896	-0.012	8.010	0.034	**7.924**	0.076	**0.002**	0.027
1600	9.816	0.031	9.696	0.063	9.855	0.004	**9.789**	0.083	**0.032**	0.030

Dynamic Draft Table, R352_MB.hvf



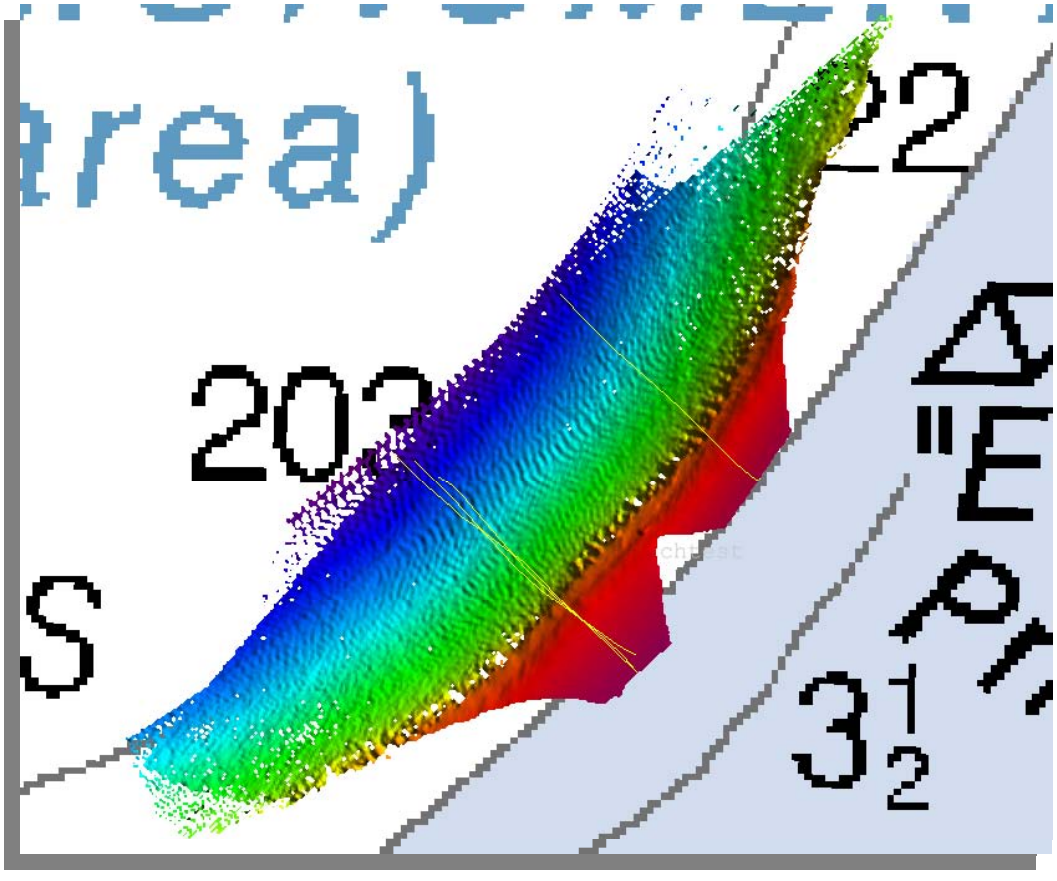
Calibration Survey Information

A patch test was performed before the surveying operations commenced. Biases were estimated by running a series of calibration lines, as described in the NOS Hydrographic Specifications and Deliverables, March 2003 Edition (HSSD). The patch test calibration quantified residual biases between the POS/MV V4's Inertial Measurement Unit and the EM1002 multibeam transducer alignments. The patch test also identified time latency within the positioning and acquisition system. All values in Merlin and in the CARIS vessel configuration file were changed to zero before the patch test was collected.

Calibration Area

Site Description for Latency, Pitch and Yaw Procedures

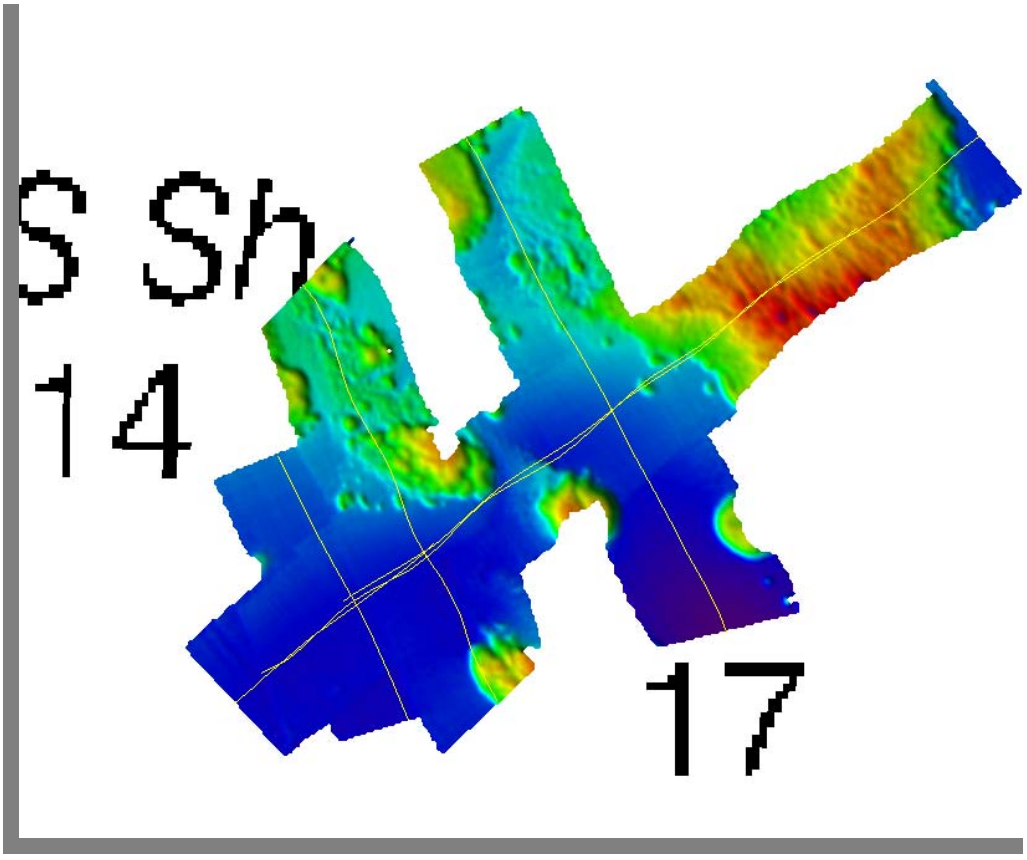
An area 1.5 nautical miles west of Buck Island was identified to provide the steep and smooth slope with little change in across track depth to accurately assess the latency, pitch and yaw biases for the Nancy Foster's EM1002 multibeam system. Two planned survey lines were oriented perpendicular to slope, parallel and spaced apart to ensure overlap of outer beams for the yaw calibration. A sound velocity cast was performed prior to conducting the patch test in the immediate vicinity. A total of four lines were surveyed. Vessel speeds were consistent for the latency, pitch and yaw transects at approximately 4 knots. Vessel speeds were increased to approximately 7 knots for the second latency line of the patch test.



Site Description for Roll and Outer Beam Angle Offset Procedures

The roll and outer beam angle offset calibration procedures require a flat seafloor. An area 5.1 nautical miles to the east of Buck Island, near Lang Bank, proved to be sufficient enough for calibrations. A deeper site would have been preferred but the bathymetry of the area deemed it necessary to make due with the 15-fathom plateau east of Buck Island. A sound velocity cast was performed before the calibration lines were surveyed.

The outer beam angle offset calibration procedure is unique to the EM1002 and is required for electronic beam steering for all beam angles larger than 50°. The EM1002 transducer coating has a sound speed that is significantly different from the sound speed of water and varies with temperature. The outer beam angle offset coefficient is found by estimating the beam pointing angle error in degrees by comparing the depths measured in the outer beams to those of the nadir beams. Comparing two perpendicular surveyed lines with CARIS's roll calibration tool, entering the estimated offset value into Merlin, and re-surveying the lines for verification was necessary before the surveying operations commenced.

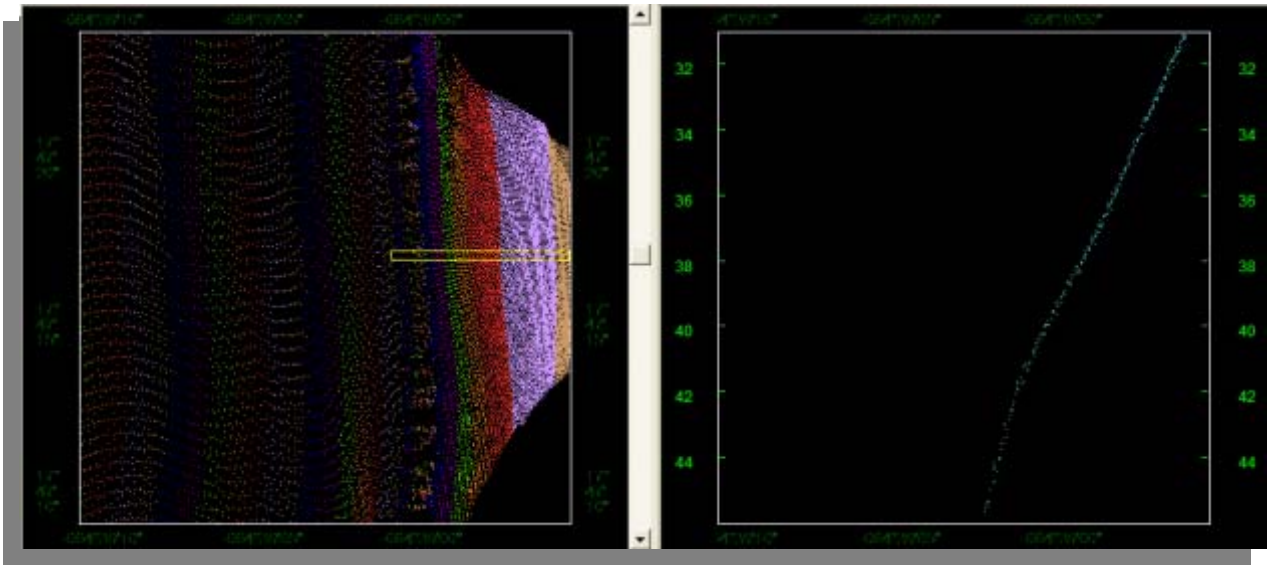


Calibration Survey Information

The hydrographer performed the biases calculations in the order described in the HSSD using CARIS HIPS's calibration tool.

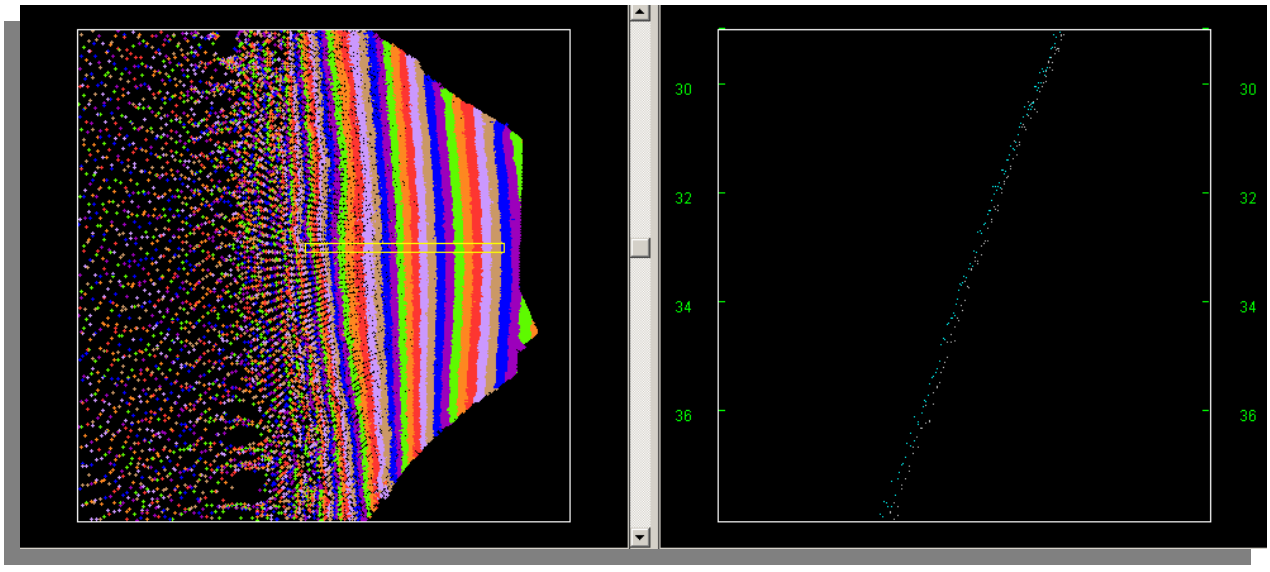
- Latency was calculated first, observing two surveyed lines in the same direction up a slope, at different speeds. Nadir beams were observed with an estimated 0.0 seconds of latency, which is typical of the POS/MV systems.

1) Latency

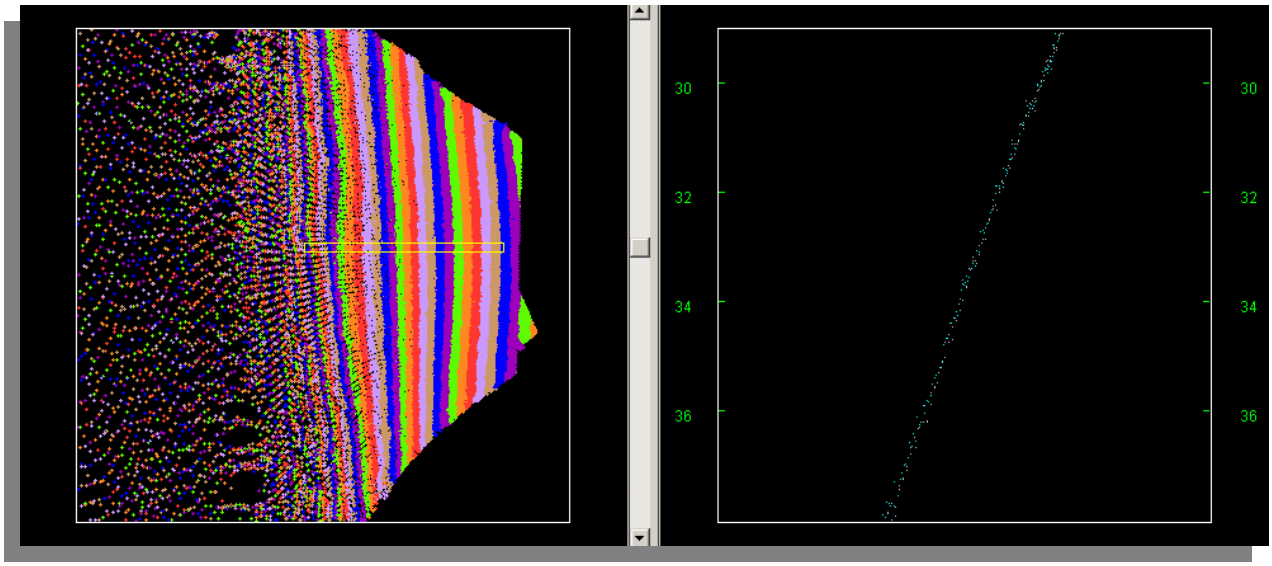


- The pitch offset was calculated next, observing nadir data with two-surveyed lines in opposing directions over a slope.

2) Pre-Pitch Alignment



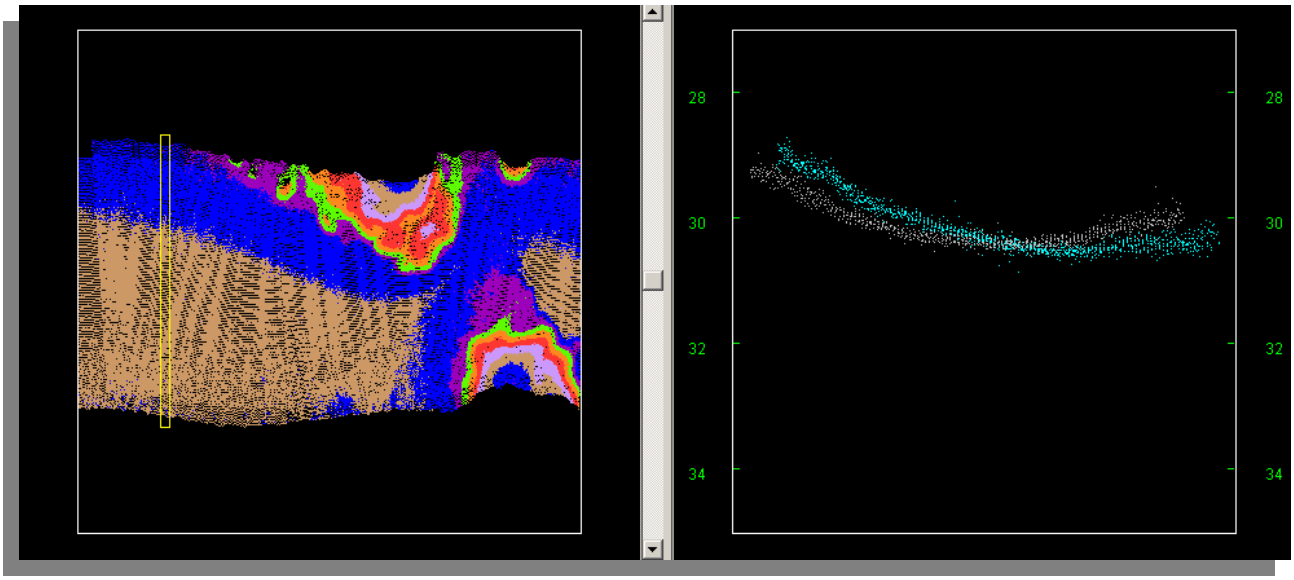
2a) Post-Pitch Alignment



- A Pitch offset of -0.9° was identified and entered into the R352_MB.hvf.

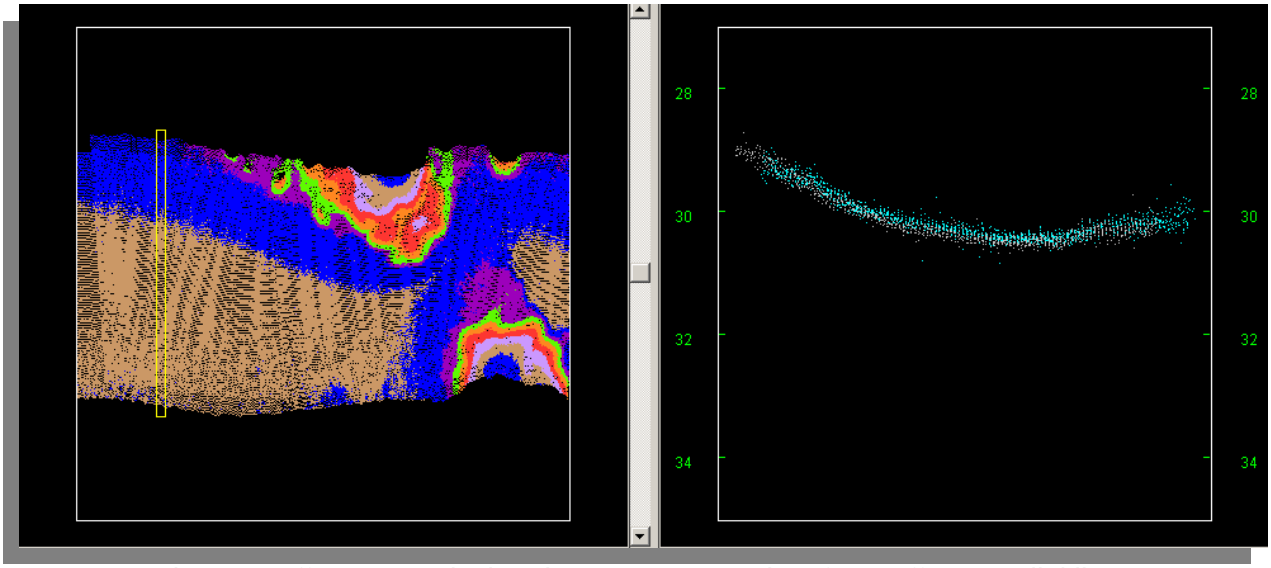
3) Pre-Roll Alignment

- The Roll offset was calculated next, observing the full swath of two-surveyed lines in opposing directions over a flat area.



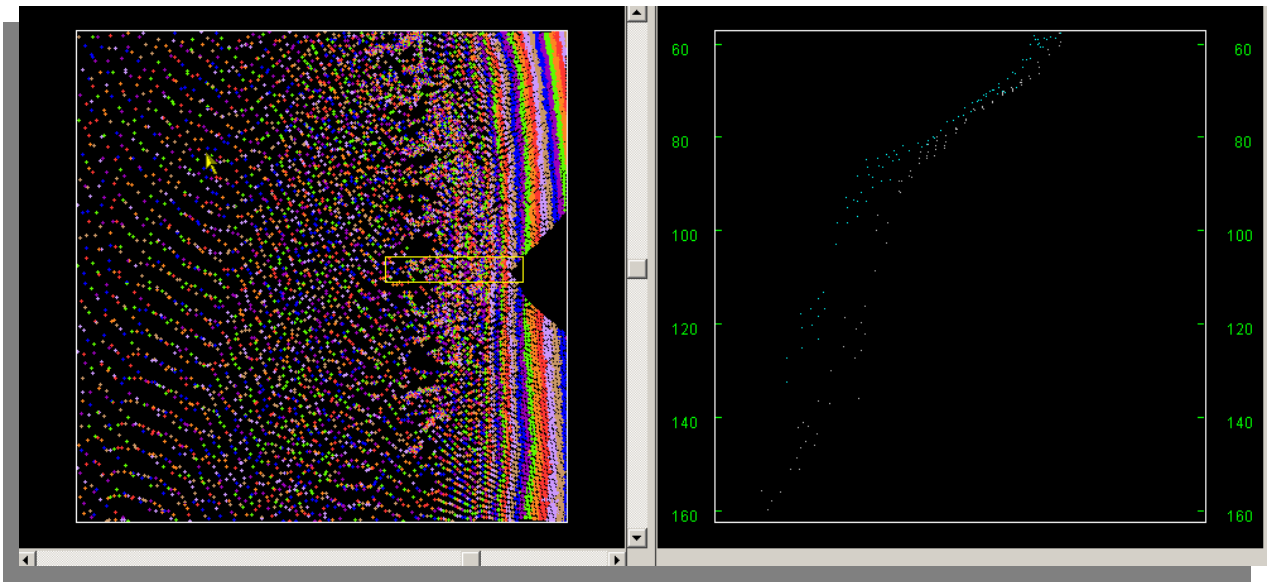
- A roll offset alignment of -0.11° was identified and entered into the R352_MB.hvf.

3a) Post-Roll Alignment



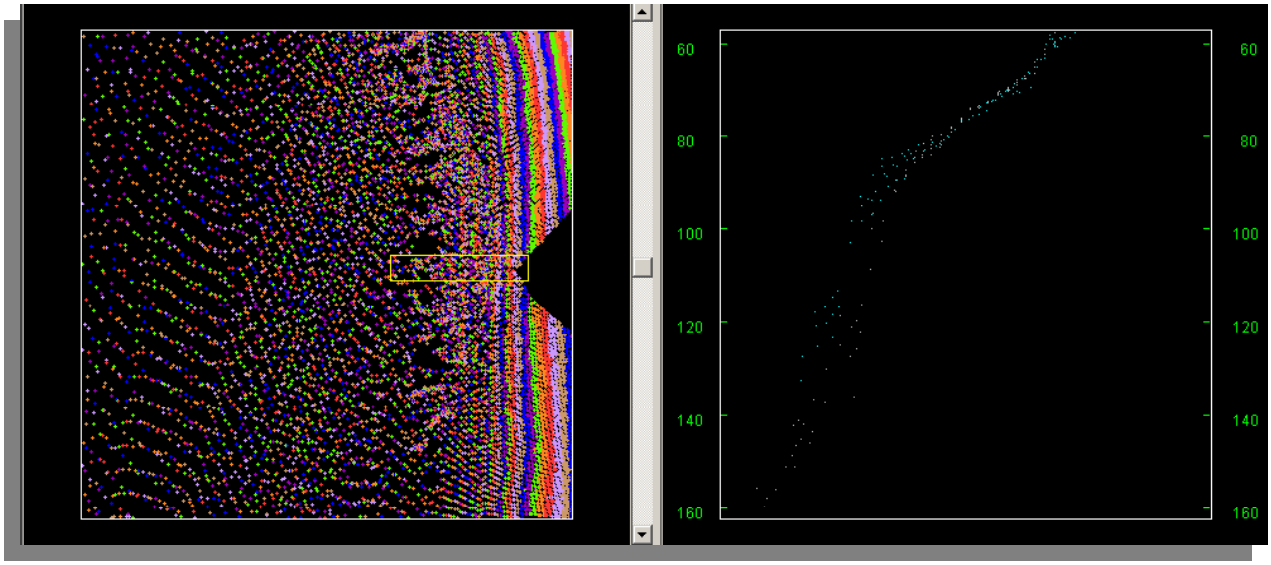
- The Yaw offset was calculated next, outer swaths of two offset parallel lines surveyed in the same direction over a slope.

4) Pre-Yaw Alignment



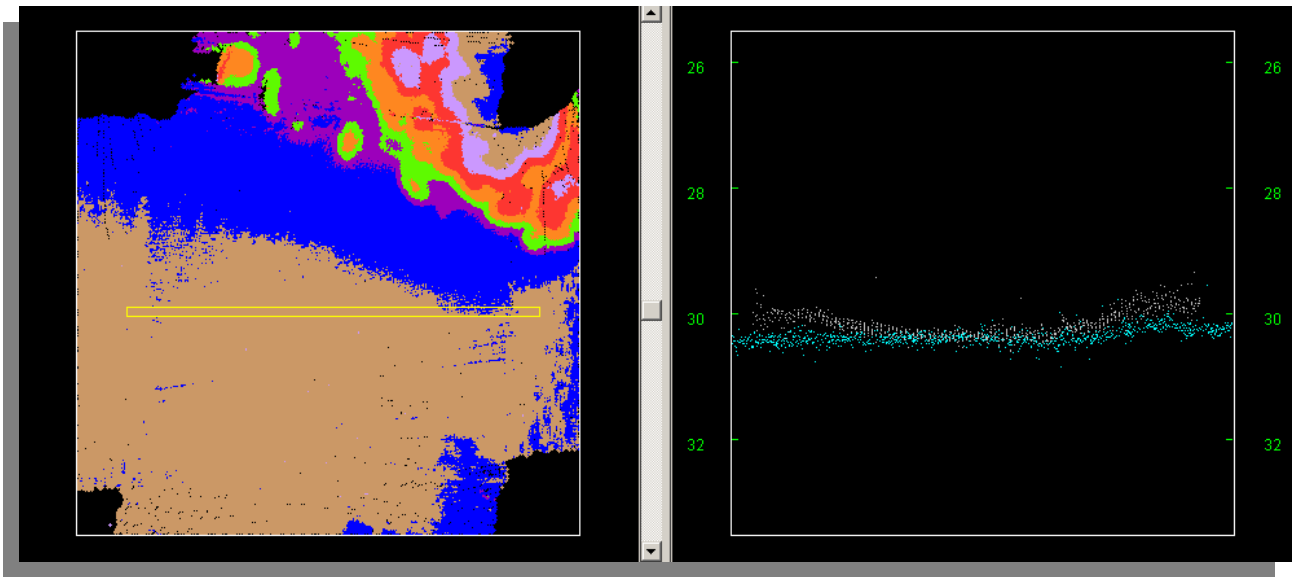
- A Yaw offset alignment of -0.2° was identified and entered into the R352_MB.hvf

4a) Post-Yaw Alignment



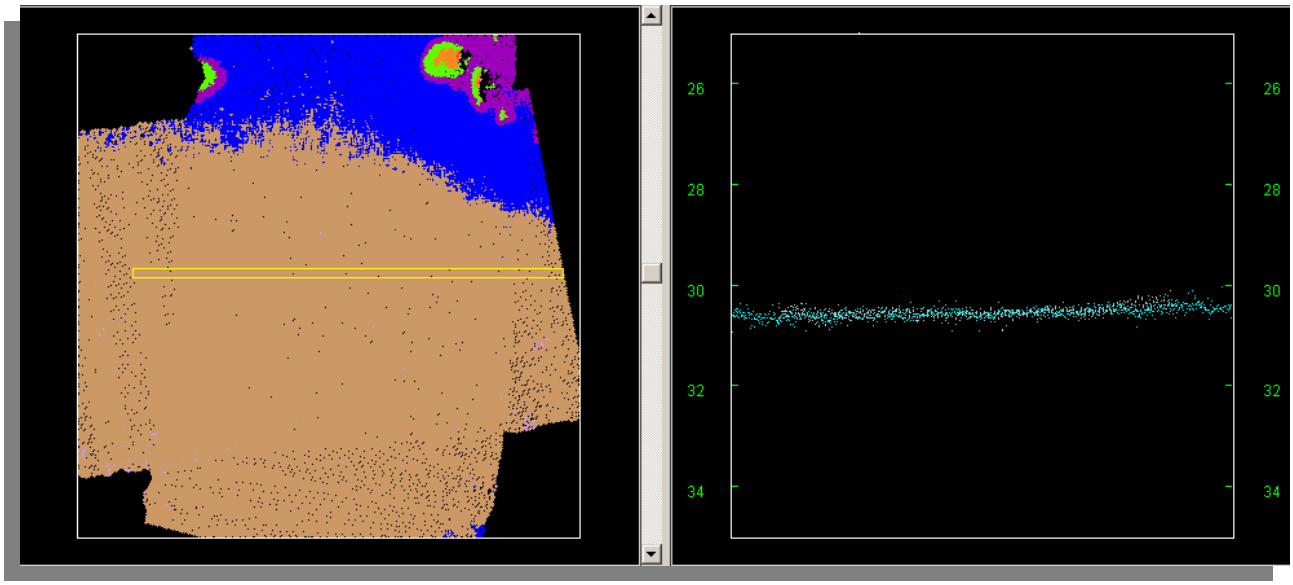
- The outer beam angle offset was the final calculation, observing the nadir beams versus the full swath, of two perpendicular lines over a flat area.

4) Pre-Outer beam angle offset



- An outer beam angle offset of -0.36 was identified and entered into the Merlin acquisition system.

4a) Post-Outer beam angle offset



The patch test results were proven with seafloor alignment from opposing swaths throughout the data set. The CARIS vessel configuration file R352_MB.hvf was updated with the values obtained from the patch test and used for the duration of the S-1911-NF-06 cruise and the post-processing of multibeam data.

Calibration Lines

Line	Direction	Speed	Bias Measured
0001_20060321_204909	NE	5	R1
0003_20060321_212834	NW	5	OBC 1
0003_20060321_212834	SE	5	OBC 2
0005_20060322_000559	SE	4	L1,P1
0006_20060322_002023	NW	4	Y1
0007_20060322_002922	SE	7.5	L2
0008_20060322_003522	NW	4	P2,Y2
0009_20060322_0042103	SW	5	OBC Check
0010_20060322_043013	NW	5	OBC Check

Sound Velocity Correction

Measure water sound velocity (SV) prior to survey operations in the immediate vicinity of the calibration site. Conduct SV observations as often as necessary to monitor changing conditions and acquire a SV observation at the conclusion of calibration proceedings. If SV measurements are measured at the transducer face, monitor surface SV for changes and record surface SV with profile measurements.

Sound Velocity Measurements

Cast	Time	Depth(m)	Northing	Easting
13_060800152.359	2030	36	1966085	337946
14_06080230.4608	2325	450	1967715	324843

Tide Correction

Predicted tides applied.

Gauge ID

Approximate distance of gauge from calibration site: (n. N/A **mi.)**

Approximate water level range at calibration site: .050 **(meters)**

Water level corrections applied:

- [X] Predicted
- [ ] Preliminary
- [X] Zoned
- [ ] Verified

Data Acquisition and Processing Guidelines

Initially, calibration measurement offsets were set to zero in the vessel configuration files. Static and dynamic draft offsets, inertial measurement unit (IMU) lever arm offsets, and vessel reference frame offsets were entered in appropriate software applications prior to bias analysis. Performed minimal cleaning to eliminate gross flyers from sounding data.

Navigation Timing Error (NTE)

Measure NTE correction through examination of a profile of the center beams from lines run in the same direction at maximum and minimum vessel speeds. NTE is best observed in shallow water.

Transducer Pitch Offset (TPO)

Apply NTE correction. Measure TPO correction through examination of a profile of the center beams from lines run up and down a bounded slope or across a conspicuous feature. Acquire data on lines oriented in opposite directions, at the same vessel speed. TPO is best observed in deep water.

Transducer Roll Offset (TRO)

Apply NTE and TPO corrections. Measure the TRO correction through examination of roll on the outer beams across parallel overlapping lines. TRO is best observed over flat terrain in deep water.

Transducer Azimuth Offset (TAO or yaw)

Apply NTE, TPO and TRO corrections. Measure TAO correction through examination of a conspicuous topographic feature observed on the outer beams of lines run in opposite directions.

Patch Test Results and Correctors

Evaluator	NTE (sec)	TPO (deg)	TAO (deg)	TRO (deg)
Mike Stecher	0.0	0.90	-0.2	-0.11

Corrections calculated in: CARIS HIPS

[X] Caris [ ] ISIS

[ ] Other _____

Caris Vessel Configuration File

Name: R352_MB.hvf

Version: 6.0 SP 1 HF 1-18

New [X] Appended values with time [ ] tag

Evaluator: Mike Stecher, Lead Hydrographer

APPENDIX J:

CO-OPS Tide Requirements, Tide Note and Correspondence

Tide Requirements for S-I911-NF-2006
Puerto Rico and Virgin Islands, USVI
MMC 12/19/2005

5.0. TIDES

5.1. Purpose: All tide requirements in these instructions are in direct support of hydrographic survey operations.

5.2 through 5.6. Refer to Standing Instructions.

5.7. Vertical Datums:
Refer to Standing Instructions.

5.7.1. The operating National Water Level Observation Network (NWLON) stations at Magueyes Island, PR (975-9110) and Lime Tree Bay, St.Croix (975-1401) will serve as datum control for the survey area. Therefore, it is critical that these stations remain in operation during all periods of hydrography.

5.7.1.1. Water level data acquisition monitoring
Refer to Standing Instructions.

5.7.1.2. Water level station operation and maintenance
Refer to Standing Instructions.

5.7.1.3. No leveling is required at Magueyes Island, PR (975-9110) and Lime Tree Bay, St.Croix (975-1401) by NOAA Ship NANCY FOSTER personnel.

5.8. Water Level Station Requirements: The operating water level stations at Magueyes Island, PR (975-9110) and Lime Tree Bay, St.Croix (975-1401) will also provide water level reducers for this project, reiterating the importance of their operation during all periods of hydrography. See Sections 5.7.1.1. and 5.7.1.2. concerning responsibilities.

5.8.1. There are no subordinate water level stations required for this project.
Please see attached graphics for recommended survey areas if not installing a subordinate water level gauge.

5.8.1.2. This section is not applicable for this project.

5.8.1.3 Tide Component Error Estimation: The estimated tidal error contribution to the total survey error budget in the vicinity of Puerto Rico cannot be computed due to a lack of available water level time series data.

5.9. Zoning: For hydrography in the area of Puerto Rico and US Virgin Islands, Magueyes Island, PR (975-9110) and Lime Tree Bay, St.Croix (975-1401) are the reference stations for

predicted tides. Predictions may be retrieved in one month increments over the Internet from the CO-OPS Home Page at http://www.co-ops.nos.noaa.gov/ and then clicking on "Predictions." Predictions are six-minute time series data relative to MLLW in metric units on Greenwich Mean Time. Apply the following time and height correctors to the predicted or preliminary tides at Magueyes Island, PR (975-9110) and Lime Tree Bay, St.Croix (975-1401) during the acquisition and preliminary processing phases of this project for correcting all sounding data.

Zone Name	**Time Corrector(mins)**	**Range Ratio**	**Predicted Reference**
PRS2	0	x1.01	975-9110
PRS6	+6	x0.94	975-9110
PRS7	0	x0.94	975-9110
PRS8	-6	x0.94	975-9110
PRS9	-24	x0.94	975-9110
PRS9A	-18	x0.94	975-9110
PRS10	-24	x0.94	975-9110
VIR12	0	x1.01	975-9110
VIR41	0	x1.06	975-1401
VIR42	0	x1.06	975-1401
VIR43	0	x1.06	975-1401

NOTE: The tide corrector values referenced to Magueyes Island, PR (975-9110) and Lime Tree Bay, St.Croix (975-1401) **are provided in the zoning file "I911NF2006CORP" for this project and are in the fourth set of correctors designated as TS4.** Longitude and latitude coordinates are in decimal degrees. Negative (-) longitude is a MapInfo representation of west longitude.

NOTE: For time corrections, a negative (-) time correction indicates that the time of tide in that zone is earlier than (before) the predicted tides at the reference station, whereas, a positive (+) time correction indicates that the time of tide in that zone is later than (after) the predicted tides at the reference station. For height corrections, the water level heights **relative to MLLW** at the reference station are multiplied by the range ratio to estimate the water level heights relative to MLLW in the applicable zone.

5.9.1. A zoning diagram, created in MapInfo, is to assist with the zoning provided in Section 5.9.

5.9.2. Preliminary six minute water level time series data may be retrieve from the CO-OPS database via TideBot. TideBot delivers timely preliminary tidal and Great Lakes six minute water level observations via email to users on a scheduled, recurring basis. To access TideBot through an email account, send an email to TideBot@noaa.gov with the word "help" as the subject. An email reply will be sent with instructions on how to subscribe to TideBot for time series data retrieval.

5.10. Tidal Records:

Refer to Standing Instructions on what data records, reports and requests to submit to CO-OPS and the address where these documents should be submitted too.

UNITED STATES DEPARMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Silver Spring, Maryland 20910

TIDE NOTE FOR HYDROGRAPHIC SURVEY

DATE : May 30, 2006

HYDROGRAPHIC BRANCH: Atlantic
HYDROGRAPHIC PROJECT: NF-06-03-USVI
HYDROGRAPHIC SHEET: S-I911-NF-2006

LOCALITY: U.S Virgin Islands and Puerto Rico
TIME PERIOD: March 19 - April 2, 2006

TIDE STATION USED: 975-9110 Magueyes Island, PR
Lat. 17 58.3′ N Long. 067 02.8' W
PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters
HEIGHT OF HIGH WATER ABOVE PLANE OF REFERENCE: 0.201 meters

TIDE STATION USED: 975-1401 Lime Tree Bay, St. Croix, USVI
Lat. 17 41.8' N Long. 064 45.2' W
PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters
HEIGHT OF HIGH WATER ABOVE PLANE OF REFERENCE: 0.214 meters

REMARKS: RECOMMENDED ZONING
Use zone(s) identified as: PRS6, PRS7, PRS8, VIR40, VIR41, VIR42, VIR43, VIR44 & VIR45

Refer to attachments for zoning information.

Note 1: Provided time series data are tabulated in metric units (meters), relative to MLLW and on Greenwich Mean Time on the 1983-2001 National Tidal Datum Epoch (NTDE).

CHIEF, PRODUCTS AND SERVICES DIVISION

Final tide zone node point locations for NF-06-03-USVI, S-I911-NF-2006

Format: Tide Station (in recommended order of use)
Average Time Correction (in minutes)
Range Correction
Longitude in decimal degrees (negative value denotes Longitude West),
Latitude in decimal degrees

	Tide Station Order	AVG Time Correction	Range Correction
Zone PRS6	975-9110	+6	x0.94
-66.925433 17.929159			
-66.990356 17.800488			
-67.212539 17.64124			
-67.679232 17.55303			
-67.738618 17.552247			
-66.896996 17.228788			
-66.396582 17.166077			
-66.575223 17.339165			
-66.662765 17.686507			
-66.669648 17.858163			
-66.673715 17.982313			
-66.694639 18.017255			
-66.786521 18.025831			
-66.869439 18.03012			
-66.945634 18.017254			
-66.925433 17.929159			
Zone PRS7	975-9110	0	x0.94
-66.925433 17.929159			
-66.945634 18.017254			
-67.039278 18.025907			
-67.057375 17.975098			
-67.094967 17.841809			
-67.241709 17.749238			
-67.601429 17.678206			
-68.124176 17.710005			
-67.738618 17.552247			
-67.679232 17.55303			
-67.212539 17.64124			
-66.990356 17.800488			
-66.925433 17.929159			
Zone PRS8	975-9110	-6	x0.94
-67.601429 17.678206			
-67.241709 17.749238			
-67.094967 17.841809			

-67.057375 17.975098			
-67.039278 18.025907			
-67.105817 17.998069			
-67.124161 17.947815			
-67.153904 17.894556			
-67.297115 17.842333			
-67.580226 17.825058			
-68.367866 17.870448			
-68.612485 17.910078			
-68.124176 17.710005			
-67.601429 17.678206			
Zone VIR40	975-1401	0	x1.06
-64.40552 17.876336			
-64.411897 17.864737			
-64.426628 17.838315			
-64.44749 17.814411			
-64.691865 17.976031			
-64.753414 17.998327			
-64.737089 18.066938			
-64.574576 17.991234			
-64.40552 17.876336			
Zone VIR41	975-1401	0	x1.06
-64.753414 17.998327			
-64.767406 17.945874			
-64.602945 17.836802			
-64.52727 17.774202			
-64.47978 17.788497			
-64.44749 17.814411			
-64.691865 17.976031			
-64.753414 17.998327			
Zone VIR42	975-1401	0	x1.06
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-64.777901 17.888381			
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-64.601506 17.751963			
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-64.52727 17.774202			
-64.602945 17.836802			
-64.767406 17.945874			
Zone VIR43	975-1401	0	x1.06
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-64.601506 17.751963			
-64.66082 17.806983			
-64.7159 17.849183			
-64.777901 17.888381			

-64.7849 17.854646			
-64.716699 17.817308			
-64.675894 17.789491			
-64.640412 17.75214			
Zone VIR44	975-1401	0	x1.06
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-64.79421 17.825276			
-64.724279 17.791726			
-64.675589 17.755884			
-64.640412 17.75214			
-64.675894 17.789491			
-64.716699 17.817308			
-64.7849 17.854646			
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-64.791985 17.779187			
-64.79421 17.825276			
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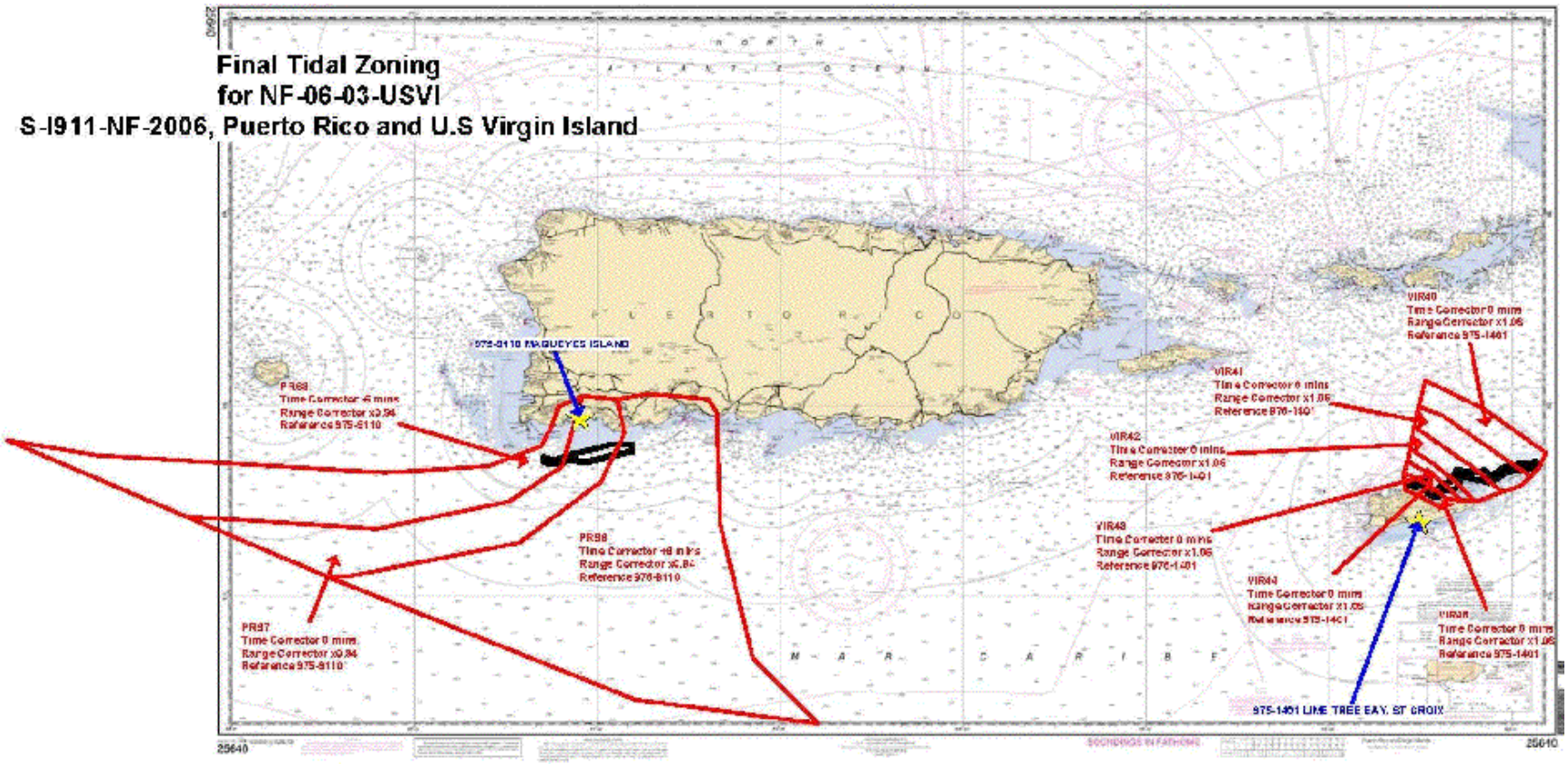
Final Tidal Zoning for NF-06-03-USVI

S-l911-NF-2006, Puerto Rico and U.S Virgin Island



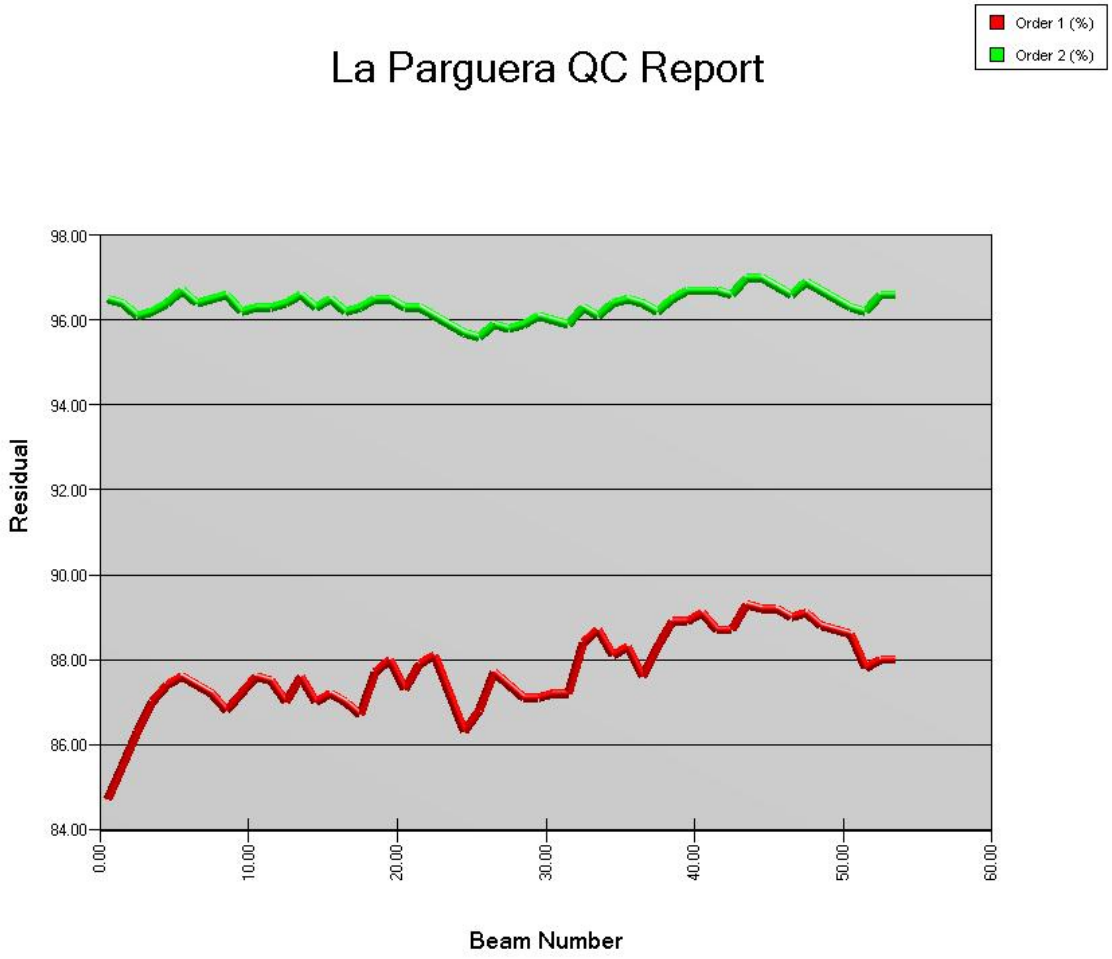
Mike Stecher

From: Monica Cisternelli [Monica.Cisternelli@noaa.gov]
Sent: Thursday, June 01, 2006 11:07 AM
To: mike@solmarhydro.com
Cc: Ada Otter; Craig Martin
Subject: re: error values for Maygues and Lime Tree Bay

*Tide Component Error Estimation : *The estimated tidal error contribution to the total survey error budget in the vicinity of Maygues, PR is 0.02 meters at the 95% confidence level, and includes the estimated gauge measurement error (~.012m), tidal datum computation error (0 m), and tidal zoning error (0 m). The estimated tidal error contribution to the total survey error budget in the vicinity of Lime Tree Bay, St.Croix is 0.110 meters at the 95% confidence level, and includes the estimated gauge measurement error (~.012m), tidal datum computation error (0 m), and tidal zoning error (~0.03 m) It should be noted that the tidal error component can be significantly greater than stated if a substantial meteorological event or condition should occur during time of hydrography.

APPENDIX K:

CARIS Quality Control Reports


La Parguera QC Report
Order 1 (%)
Order 2 (%)
Residual
98.00
96.00
94.00
92.00
90.00
88.00
86.00
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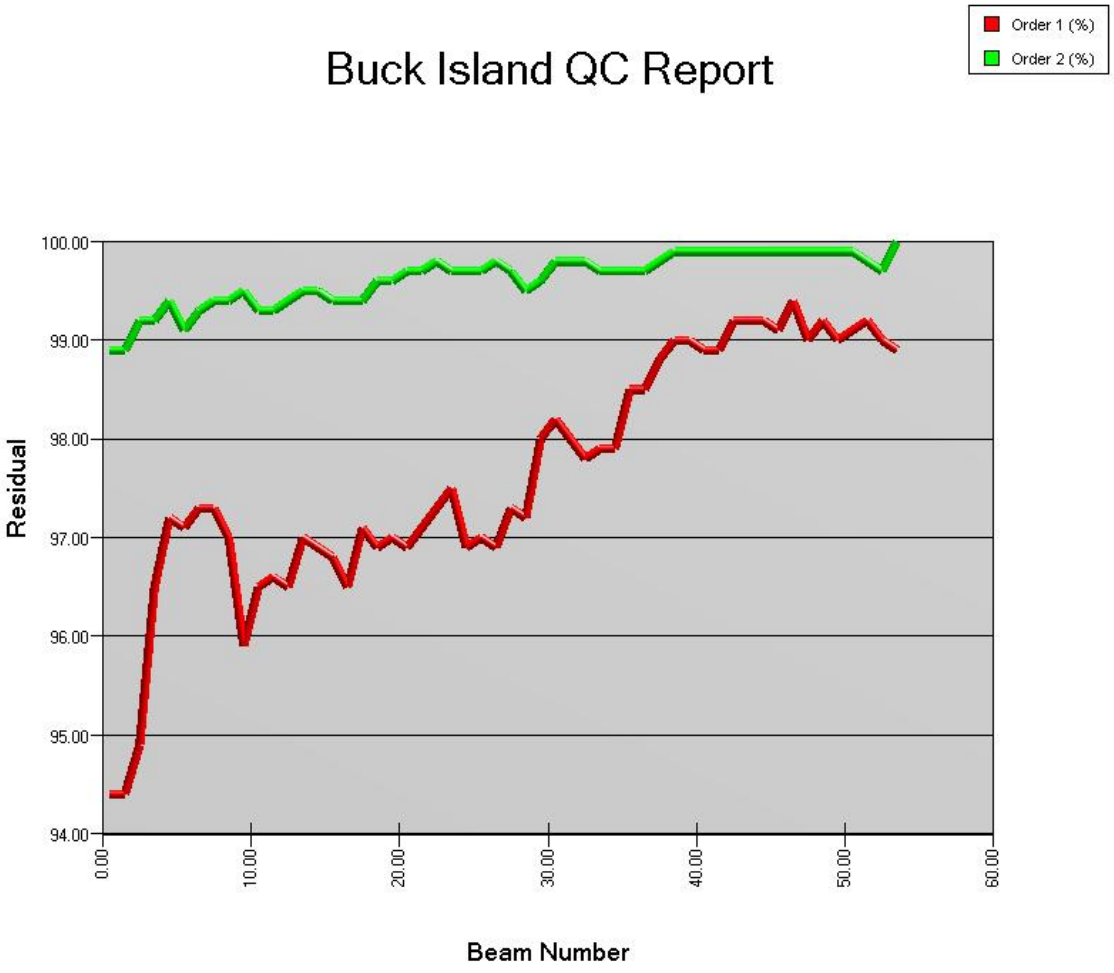
10.00
20.00
30.00
40.00
50.00
60.00
Beam Number


Buck Island QC Report
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Order 2 (%)
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97.00
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0.00
10.00
20.00
30.00
40.00
50.00
60.00
Beam Number

APPENDIX L:

NF-06-03 Cruise Instructions

CRUISE INSTRUCTIONS: NOAA SHIP NANCY FOSTER

Cruise Title: **Characterization of midwater seafloor habitats of the Buck Island Reef National Monument (BIRNM), St. Croix and southwest Puerto Rico**

Cruise Number NF-06-03-USVI

Period of Cruise:

DEP: 3/13/06 Ship transit to Frederiksted, St. Croix
ARR: 3/18/06 Ship arrive Frederiksted, St. Croix, USVI
DEP: 3/21/06 Begin seafloor mapping St. Croix, USVI
ARR: 4/2/06 Disembark at San Juan, Puerto Rico

Area of Operation: Buck Island National Monument St. Croix and La Parguera, Puerto Rico

1.0 Scientific Objectives:

The Center for Coastal Monitoring and Assessment (CCMA) will be conducting the third year of an ongoing scientific research mission onboard the NOAA ship Nancy Foster. The purpose of the cruise will be to continue to collect swath bathymetry and acoustical backscatter data in three high priority areas within the USVI and Puerto Rico. Scientists will collect high resolution multibeam in mid-water depths approximately 20 to 1000 meters so as to continue to characterize seafloor habitats within the USVI and Puerto Rico. The objective of this project is to collect a multibeam bathymetry dataset with 100% seafloor ensonification, along with multibeam backscatter suitable for seafloor characterization. Multibeam data will be collected to conform to IHO Order 1 (<100m) and Order 2 (>100m) accuracy standards. The strategies developed for each survey area will take into account the minimum depths, general bathymetry, and time allotment. The delineation and identification of seafloor habitats will be assisted by the use of a moderate depth Remotely Operated Vehicle (ROV). The vehicle has video and frame camera capability to depths of 1000 meters and will be used to conduct transects within areas mapped during this mission.

2.0 Schedule of Operations:

2.1 Daily Schedule:

See Table 1

18 March (Friday): Nancy Foster arrives in Frederiksted, St. Croix
Survey NF: Survey team installs survey gear, does a gear shake-down of multibeam unit and survey planning.
ROV: ROV team remaining survey gear, does a gear shake-down of ROV unit and video planning.

19 March (Sunday):
Survey NF: Survey team installs survey gear, does a gear shake-down of multibeam unit and survey planning.
ROV: ROV team remaining survey gear, does a gear shake-down of ROV unit and video planning.

20 March (Monday):
Survey NF: Survey team installs survey gear, does a gear shake-down of multibeam unit and survey planning.
ROV: ROV team remaining survey gear, does a gear shake-down of ROV unit and video planning.
Other: Press Briefing. Science party mission meeting.

21 March (Tuesday):
Transit/Patch Test NF: (0800-1200) Ship transit from Frederiksted to Buck Island. Survey team conducts Patch Test to calibrate the Multibeam Echosounder (MBES) system.
ROV: (1200-2000) ROV Buck Island Priority area.
Survey NF: (2000-2400) MBES Buck Island Priority area.

22 March (Wednesday):
Survey NF: (2400-0800) MBES Buck Island Priority area.
ROV: (0800-1600) ROV Buck Island Priority area.
Survey NF: (1600-2400) MBES Buck Island Priority area.

23 March (Thursday):
Survey NF: (2400-0800) MBES Buck Island Priority area.
ROV: (0800-1600) ROV Buck Island Priority area.
Survey NF: (1600-2400) MBES Buck Island Priority area.

24 March (Friday):
Survey NF: (2400-0800) MBES USVI Alternate area.
ROV: (0880-1600) ROV Buck Island Priority area.
Transit/Survey NF: (1600-2400) Transit to Escollo Grappler (Puerto Rico).

25 March (Saturday):
Survey NF: (2400-0800) MBES Escollo Grappler.
ROV: (0800-1600) ROV Escollo Grappler.
Survey NF: (1800-2400). MBES Escollo Grappler.

26 March (Sunday):
Transit NF: (2400-0800) Transit to Parguera.
ROV: (0800-1600) ROV Parguera Priority.
Survey NF: (1600-2400) MBES Parguera Priority.

27 March (Monday):
Survey NF: (2400-0800) MBES Parguera Priority.
ROV: (0800-1600) ROV Parguera Priority.
Survey NF: (1600-2400) MBES Parguera Priority.

28 March (Tuesday):
Survey NF: (2400-0800) MBES Parguera Priority.

ROV: (0800-1600) ROV Parguera Priority.
Survey NF: (1600-2400) MBES Parguera Priority.

29 March (Wednesday):
Survey NF: (2400-0800) MBES Parguera Priority.
ROV: (0800-1600) ROV Parguera Priority.
Survey NF: (1600-2400) MBES Parguera Priority.

30 March (Thursday):
Survey NF: (2400-0800) MBES Parguera Alternate.
ROV: (0800-1600) ROV Parguera Alternate.
Survey NF: (1600-2400) MBES Parguera Alternate.

31 March (Friday):
Survey NF: (2400-0800) MBES Parguera Alternate.
ROV: (0800-1600) ROV Parguera Alternate.
Survey NF: (1600-2400) MBES Parguera Alternate.

1 April (Saturday):
Survey NF: (2400-0800) MBES Parguera Alternate.
ROV: (0800-1600) ROV Parguera Alternate.
Survey NF: (1600-2400) MBES Parguera Alternate.

2 April (Sunday):
Transit NF: (2400-1400) Transit to San Juan Puerto Rico.
Demobilization: (1400-1800) Demobilization

2.2 Watches:

Vessel operations will typically be a ~ 24 hour workday. A "give and take" operation cycle will be instituted during these workdays via consultation between the Chief Scientist and Commanding Officer in order to balance crew complement with demands of day-night operations. One crew member will be required on deck to work the winch for the ROV and CTD casts.

In Science Party, the Field Party Chief is responsible for organization of operations and data, respectively.

3.0 Map of Operations:

(See Figures 1 and 2)

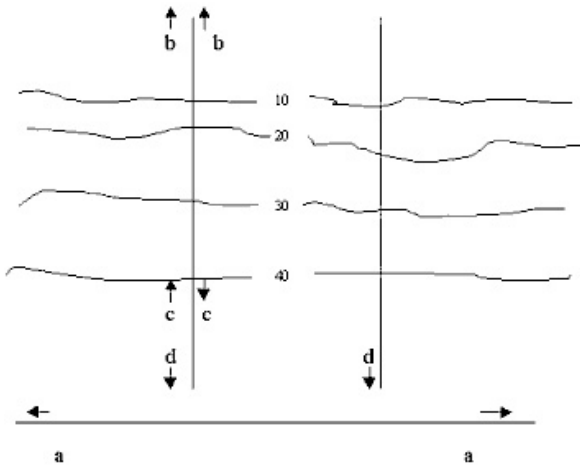
4.0 Description of Operations:

Multibeam Operations:

Survey Schedule/Personnel:
A timeline has been developed for the installation and calibration of the multibeam systems, as well as the data acquisition periods for surveying. A team from the NOAA Marine and Aviations Operations (NMAO) will be responsible for the installations of the Simrad EM 1002 and Reson 8124 multibeam systems and ancillary sensors. NMAO will be installing the multibeam transducers and acquisition systems on the NOAA ship NANCY FOSTER (NF) during scheduled drydock maintenance. NMAO and Kongsberg Simrad will perform the Harbor Acceptance Test (HAT) and the Sea Acceptance Test (SAT) procedures offshore of Charleston, South Carolina in February 2006. They will also provide informal training to the CCMA Biogeography Program team, survey technicians and independent contractors. Final calibrations and confidence checks will occur on March 21st, 2006 in the vicinity of Buck Island, St. Croix for the Nancy Foster. Survey operations will continue for 13 days, demobilization is scheduled for April 2rd, in San Juan, Puerto Rico (Figures 1 and 2).

Patch Test:
The patch test will be performed before surveying operations commence. The patch test calibration will quantify any residual biases from the alignment between the motion sensor, gyro and the multi-beam transducer. The patch test also quantifies the time lag (latency) between the time positioning data is received, and the time the computed position reaches the acquisition system. To ensure quality results from the patch test procedure it is necessary to have a relatively calm sea state, collection of clean data and a helmsman that can stay online during the procedure. Static transducer draft, settlement and squat corrections, sound velocity corrections, and preliminary tide corrections will be applied to the data prior to bias determination. The general patch test procedure requires

multibeam data collection along a series of transects as described in Figure 3. Alternatively, yaw bias can also be determined by surveying two lines on each side of a submerged object in relatively shallow water (Fig. 4). Patch test results will be calculated with CARIS's v5.4 calibration program in the following order: Latency, pitch, roll and yaw.



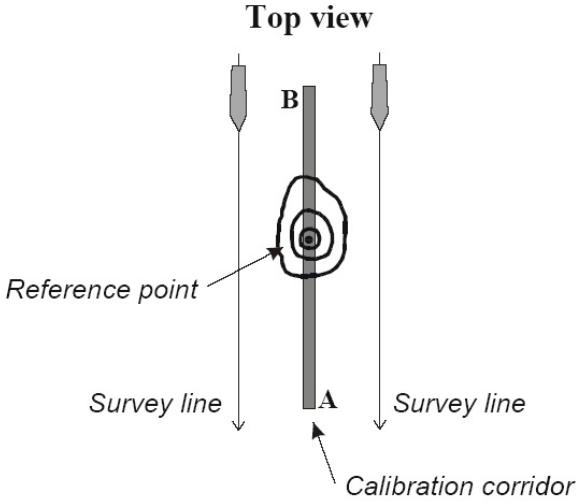


Fig 3. a = Roll, b = Latency, c= Pitch, d= Yaw **Fig. 4** Yaw bias test performed on submerged object

An area 1.5 nautical miles west of Buck Island has been identified (Fig. 5) to provide the steep and smooth slope with little change in across track depth to accurately assess the latency, pitch and yaw biases for the NF. Two planned survey lines (1&2) oriented perpendicular to slope are parallel and spaced apart to ensure abundant overlap of outer beams. Offshore of the slope is a relatively deep and flat area that will be used to perform the roll segment of the patch test. An area that was used for conducting a previous patch test near Butler Bay has mapped a submerged wreck at a depth of 26 meters (Fig. 6). This wreck is described as Wreck 2, dimensions of 56 m x 13 m x 4.6 m, location at 17 45 10.20 N, 064 53 43.71 W and is described in detail in the NF-04-06 patch test report. Wreck 2 can be used as an alternative option to determine yaw bias utilizing a submerged feature instead of a slope. In the immediate vicinity is a fish haven obstruction charted at 11.5 fathoms that can also be used for the yaw bias test.

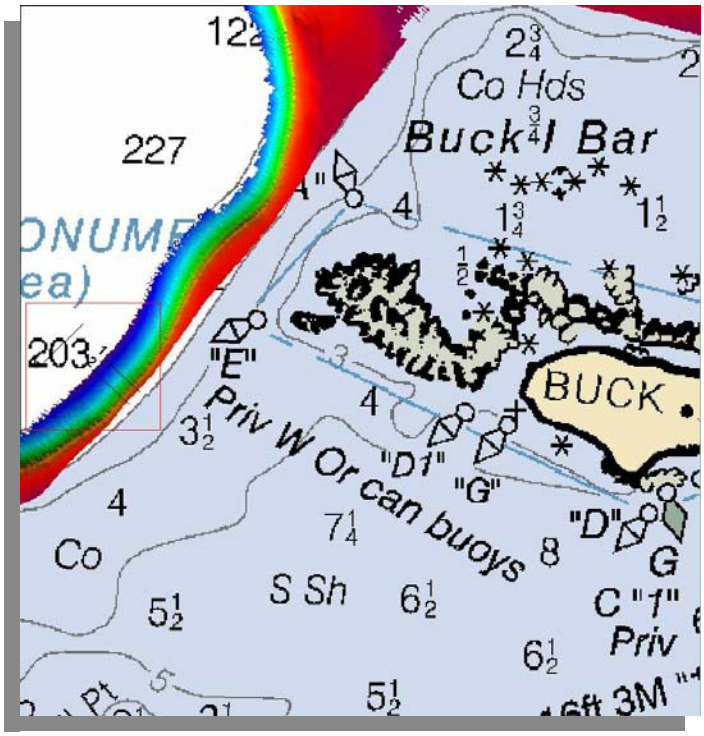


Fig 5 Primary patch test line plan

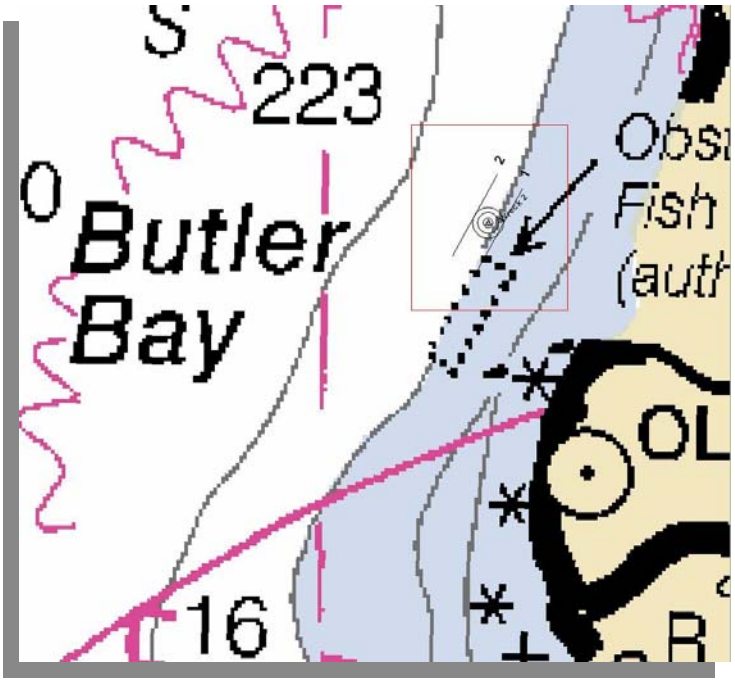


Fig. 6 Alternative yaw test line plan

The lines will be surveyed in the following order at the primary patch test location. Vessel speed should be consistent for the roll, pitch and yaw transects. Vessel speeds should be varied up to 5 knots for the latency section of the patch test.

Preliminary Patch Test Area (ref Fig. 5)

Order	Line	Direction	Speed	Bias Measured
1	1	SE	Normal	P1a
2	1	NW	Normal	P1b, Y1a
3	1	SE	Fast	L1a
4	1	SE	Slow	L1b
5	2	NW	Normal	Y1b
6	3	NE	Normal	R1a
7	3	SW	Normal	R1b

Alternative Yaw Bias Test (ref Fig. 6)

Order	Line	Direction	Speed	Bias Measured
1	1	SW	Normal	Y2a
2	2	SW	Normal	Y2b

Sufficient time between passes on the same line will be given to ensure ship propeller disturbances have cleared and will not impact data quality. Additional lines can be included and the schedule is preliminary.

Data Acquisition Methodology:

Upon the completion of the verifiable patch test, the area north of Buck Island will be surveyed, followed by Escollo Grappler, and finishing with SW Puerto Rico. A line plan has been developed for the 2006 proposed project areas, totaling 4,444 nautical line miles. Due to the shoal depths along SW Puerto Rico (approx.10 fath/18.3 m) a line spacing of 55 meters is required to provide sufficient coverage and accounts for 4067 nautical miles, including line splits for the shoaler areas. Reducing the anticipated coverage area will be required. The line plan is generally orientated parallel with the contours to maximize swath coverage and improve acoustic returns. The line plan has taken into account water depths, swath width filters and overlap requirements (Table 2). Restricting the swath limit ensures the data will meet IHO standards, and make the data cleaning process more efficient. All deep survey areas will be accepting soundings 55° from nadir, port and starboard, with 10% swath overlap. Areas shoaler than 55 meters will accept 60° port and starboard with a 10% overlap. Surveying operations in the shallow water should ideally be performed during daylight hours at higher tides to maximize swath widths, and for vessel safety reasons. Surveying during calm waters and steady piloting of the vessel will improve data quality. This is a preliminary line plan and field adjustments may be required.

The EM1002 data packets will be logged in Coastal Oceanographics Hysweep navigation program to create real time coverage maps to ensure coverage. During line turns data will be transferred to CARIS processing stations where preliminary zoned tides, swath filters and SVP cast corrections will be applied. The preliminary data will be used to create preliminary sun-illuminated Base surfaces for QA/QC analysis and then exported into geo tiff format. These geo tiffs will be superimposed on top of the charts in Coastal Oceanographics Hypack for additional line planning and navigation purposes.

Data Quality Assurance/Quality Control Methodology:

To ensure that the data collected meets IHO Level 1 & 2 standards several quality assurance/quality control measures will be implemented. The velocity of sound through the water column will be derived from conductivity, temperature, and depth measurements (CTD casts) collected no more than 4 hours apart. A CTD cast will be will be taken prior to the commencement of daily multibeam operations. Spatial variability will be taken into account as well as temporal variability when determining cast locations. These locations will be recorded and each cast will be compared to the previous to identify any significant changes in the water column. Turns will be limited and vessel speed will be adjusted to ensure that no less than 3.2 beam foot prints, center-to-center, fall within 3 m, or a distance equal to 10 percent of the depth, whichever is greater, in the along track direction. System confidence checks prior to, and during, multibeam operations will be conducted. These include position checks, lead lines and bar checks. Cross lines totaling 5% of main scheme will also be collected across each of the survey areas. Comparison of singlebeam, priors' and multibeam data will be used as an independent verification of the survey.

ROV Operations:

Benthic habitats in deep waters (>20m and <1000m) around the United States Virgin Islands (USVI) and southwestern Puerto Rico will be visually-characterized using a remotely operated underwater vehicle (ROV). This data will be collected to train and validate an automated benthic habitat characterization technique which uses fine-scale (<5 m) multibeam data.

Two independent and distinct sampling designs were chosen to acquire images of the benthic habitat: one for training and the other for validating the automated habitat characterization technique. Both designs were chosen for their ability to overcome the constraints of cost and time associated with sampling a very large area (>100 square km). A design using non-random transects defined *a priori* was chosen to provide representative training data for the entire study region. This design was chosen to ensure that representative benthic habitat features and transitional areas would be adequately included in the training dataset. Transect placement for training data was aided by visual examination of fine-scale multibeam data collected in prior to the day of sampling (data collected in 2004, 2005 and 2006) and moderate-scale GEODAS bathymetry data (GEODAS, 2005).

A random sampling design was used to position transects for the validation dataset. These transects were placed using randomly positioned geographic coordinates within each study area. Transect's mid points were placed on random points and oriented as a compromise between bathymetric slope and predominant wind direction to reduce sampling cost. The length of transects for both datasets represent approximately 1 hour of sampling (2 km). Tthe ROV sampling frame will include only depths between 20 and 500 meters for safety reasons (Figures 7 through 9).

A total of 65 transects make up the sample size: 32 transects for validation and 33 for training. This estimate was based on working 8 hours each day for a total of 13 days. The total time was divided into 4 days around Buck Island, 1 day around Escollo Grappler and 8 days around southwestern Puerto Rico. Table 3 provides the number and identity of transect types for each region. Estimated transit time between transects, an ROV speed of 1m s^{-1} (2 knots), and bathymetric slope were incorporated into the estimation of sampling effort.

Table 3: Summary of ROV transect work in the three 2006 Study Regions

Region	Study Area (km^2)	Work Days	Number of Training Transects	Number of Validation Transects	Total Number of Transects
Buck Island	25.22	4	11	9	20
Escollo Grappler	40.31	1	2	3	5
Puerto Rico Priority	262	3	10	5	15
Puerto Rico Alternate	318	5	10	15	25

GEODAS, 2005. NOAA's GEOphysical Data System (GEODAS). Website http://www.ngdc.noaa.gov/mgg/geodas/geodas.html, accessed September, 2005.

5.0 Requirements and Equipment:

5.1 Vessel Provided:

1) Hand held radios for communication between bridge and deck.
2) EM 1002 and Reson 8124 multibeam Shipboard multibeam, CARIS Processing station, Hypack, Velociwin
3) CTD's 100m and1000 m depth rating.

5.2 Program Provided:

	Equipment	Leg
1)	Underwater video + camera equipment + tow bodies (ROV) (Vendor TBD).	Charleston
2)	6 USB 250GB Maxtor 5000XT harddrives (CCMA).	USVI
3)	Five high end laptops and two flat screen monitors.	USVI
4)	CARIS and ArcGIS	USVI

6.0 Scientific Personnel:

6.1 Chief Scientist Authority

The Chief Scientist has the authority to revise or alter the technical portions of the instructions provided that, after consultation with the Commanding Officer, it is ascertained that the proposed changes will not: 1) jeopardize the safety of the personnel on the ship, 2) exceed the time allotted for the project, 3) result in undue additional expense, or 4) alter the general intent of the Project Instruction.

6.2 Scientific Personnel List:

Chief Scientist: Tim Battista
Lead Hydrographer: Mike Stetcher
ROV Lead: Matt Kendall (3/21-3/23) and Charlie Menza (3/23- 4/2)

Male:	Organization:	ROV	Multibeam	Legs
Tim Battista	NOAA		X	USVI/PR
Mike Stetcher	NOAA		X	USVI/PR
Bryan Costa	NOAA		X	USVI/PR
Matt Kendall	NOAA	X		USVI
Charlie Menza	NOAA	X		USVI/PR
Ken Buja	NOAA	X		USVI/PR
Jay Lazar	NOAA		X	USVI/PR
Adel Sterling	HMRG		X	USVI/PR
Henry Tonnemacher	NPS	X		USVI
Michael Nemeth	UPRM	X		PR
Hector Ruiz	UPRM	X		PR
Jose Rivera	UPRM		X	pr
Jeff Snyder	Contractor	X		USVI/PR
Matt Cook	Contractor	X		USVI/PR

Female	Organization:	ROV	Multibeam	Legs
Ada Otter	NOAA		X	USVI/PR
Monica Cisternelli	NOAA		X	USVI/PR

TASK TEAMS

ROV

1) **(USVI) Kendall ,** Menza, Snyder, Cook, Buja, Tonnemacher.
2) **(Puerto Rico) Menza,** Snyder, Cook, Buja, Nemeth, Ruiz.

MULTIBEAM

1) **NF Team A (2400-0800): Stetcher**, Costa
2) **NF Team B (1600-2400): Lazar**, Otter.
3) **Processing (0800-1600):** Cisternelli, Sterling

Person in **bold** is field party chief – responsible for prepping rest of team. Multibeam team members will rotate positions throughout the cruise.

Identification: All scientific personnel planning to board the ship should have in their possession at the time of boarding, a proper photo identification card (agency ID, drivers license, etc.).

6.4 History Reports:

Upon acceptance of this proposal, and receipt by the Chief Scientist of the forms, the Chief Scientist will forward completed copies of the NOAA Health Services Questionnaire for all embarking scientific personnel to the Commanding Officer for review at lease 7 days in advance of the cruise.

7.0 Miscellaneous Activities:

None known at this time.

7.1 Bridge Activities:

It is requested that a copy of the ship's *Deck Log - Weather Observation Sheet NOAA 77-13d* for and digital SCS data for the entire cruise be provided to the Chief Scientist upon departure of the science party or transmitted within 2 weeks thereafter.

8.0 Modification of Cruise Instructions:

Additional operations and ancillary projects, not covered under the main project, may be performed on a "not to interfere" basis. The Chief Scientist is responsible for determining the priority of the additional work, provided that any changes are discussed with the Commanding Officer and do not constitute a risk to the safety of the ship or personnel and do not significantly change the schedule for this cruise. If the requirements for the additional work place significantly different requirements on the ship, amendments to the Cruise Instructions must be prepared and approved.

9.0 Ancillary Tasks:

Ship's personnel conduct ancillary tasks. Instructions for ancillary tasks routinely assigned to Marine Operations Center ships are contained in *Marine Operations Center Directive 1803.00, Ancillary Tasks for NOAA Vessels*.

10.0 Hazardous Materials:

An inventory list and a *Material Safety Data Sheet* for each hazardous material will accompany hazardous material brought on board NANCY FOSTER by scientific parties. This information should be provided to the Commanding Officer. On departure from the ship, scientific parties will provide an inventory of hazardous material to the Commanding Officer showing that all hazardous material brought on board have been properly used up or removed in suitable waste containers. No anticipated hazardous materials is anticipated to be brought onboard.

The *Material Safety Data Sheet* is normally available from the manufacturer of the hazardous product. Procedures followed for use of chemicals will be those outlined in the *Chemical Hygiene Plan for Chemical Labs* aboard NOAA ships. The Science Party will provide a small spill containment kit appropriate for these chemicals.

11.0 Navigation:

Survey and ROV operations will be operated using DGPS. Navigation information via Hypack software will be fed to the Bridge monitor from the Wet and Dry labs via cable.

12.0 Communications:

A progress report on operations prepared by the Chief Scientist may be relayed to the program office. Sometimes it is necessary for the Chief Scientist to communicate with another vessel, aircraft, or shore facility. Through various modes of communication, the ship is able to maintain contact with the Marine Operations Center on an as needed basis. These methods will be made available to the Chief Scientist upon request, in order to conduct official business. Due to a new directive from Marine Operations Center, the ship must charge the science party for all calls made

on the cell or sky-cell telephone. INMARSAT, Sky Cell and cellular communication costs shall be reimbursed to the ship for telephone calls made by all scientific personnel. Currently, Sky Cell and cellular telephone services are about $0.89 per minute and INMARSAT Mini-M is around $1.68 per minute for voice. These charges will be assessed against the program after NANCY FOSTER receives the bill. There is generally a three-month delay receiving the bill for review. The Chief Scientist will be required to keep a log of all calls made by the science party. The program will also provide a cell phone to be kept on the bridge.

13.0 Disposition of Data:
The Chief Scientist is responsible for the disposition of data.

14.0 Reports:
The requirement for a formal cruise report by the Chief Scientist is left to the discretion of the CCMA Center Director. A Ship Operations Evaluation Form is to be completed by the Chief Scientist(s) and forwarded to:
Office of Marine and Aviation Operations
Program Services and Outsourcing Division
SSMC3, Room 12872
1315 East-West Highway
Silver Spring, MD 20910-3282

15.0 Cruise Instruction Approvals:

The Marine Operations Center and NANCY FOSTER will acknowledge receipt of these instructions.

Submitted by:

Dr. Russell Callender Center Director, Center for Coastal Monitoring and Assessment	Mr. Timothy A. Battista Biogeographic Team, Center for Coastal Monitoring and Assessment
Date_____	Date_____

Approved by:

Captain Gary Bulmer, NOAA
Commanding Officer, Marine Operations Center Atlantic

Date_____

Table 1. Nancy Foster operation schedule.

			Time																					
DAY	DATE	LOCATION	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Mon	18-Mar	STX	MOBILIZATION/TRAINING/PRESS																							
Sun	19-Mar	STX																								
Mon	20-Mar	STX																								
Tue	21-Mar	STX	OFF DUTY								NF Transit Buck/Patch Test				ROV Buck Priority								Multibeam Buck Priority			
Wed	22-Mar	STX	Multibeam Buck Priority								ROV Buck Priority								Multibeam Buck Priority							
Thu	23-Mar	STJ/STT	Multibeam Buck Priority								ROV Buck Priority								Multibeam Buck Priority							
Fri	24-Mar	STJ/STT	Multibeam USVI Alternate								ROV Buck Priority								TRANSIT Escollo Grappler							
Sat	25-Mar	STJ/STT	Multibeam Escollo Grappler								ROV Escollo Grappler								Multibeam Escollo Grappler							
Sun	26-Mar	STJ/STT	TRANSIT Paguera								ROV Paguerra Priority								Multibeam Paguerra Priority							
Mon	27-Mar	STJ/STT	Multibeam Paguerra Priority								ROV Paguerra Priority								Multibeam Paguerra Priority							
Tue	28-Mar	STJ/STT	Multibeam Paguerra Priority								ROV Paguerra Priority								Multibeam Paguerra Priority							
Wed	29-Mar	STJ/STT	Multibeam Paguerra Priority								ROV Paguerra Priority								Multibeam Paguerra Priority							
Thu	30-Mar	STJ/STT	Multibeam Paguerra Alternate								ROV Paguerra Alternate								Multibeam Paguerra Alternate							
Fri	31-Mar	STJ/STT	Multibeam Paguerra Alternate								ROV Paguerra Alternate								Multibeam Paguerra Alternate							
Sat	1-Apr	STJ/STT	Multibeam Paguerra Alternate								ROV Paguerra Alternate								Multibeam Paguerra Alternate							
Mon	2-Apr	STT	TRANSIT San Juan																DEMOBILIZATION							

Figure 1. Buck Island, USVI Priority (multibeam and ROV) and Alternate Areas (multibeam).

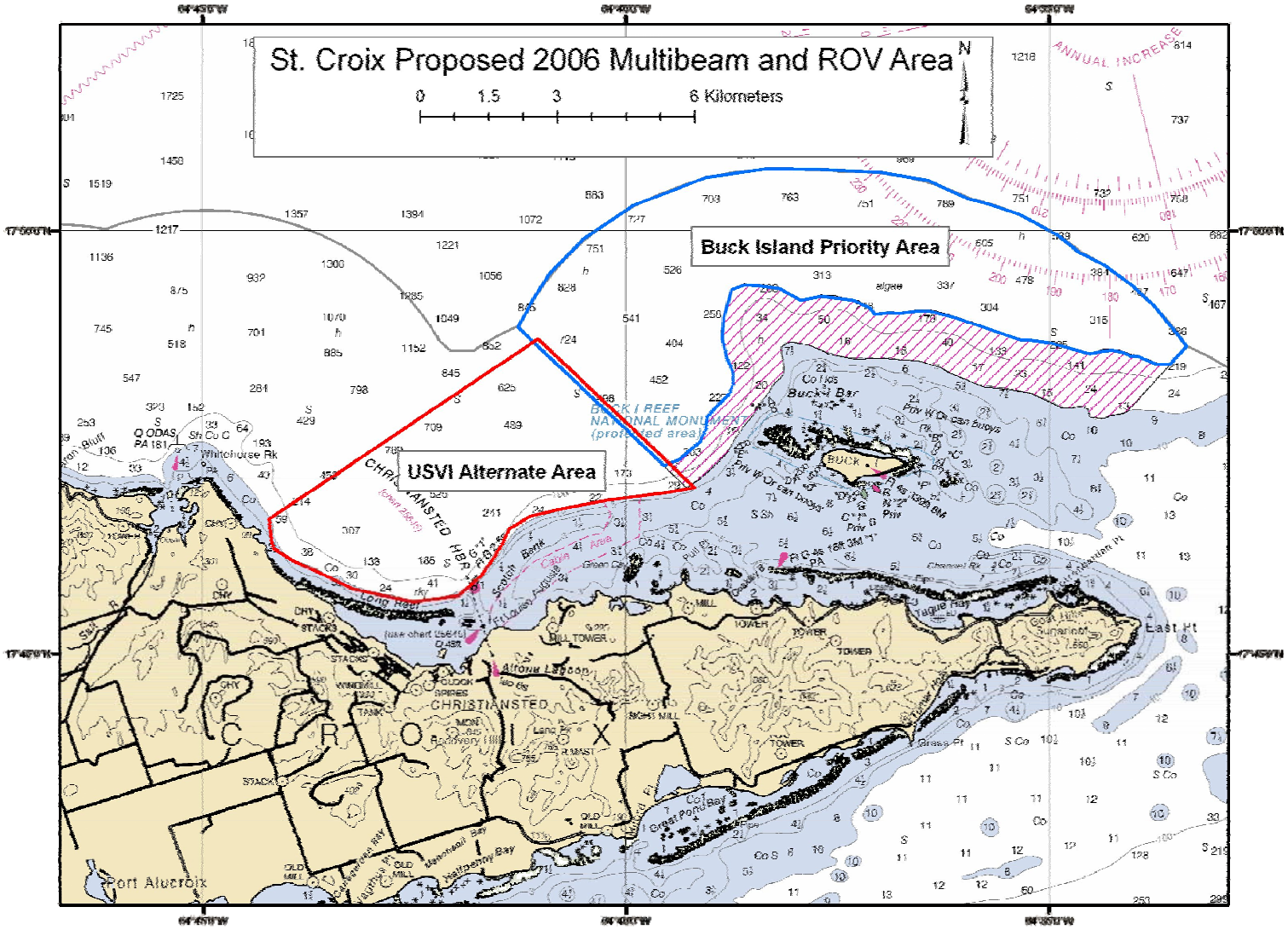


Figure 2. Parguera Puerto Rico Priority (multibeam and ROV) and Alternate Areas (multibeam and ROV).

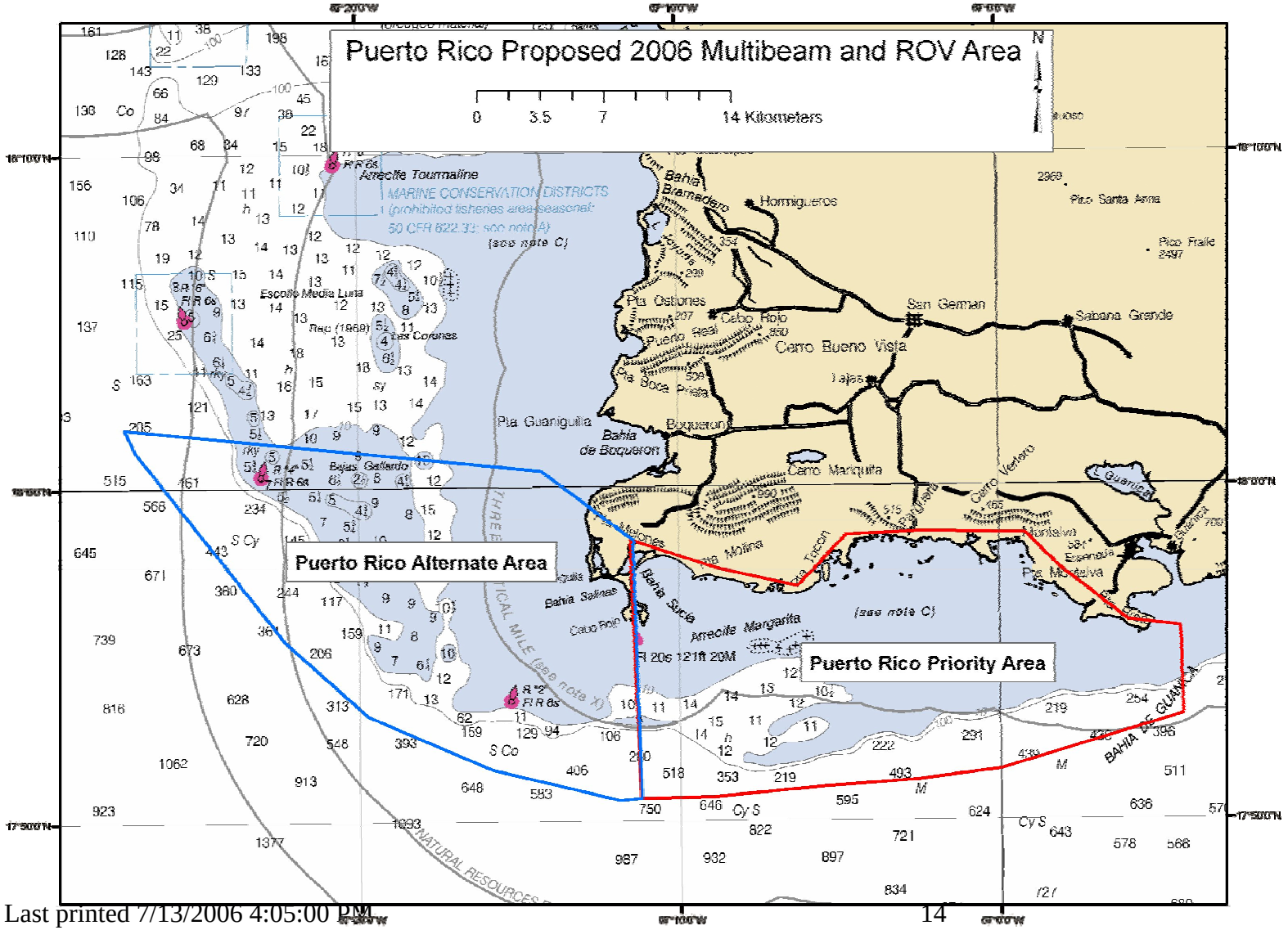


Table 2. Line Spacing Specifications

Depth (Fath)	Depth (M)	Depth (ft)	Swath Angle (Degrees)	Swath Overlap (%)	Line Spacing (M)	Line Spacing (ft)
5	9.1	30.0	55	10	23.5	77.1
10	18.3	60.0	55	10	47.0	154.2
15	27.4	90.0	55	10	70.5	231.4
20	36.6	120.0	55	10	94.0	308.5
25	45.7	150.0	55	10	117.5	385.6
30	54.9	180.0	55	10	141.0	462.7
40	73.2	240.0	55	10	188.0	617.0
50	91.4	300.0	55	10	235.1	771.2
75	137.2	450.0	55	10	352.6	1156.8
100	182.9	600.0	55	10	470.1	1542.4
125	228.6	750.0	55	10	587.7	1928.0
150	274.3	900.0	55	10	705.2	2313.6
175	320.0	1050.0	55	10	822.7	2699.2
200	365.8	1200.0	55	10	940.2	3084.8
250	457.2	1500.0	55	10	1175.3	3856.0
300	548.6	1800.0	55	10	1410.4	4627.2
350	640.1	2100.0	55	10	1645.4	5398.4
400	731.5	2400.0	55	10	1880.5	6169.6
450	823.0	2700.0	55	10	2115.6	6940.8
500	914.4	3000.0	55	10	2350.6	7712.0
550	1005.8	3300.0	55	10	2585.7	8483.2
600	1097.3	3600.0	55	10	2820.7	9254.4
650	1188.7	3900.0	55	10	3055.8	10025.6
700	1280.2	4200.0	55	10	3290.9	10796.8

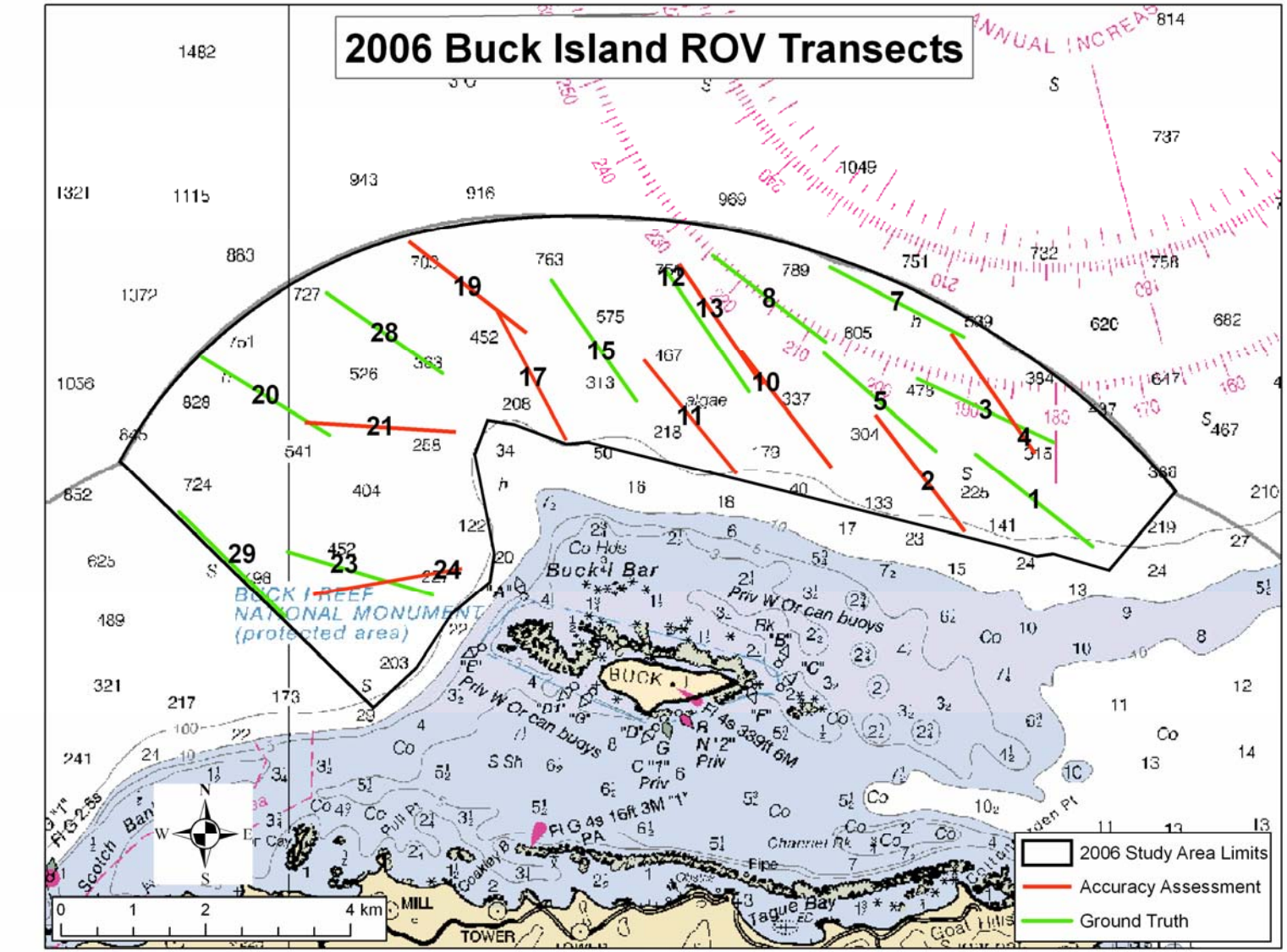
L=2 d tan (a/2) * (1-s)

a = Multibeam Swath Angle

d = Water Depth (ft)

s = Swath Sidelap

Figure 7. Buck Island ROV transects.



Las

Figure 8. Escollo Grappler, Puerto Rico ROV transects.

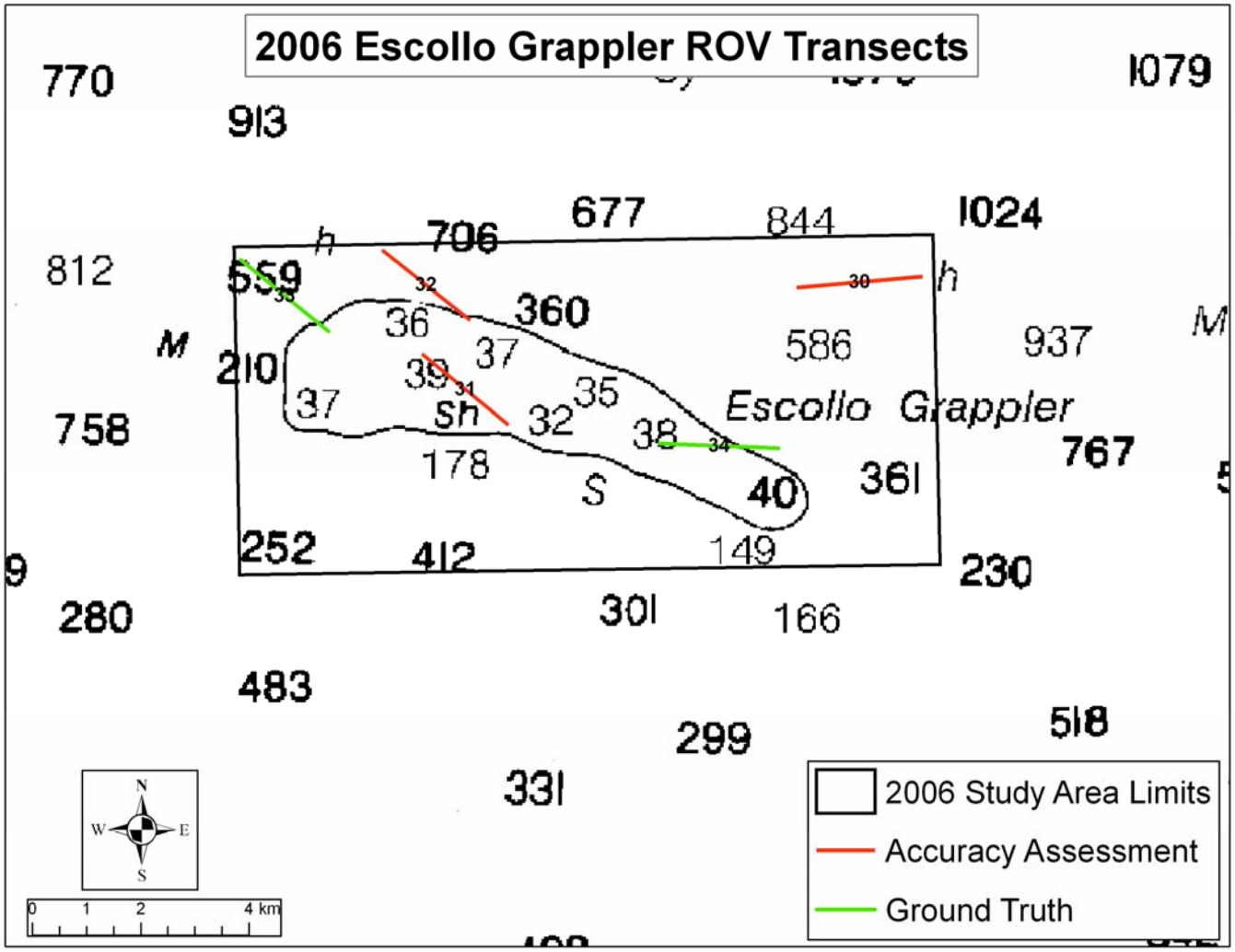


Figure 9. Parguera Puerto Rico Priority and Alternate ROV transects.