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

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey	**Hydrographic**
Project	**OPR-E349-KR-06**
Contract No	**DG133C-05-CQ-1078**
Task Order No	**T0001**
Time Frame	**May - September, 2006**

LOCALITY

State	**Virginia**
General Locality	**Central Chesapeake Bay**

2006

CHIEF OF PARTY

Jonathan L. Dasler, PE (OR) , PLS (OR,CA)

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Acronyms and Abbreviations

AML	Applied Microsystems, Ltd.
ATC	Average Time Corrector
BAG	Bathymetric Attributed Grid
CO-OPS	Center for Operational Oceanographic Products and Services
CTD	Conductivity, Temperature and Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
DEA	David Evans and Associates, Inc.
DXF	Drawing Exchange Format
DGPS	Differential Global Positioning System
GGA	Global Positioning System position message
GPS	Global Positioning System
HDCS	Hydrographic Data Cleaning System
HIPS	Hydrographic Information Processing System
HSX	Hypack Hysweep File
HVF	HIPS Vessel File
Hz	Hertz
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
kHz	kilo Hertz
MLLW	Mean Lower Low Water
MVP	Moving Vessel Profiler
NATSUR	Nature of Surface
NATQUAL	Nature of Surface Qualifying Terms
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per Second
QA/QC	Quality Assurance and Quality Control
R/V	Research Vessel
RPM	Revolutions per Minute
RTK	Real-Time Kinematic
SBDARE	Seabed Area
SN	Serial Number
SVP	Sound Velocity Profile
TIF	Tagged Image Format
TPE	Total Propagated Error
UTC	Universal Time Coordinated

XTF	Extended Triton format file extension
ZDA	Global Positioning System timing message
ZDF	Zone Definition File

OPR-E349-KR
Data Acquisition and Processing Report
Central Chesapeake Bay, Virginia

Year 2006
R/V Sealth
Lead Hydrographer, Jonathan Dasler, P.E., P.L.S.
David Evans and Associates, Inc.

INTRODUCTION

This report applies to surveys H11503, H11504, H11505, and H11535 located in Central Chesapeake Bay, Virginia. These contract surveys were performed under OPR-E349-KR as specified in the *Statement of Work* dated March 28, 2006. All survey methods meet or exceed requirements as defined in the *NOS Hydrographic Surveys Specifications and Deliverables DRAFT* February, 2006.

A. EQUIPMENT

For this project David Evans and Associates, Inc. (DEA) implemented a state-of-the-art data acquisition and preliminary processing system aboard the Research Vessel (R/V) *R/V Sealth*, in accordance with National Oceanic and Atmospheric Association (NOAA) standards and modern remote sensing techniques. Instrumentation used to conduct the survey and redundant systems to provide confidence checks consisted of the equipment listed in Table 1.

Table 1. Hardware

Instrument	Manufacturer	Model	S/N	Function
Side scan				
	Edgetech	**4200 FS**		Digital side scan sonar imagery with tow fish heading and depth sensors.
Deck Unit			31913	
Towfish			32060	
	Measurement Technology NW	**LCI-90**	350	Continuous digital output of deployed side scan tow cable length for layback calculations
Multibeam				
	RESON	**7125**		Dual Frequency Multibeam sonar
Deck Unit	7P		57729	
Transducer			52007	
Sound Speed	SVP 70		3205687	
Attitude and Position				
	Applanix	**POS MV 320 v4**		Integrated Differential Global Positioning System (DGPS) and inertial reference system for position, heading, heave, roll and pitch data
Deck Unit			2204	
IMU			447	
Port Antenna		Compact Zephyr	60084986	
Starboard Antenna		Compact Zephyr	60073510	
	Trimble	**ProBeacon**		Obtain differential corrections United States Coast Guard differential beacons.
Unit			220014495	
Antenna			220014366	
	Trimble	**DMS 132**		Secondary positioning system for Quality Assurance/Quality Control (QA/QC)
Unit			224094182	
Antenna			220360424	
Sound Velocity				
	Brooke Ocean	**MVP 30**		Primary sound velocity profiler for sound velocity profiles
Winch			10424	
Sheave			10425	
Controller			10428	
Single Sensor Fish			10426	
Sensor	AML	Smart SV&P	5110	
Unit	**Seabird**	**SBE 19*plus***	19P42715-4962	Secondary Conductivity, Temperature, and Depth (CTD) profiler for sound velocity profiles
Bottom Samples				
	Wildco	Standard Ponar Grab Sampler		

A1. Side Scan Sonar System

Side scan sonar imagery was acquired with an EdgeTech 4200-FS dual frequency (100/400 kHz) digital side scan sonar (Figure 1) running in high speed mode. Imagery was logged on DEA's Triton Isis system in extended Triton format (XTF) (16 bit, 1024 pixels/channel) along with ancillary data including; towfish heading, towfish depth, ship position and computed towfish position from layback calculations. Layback was computed in the Isis by using measured tow point offsets and digital input of cable out and towfish depth. An LCI-90 Cable Payout Meter was used to provide a continuous digital cable length of deployed side scan tow cable to the Isis system. An EdgeTech 4200-FS dual high frequency (300/600 kHz) digital side scan sonar (Figure 1) running in high speed mode was used in shallow water portions of H11535 (G) to remove crosstalk between the side scan and multibeam sonars.

Figure 1. Edgetech 4200-FS Side Scan Sonar used in research.

Daily checks were performed to ensure the side scan sonar was working correctly. Each day prior to deploying the towfish, a rub test was performed to ensure that both the port and starboard transducers were functioning and wired correctly. Confidence checks to confirm adequate target resolution at the outer limits of the selected range were conducted on a daily basis during acquisition and noted in the acquisition logs. Confidence checks were performed more frequently in deteriorating conditions to confirm detection of features at the outer range limits.

A2. Multibeam System

The Reson 7125 multibeam sonar with dual frequency configuration and integrated SVP-70 sound velocity profiler ran concurrently with side-scan operations. Reson 7125 multibeam data and side-scan data from the Edgetech towfish were logged into the same XTF file on the Triton Isis acquisition system. The Reson 7125 series operates at either 400 kHz or 200 kHz producing a 128° swath of 256 uniform beams with a beamwidth of 0.5° x 1.0°. All data were acquired using high frequency (400 kHz) with range changes being made online as dictated by the depth at time of acquisition.

Weekly lead line checks were performed to ensure that the sonar was functioning properly and static draft was accurately documented. The lead line was constructed by attaching a mushroom anchor to a metric reel fiberglass tape enabling depths to be read to 5 mm.

A3. Position, Heading and Motion Reference System

An Applanix POS/MV 320 version 4 integrated DGPS and inertial reference system was used to measure attitude, heading and position for the survey. The system was comprised of an inertial motion unit (IMU), dual GPS antennas, and a data processor. A Trimble ProBeacon receiver, acquiring corrections from the U.S. Coast Guard beacon located at Driver, Virginia (broadcasting at 289 kHz) provided differential corrections for both the primary and secondary positioning systems. Position, heading, and motion data were output to Isis acquisition system using the real-time Ethernet option at 25 Hz. Motion and position data were output to the Hypack backup acquisition system over a serial connection with motion data output at 38400 baud and 25 Hz and position and heading at 9600 baud and 1 Hz.

The POS/MV provided time synchronization of sonar instruments and logging computers using a combination of outputs from the POS/MV v4. The Reson 7-P processor and Hypack logging computer were provided both a PPS (pulse per second) and a NMEA ZDA message to achieve synchronization with the POS/MV. The EdgeTech 4200 side scan sonar deck unit was provided a NMEA ZDA message for time synchronization. The Isis logging computer synchronized its time using the proprietary Trimble UTC message provided by the POS/MV. All messages contain time strings and cause the clocks of the computers and sonars to synchronize to the time contained within the message. Time offsets between instruments and computers, relative to times contained in POS/MV network packets, are typically sub-millisecond.

As a quality check a Trimble DMS132 was used as a secondary positioning system. Positions from both the primary and secondary systems were displayed in real-time using Hypack and compared while online. The POS/MV system position and heading were displayed as a vessel shape and the Trimble position was displayed with a circle and cross hair overlaid on the vessel shape in a different color. Position data from both systems were displayed and tracks from both systems were drawn in different colors such that a history of derived positions could be observed for quality control.

A weekly comparison between positions from the POS/MV and the DMS 132 was observed and documented while the vessel was stationary in port. Logged position data was imported into Excel and a difference computed.

TrueHeave™ was logged from the POS/MV during data acquisition with a single file created per day under the typical operating scenario. These files were later applied to the survey data in Caris HIPS v6.0 during data processing. The POS/MV QC plot was displayed and monitored onscreen during data acquisition.

A4. Sound Velocity Measurement System

A SVP-70 mounted on the Reson 7125 sonar head was input into the Reson 7-P processor and velocities from the sensor were used real-time during acquisition for beam forming on the 7125's flat array. In addition, a Brooke Ocean Technology Moving Vessel Profiler (MVP) 30 was mounted on the port stern of the *R/V Sealth* and was used as the primary sound speed sensor used to correct multibeam data during processing.

Each sensor had been calibrated prior to the start and at the end of the survey. Factory calibration results are included in the Separates Section II of the Descriptive Report for the survey.

A5. Survey Vessel

The *R/V Sealth*, which is owned and operated by Global Seas LLC, (Figure 2) was used as the survey vessel for the project. The *R/V Sealth*, hull registration number SFU399054D99 (official number 1080270), is a 55-foot, 45 gross ton aluminum catamaran with a 20-foot beam and a draft of 3 feet. A moon pool, custom multibeam mount, A-frame, server room, and acquisition station were designed and fabricated specifically for this survey. This configuration allowed for the sonar to be mounted near the vessel's center of gravity and to be easily deployed and retracted minimizing the risk of striking the head on debris or overstressing the mount when underway at high speeds. No unusual sensor setup configurations were required for this survey.

Figure 2. *R/V Sealth*.

A6. Acquisition and Processing System

The acquisition and processing station was custom installed and integrated on the *R/V Sealth* by DEA and consisted of a Triton Isis data acquisition system, Hypack navigation software and Caris Hydrographic Information Processing System (HIPS) software (Figure 3). During acquisition, data were logged locally on acquisition PCs and then transferred to a high capacity onboard RAID server while offline in order to minimize network activity. Initial processing was performed aboard the *R/V Sealth*, while final processing and review was performed at DEA's office in Portland, Oregon.

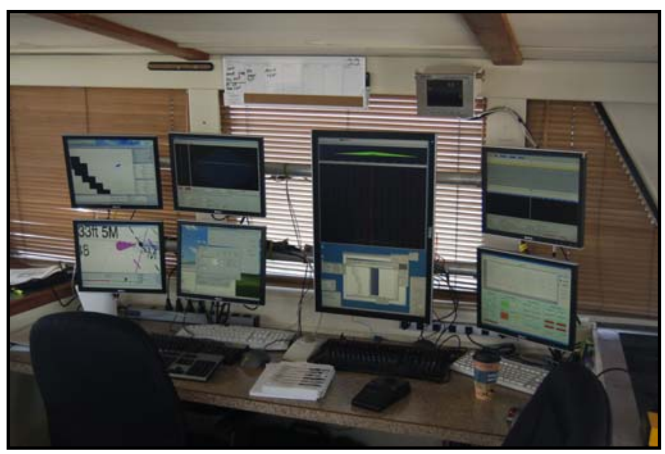

Figure 3. Acquisition station used on *R/V Sealth.*

The software and version numbers used throughout the survey are listed in Tables 2 and 3.

Table 2. Onboard Software

SURVEY SOFTWARE				
	Company	**Program Name**	**Version**	**Date**
Acquisition				
	Triton Imaging, Inc	Isis	7.0.417.21	5/19/2006
	HYPACK, Inc.	Hypack Max /Hysweep	4.3.55.0	5/23/2006
	EdgeTech	Discover 4200-FS	5.19	5/19/2006
	Reson	7K SeaBat	3.2.00	5/19/2006
	Reson	7K Center	2.9.0.0	5/19/2006
	Applanix	MV-POSView	3.3.0.0	5/23/2006
	Brooke Ocean Technology Ltd.	MVP Controller	MVP 2.27	5/19/2006
	Trimble	ProBeacon	1991 DOS	5/19/2006
	DEA	Digital LineLog	1.0.4	5/19/2006
Processing				
	Caris	HIPS	6.0 SP2 + Hot Fix 19	5/23/2006
	Caris	Notebook	2.2	5/23/2006
	Triton Imaging, Inc	Isis Sonar Office Suite	7.0.414.0	5/23/2006
	HYPACK, Inc.	Hypack Lite		5/23/2006
	ESRI	ArcGIS	9	5/23/2006
	NOAA	Velocwin	8.8	5/23/2006
Other				
	Microsoft	Word	2003	
		Excel	2003	
		Access	2003	

Table 3. Processing Software

DEA PORTLAND OFFICE SOFTWARE				
	Company	**Program Name**	**Version**	**Dongle/License**
Processing				
	Caris	HIPS & SIPS	See HF Tracker tab	10/3/2006
	Caris	Notebook	2.2 SP1 + Hot Fix 6	7/25/2006
	Caris	Bathy DataBASE	1.0 + Hot Fix 8	7/25/2006
	Triton Imaging, Inc	Isis Sonar Office Suite	7.0.414.0	5/23/2006
	HYPACK, Inc.	Hypack Lite	4.3a Gold	5/23/2006
	ESRI	ArcGIS	9	5/23/2006
	DEA	Digital LineLog	1.0.4	5/23/2006
	NOAA	Velocwin	8.8	5/23/2006
Other				
	Microsoft	Word	2003	
		Excel	2003	
		Access	2003	
	Adobe	Acrobat Standard	7	

A7. Survey Methodology

A7.a Mobilization

Mobilization, sensor installation, and calibration occurred from May 1 through May 21, 2006 in Deltaville, Virginia. The *R/V Sealth* was hauled out on May 4th in Ordinary, Virginia and the Reson sonar head was mounted and all sensors were surveyed in using a terrestrial land survey total station. Values from this survey were used to calculate sensor offsets and accuracies used in the HVF (HIPS vessel file). During this period effort was also spent troubleshooting initial setup of the Reson 7125 and evaluating data conversion routines and precise timing performance. Once installation was complete and the survey manager was confident that all sensors were operational, the vessel underwent system calibration tests, including settlement and squat, alignment and static vessel measurement. During mobilization the side scan sonar tow cable was marked at 10 meter intervals which were color coded for use as a comparison check against the digital cable counter during survey operations.

A7.b Survey Coverage

The Central Chesapeake area was surveyed with a north-south line orientation parallel with the sheet boundaries. For H11503 (B), H11504 (C), and H11505 (F) line spacing was run at a 130 meter spacing for each 100 percent side scan coverage. The 200 percent coverage line spacing was offset 65 meters for a total coverage of the area at 65 meter line spacing. Shallow water required portions of H11504 (G) to be surveyed at 50m side scan range scale with line spacing adjusted to 40m spacing for 200 percent coverage.

Additional lines were run within and paralleling the Rappahannock Channel on H11503 (B), and H11504 (C). The steep side slopes of the dredged channel made it difficult to adjust the towfish height when the channel was crossed on the north-south oriented lines. To avoid distorted imagery from rapid adjustments in towfish height, the towfish was not lowered when crossing the channel but maintained at the height used for imaging the area outside the channel. The towfish stayed within the 8 – 20 percent height requirement when crossing the channel on the north-south lines. The additional channel lines also increased the multibeam swath coverage within the channel.

A7.c Side Scan Sonar Operations

Side scan imagery was collected using the sonar's high frequency (400 kHz) in the multi-pulse high speed mode at a range of 75 meters for all data acquisition on H11503 (B), H11504 (C), and H11505 (F). At a 75 meter range scale the EdgeTech 4200-FS has a ping rate of 20 Hz. In accordance with the *Specifications and Deliverables* (DRAFT February 2006), vessel speed was monitored to ensure 3 pings per meter to ensure detection of a 1m x 1m x 1m object on the seafloor. The survey vessel maintained a speed under 8.5 knots throughout the side scan survey which allowed for a minimum of 4.6 pings per meter. The side scan was towed from the stern of the vessel during acquisition on H11503 (B), H11504 (C), and H11505 (F).

The side scan sonar operator was assigned the task of analyzing the digital sonogram and keeping towfish height within specification by adjusting cable out. The operator also called out contacts and daily confidence checks which were entered in the digital acquisition log by the multibeam operator/log keeper. When conditions degraded side scan sonar imagery, operations were suspended.

Side scan sonar coverage was obtained by using Technique 2 under 6.1 of the *Specifications and Deliverables* (DRAFT February 2006). This technique allows for two separate 100 percent coverages by running splits between the first coverage to obtain the second coverage. The sonar acquisition operator monitored the vessel speed, ensuring speed over ground did not exceed 9 knots thus allowing a minimum of 3 pings per meter. In addition, the side scan sonar operator monitored towfish height, ensuring a height of 8 to 20 percent of the range above the bottom and coverage displays to ensure 100 percent coverage was obtained.

The shallow waters within H11535 (G) required several operational modifications in order to meet specifications and to prevent crosstalk between the side scan and multibeam sonars. In order to meet the 8 to 20 percent altitude requirement in the shallow water areas of the sheet, the range scale was reduced to 50m and line spacing was adjusted accordingly. To prevent crosstalk between the sonars operating at similar frequencies an EdgeTech 4200-FS dual high frequency (300/600 kHz) digital side scan sonar was used in high speed mode at 600 kHz. Crosstalk was not a problem when operating at 400 kHz in deeper areas since there was adequate distance between the two sonars. In addition, when running in the shallowest areas of the sheet the tow point was moved to the bow of the vessel to maximize the distance between the sonars and to move the towfish out of the vessel's jet wash. Isis tow point offsets were modified when running in this shallow water configuration so that towfish layback was calculated correctly. Deeper areas of H11535 (G) were run with the normal side scan configuration that was used on H11503 (B), H11504 (C), and H11505 (F). See Figure 4 for a graphic of sheet G and the areas each configuration was used.

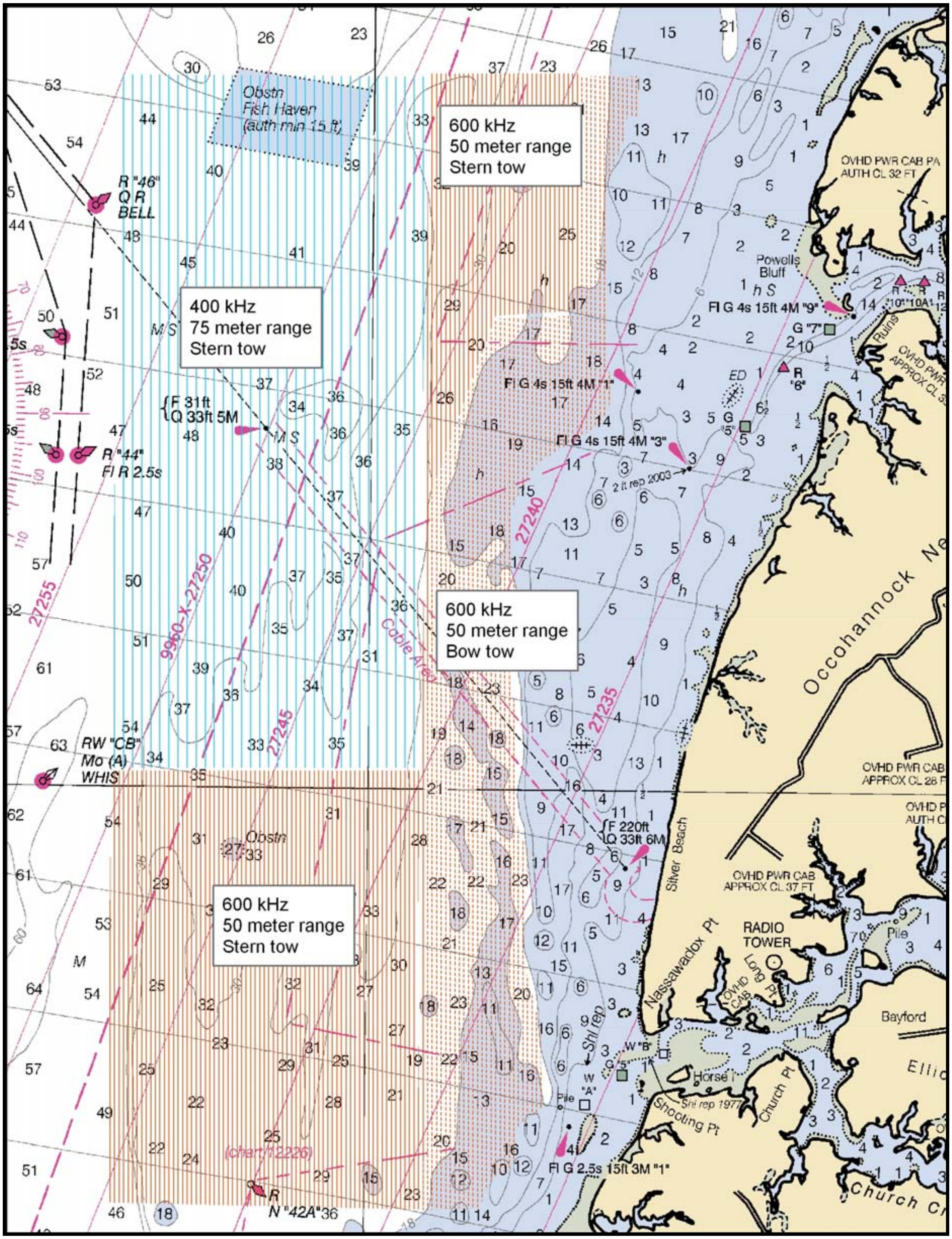

Figure 4. Chartlet showing side scan deployment methods for H11535.

A7.d Multibeam Operations

Multibeam operations occurred concurrently with side scan sonar acquisition using the Set Line Spacing coverage technique as stated in the *Statement of Work* (March 28, 2006) and defined by the *Specifications and Deliverables* (DRAFT February 2006). Full multibeam coverage was not a requirement for this survey. The multibeam sonar system was operated at a recorded ping rate of 14 Hz during all data acquisition. The multibeam sonar was able to detect shoals that measure two meters by two meters horizontally and one meter vertically in depths of 40 meters or less. Based on a sonar update rate of 14 Hz and an average vessel speed of seven knots, the bottom coverage averaged 3.9 beam footprints per meter. The multibeam sonar was operated at different range scales throughout the survey by adjusting the depth range to obtain the best coverage in varying depths of water. The depth of the survey area ranged from 18 to 65 feet (5.5 to 20 meters). The majority of the survey was run at the 40-meter range scale. Table 4 lists the typical sonar settings for the survey.

Table 4. Reson 7125 Sonar Settings

7125 Parameter	Value
Range:	Variable, depth dependent
Gain:	42 dB
Power:	202 dB
Spreading	30 dB
Absorption:	60 dB/km
Ping Rate	14 p/s
Pulse Width:	33 µs

A7.e Bottom Sampling

A total of 85 bottom sediment grab samples were obtained on a 2000 meter grid across all 4 survey sheets. Samples were obtained with a Ponar grab sampler which collects a sample size of 8.2 liters with a penetration depth of 3.5 inches. Position, depth, date, time, unique identifier, description and photograph were recorded for each sample. Each sample was described in accordance with IHO S-57 requirements for SBDARE features with attribution of COLOUR, NATQUA, and NATSUR.

A8. Quality Assurance

A processing workstation containing Triton Isis, DelphMap and Caris HIPS was installed aboard the *R/V Sealth* for preliminary processing, side scan sonar contact creation, and quality assurance. Data were transferred from the acquisition computers to the vessel's data server, during turns at the end of each line, and reviewed near real-time to ensure that the acquisition system was functioning properly, and that environmental conditions were not degrading the data. Under typical conditions a line of side scan data was transferred to the vessel server and processed as soon as the acquisition of the line ended. Side scan contacts noted while online were created in Triton Isis. Additional contacts not identified while online were also identified and created during this phase of processing. The re-evaluation of imagery for contacts by the data processor resulted in two reviews of the side scan imagery while data was still onboard the

R/V Sealth. Side scan sonar imagery was also corrected for layback, slant range, and speed in Isis on the processing station.

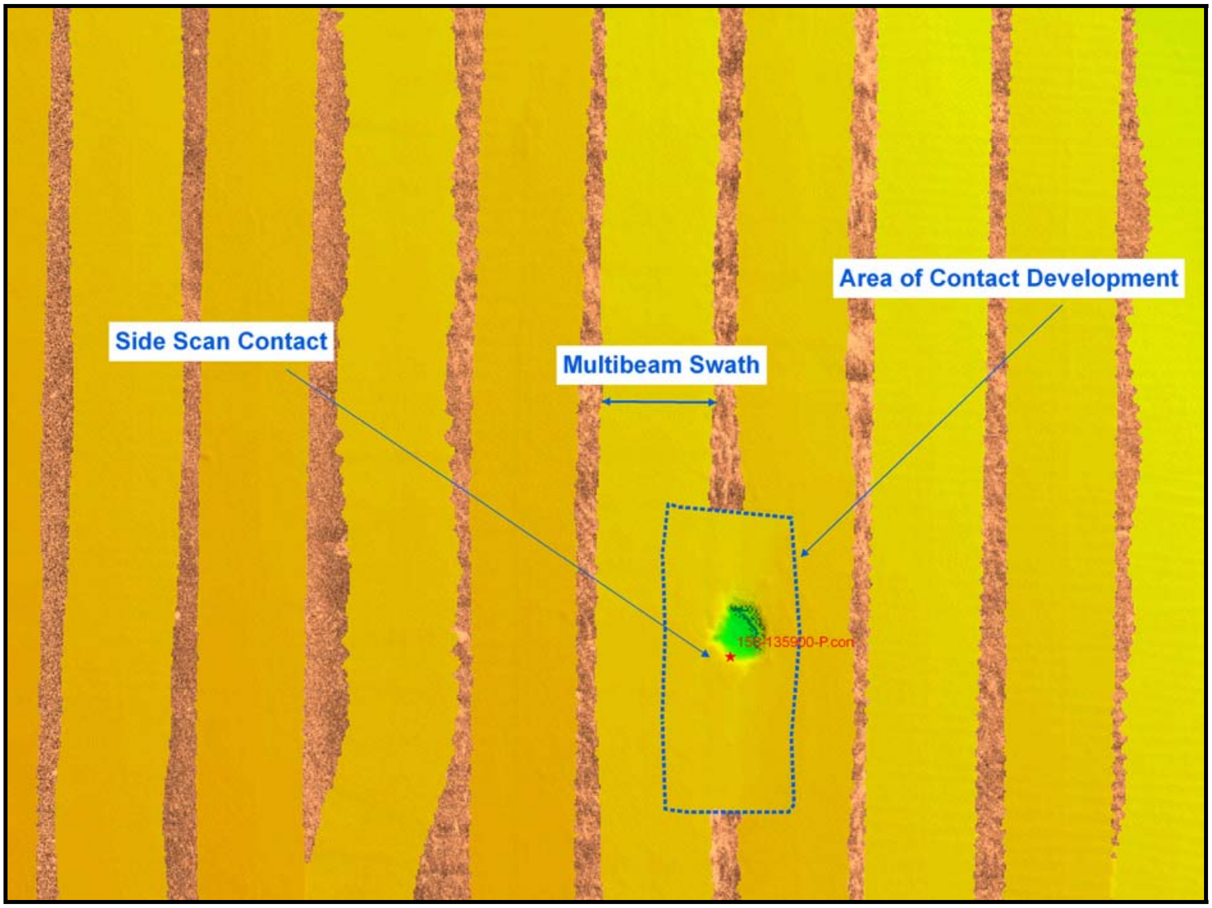

Figure 5. Graphic of side scan mosaic overlaid with contacts and multibeam swath coverage.

Multibeam data were converted in Caris HIPS v6.0 during preliminary processing of multibeam data. Attitude and navigation sensor data were evaluated for timing problems, data gaps, or erroneous data before sound speed corrections were applied.

B. QUALITY CONTROL

B1. Data Acquisition

Multibeam raw soundings, attitude, heading and position data were logged in both the Triton Isis and Hypack data acquisition systems. No correctors or offsets were applied to the data during acquisition. The Isis system stored data in XTF format and Hypack wrote the data to HSX format. At the end of each day, data were backed up to an external hard drive and removed from the vessel. Approximately every 4 days, all data that had been collected within that time period, was shipped to DEA's Portland office where additional processing occurred.

B2. Methodology Used to Maintain Data Integrity

The acquisition system and survey protocols were designed with some redundancy to demonstrate that the required accuracy was being achieved during the survey and provide a backup to primary systems. Data integrity was monitored throughout the survey through system comparisons. Two positioning systems were used to provide real-time monitoring of position data. A position confidence check and leadline to multibeam comparison were conducted weekly to confirm required accuracy was being maintained. Weekly checks of the sound speed profiler integrated into the MVP-30 were conducted by deploying a SeaBird CTD profiler in tandem with the MVP-30. Sound velocity profiles were computed for each the sensors and compared to confirm instrumentation was functioning within survey tolerances.

Side scan sonar imagery from the 400 kHz channel was displayed in real-time on the Isis data display, a 30-inch LCD flat panel monitor mounted vertically at the acquisition station. The large format display allowed the side scan sonar operator to review digital side scan imagery and have time to manage and react to multiple contacts or to ask other crew members to provide additional review of imagery before the waterfall imagery scrolled off screen. Positioned beside the side scan acquisition station was the multibeam operator who controlled the Hypack station, monitored the multibeam sonar, and entered information into the digital line log. The multibeam operator could also view the side scan monitor from their station and provided additional review when necessary. The side scan operator was tasked with identifying contacts and reading out time, ping and range values for input into the digital log by the multibeam operator.

To aid in the consistency of contact identification, a table was posted listing slant range and towfish altitude to determine minimum shadow heights for one meter contacts at 75 and 50 meter ranges. Contacts were classified as significant if their height was one meter or more. Maintaining towfish altitude at 8 to 20 percent of the range (6 to 15 meter altitude above the bottom at 75 meter range) was tasked to the side scan operator who also controlled the winch operation. The operator could view the towfish altitude above the seafloor on the Isis display and adjust cable out accordingly to fly the towfish at the required height. Digital cable out values were confirmed by stopping pay out of the tow cable when ten meter marks on the cable were at a predetermined mark on the block. Using this method, the cable out meter was calibrated each day prior to deploying the towfish. Using the MVP-30 sound velocity profile data, the operator was often able to adjust towfish height and fly below haloclines.

Acquisition and processing software was selected to ensure that data integrity was maintained throughout the data acquisition and processing pipeline. The software provided a means to track individual soundings, edits and all correctors from acquisition through processing. Edited data needed to be compatible with Caris software for data review by NOAA. To accomplish data tracking and provide a seamless transfer of data to NOAA, DEA utilized a suite of Caris programs for data processing, analysis and generation of S-57 deliverables. Side scan contacts went through several stages of review including comparison to multibeam data and CUBE surfaces.

A flow diagram of the shallow water multibeam and side scan sonar data acquisition and processing pipeline is presented in Figures 6 and 7 respectively which illustrates the processes from acquisition to Preliminary Smooth Sheet production.

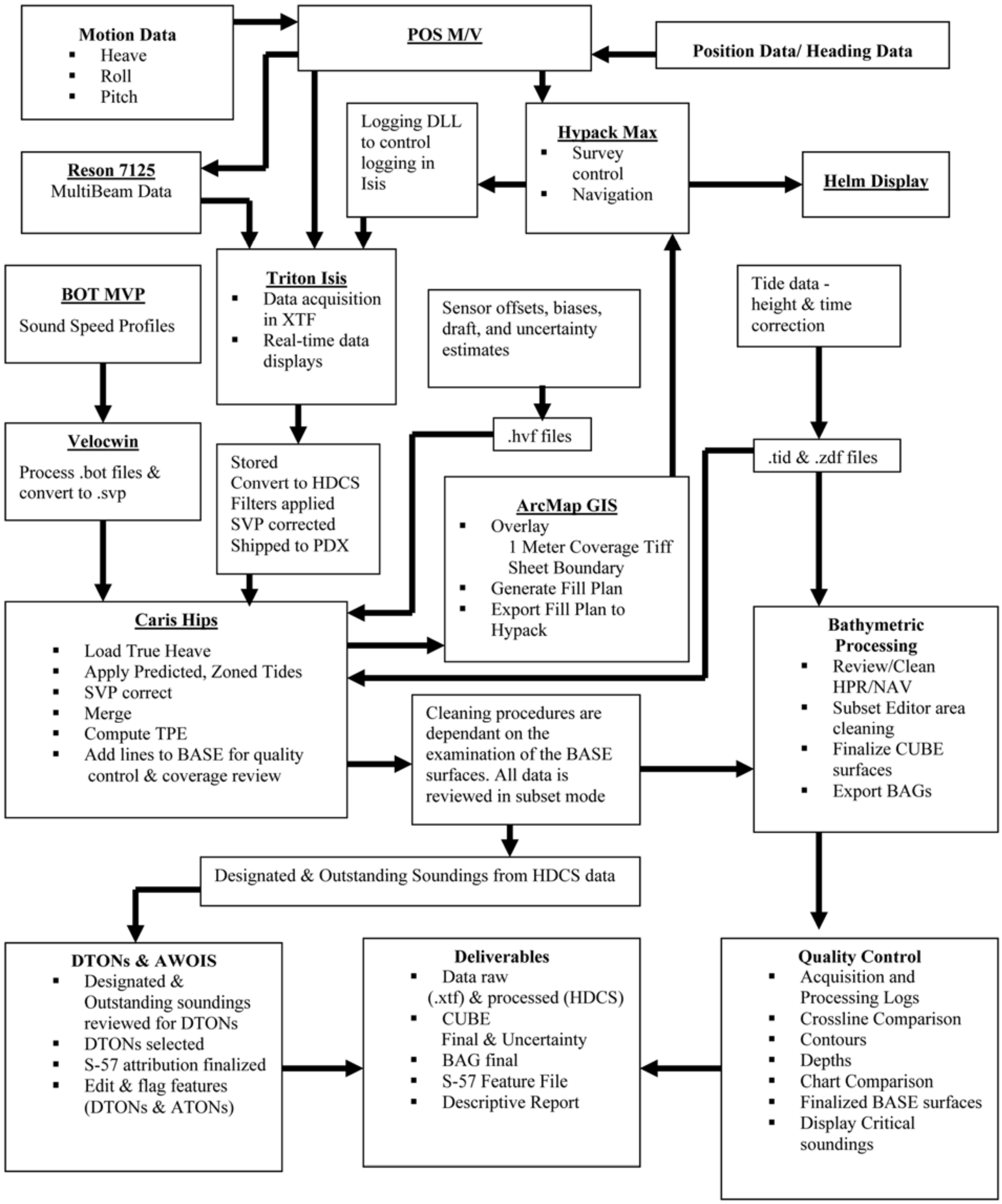

Figure 6. Flowchart of multibeam data acquisition and processing pipeline.

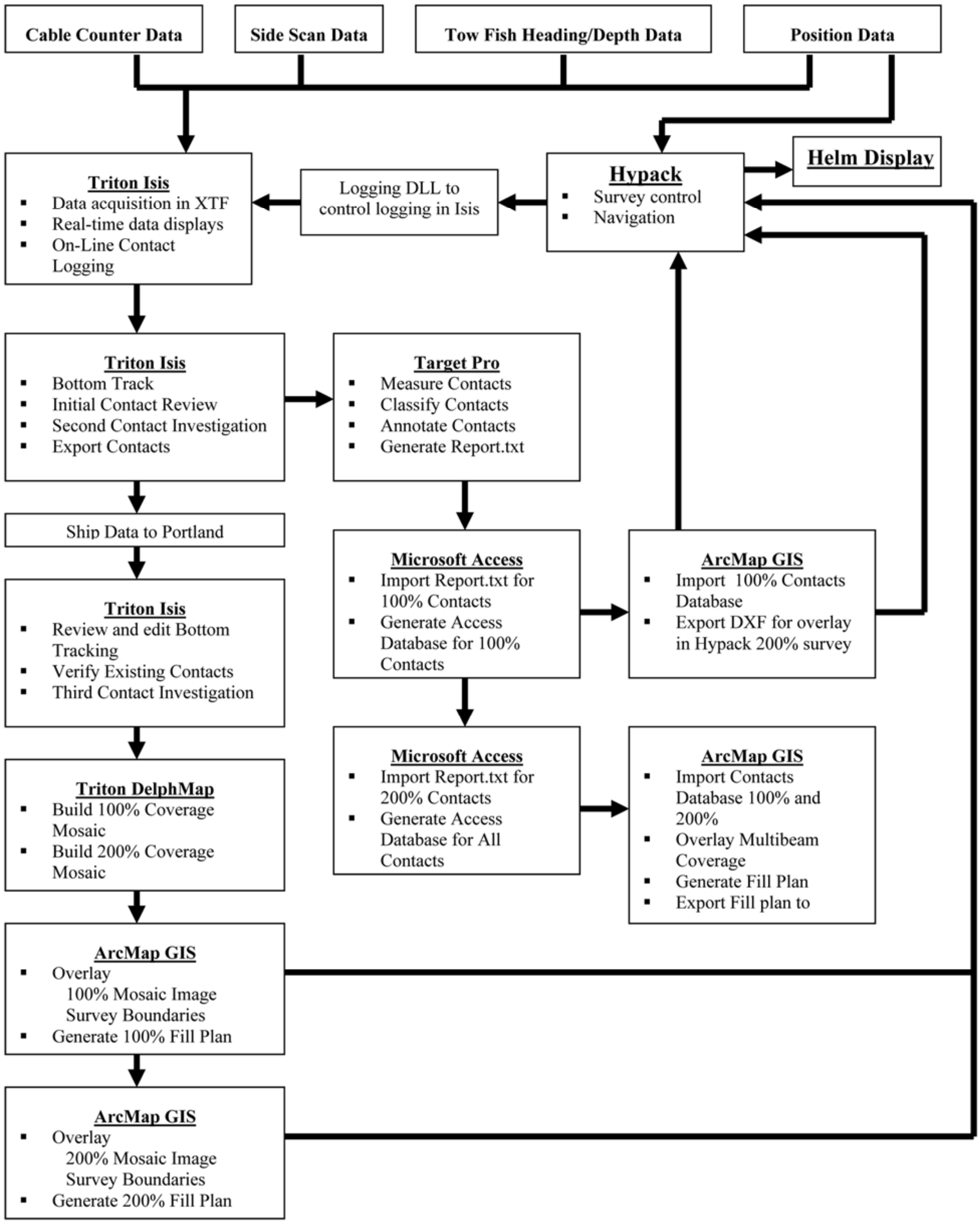

Figure 7. Flowchart of side-scan sonar data acquisition and processing pipeline

Aboard the survey vessel multibeam data processing was kept to a minimum in order to focus on side scan processing and contact identification. Data were transferred to the vessel server during turns at the end of a line and converted into Hydrographic Data Cleaning System (HDCS) format. After each survey line was converted position and sensor data were reviewed for anomalies and edited if necessary. Sounding data from the first survey line of the day were reviewed to ensure that the acquisition system was operating correctly.

A daily HIPS sound speed file of concatenated cast data was compiled at the end of the day and then applied to that day's survey lines. At this point multibeam processing was complete until the survey data were shipped to DEA's Portland office where processing continued.

B2.a Conversion

All multibeam sonar data were converted (convert_XTF7K.dll 5/23/06) to a Caris Hydrographic Data Cleaning System (HDCS) data file using ship navigation, attitude, and gyro from the raw navigation datagram. Side scan imagery was not converted during conversion since SSS processing was performed with Triton Isis.

B2.b Vessel File

Sensor offsets values were calculated from the vessel survey (5/4/06). Draft (water line) was measured and entered daily from draft marks on the port and starboard side of the vessel's hull directly abeam of the multibeam moon pool. Port and starboard draft readings were averaged to obtain the multibeam draft in the center of the vessel. The HVF "NOAA0006_*R/V Sealth*.hvf" documents static draft and is provided with the HDCS data for the survey.

Dynamic draft (settlement and squat) values were calculated through the use of Real-time Kinematic (RTK) GPS observations.

Best estimates for total propagated error (TPE) values were entered into the vessel file based on current knowledge of the TPE/CUBE processing model. Manufactures' published values were entered into the sensor accuracy fields. Other values were either calculated or estimated.

B2.c Static Draft

Static draft marks were surveyed and painted on the port and starboard side of the R/V Sealth's hull directly abeam of the multibeam moon pool. Port and starboard draft readings were averaged to obtain the multibeam draft in the center of the vessel. Multibeam draft marks were also marked on the sonar mounting poles that retract into the moon pole. At the start of the survey a diver was deployed to read the static draft on the mounting pole and measure directly the draft from the face of the 7125 receive array. This measurement was checked against the averaged port and starboard draft reading.

During survey operations, draft was observed at the beginning and end of daily survey operations to compute average draft for the day. This provided an accurate draft reading during survey operations with the majority of the fuel load change during the day being burned during transit out and back from the survey area. The average of the start and end of day draft values was calculated daily and entered into the waterline field in the HIPS HVF.

B2.d Sound Velocity

The sound velocity correction was applied to each line using the nearest in distance within time (2 hours) option in the Caris SVP correct routine. Velocity casts were taken at frequent intervals (typically ever 15 minutes) through the use of the MVP-30. A real-time comparison of sound velocity measurements was made during survey operations between the SVP-70 mounted on the sonar head and the MVP-30 when being towed near the surface.

B3. Preliminary Side Scan Processing

Side scan imagery underwent preliminary processing aboard the survey vessel. Imagery was corrected for layback, slant range and speed as well as re-bottom tracked in Isis at the processing station. The data processor reviewed acquisition logs for contacts and performed a second review of side scan data. Using Triton Target Pro utility, the processor generated Isis targets for each contact. Contacts were designated as significant or insignificant and a remark indicating the processor's opinion about the contact was added. At the end of the survey day all Isis contacts were imported into a Microsoft Access database which was used to track and manage contacts for each survey sheet.

B4. Caris Data Processing

Multibeam data processing followed the standard HIPS workflow for CUBE editing except that the hypothesis surface was not edited. Instead fliers influencing the CUBE surface we rejected and critical soundings not incorporated in the CUBE surface were designated.

Prior to the creation of CUBE surfaces the data were filtered using the HIPS filter tool. The filter tool used the following parameters.

B4.a IHO Filter

An Order 1 IHO filter was applied. Since the vertical TPE value for all soundings was less than 0.5 meters this step proved to be unnecessary.

B4.b Depth Filter

Based on the overall depth of the area, a depth filter was used to eliminate any flyers in the data. For this survey, a filter with a minimum depth of 2 meters and maximum depth of 50 meters was applied. Depths outside this range were flagged as bad data, though these could be viewed to prove or disprove a sonar contact and least depth if necessary. Depth filtering was a two step process once during conversion at 2 to 50 and then a filter was applied after conversion >22m.

B4.c Beam Quality

Data having Reson quality codes of 0 or 1 were rejected during the filter process.

After filtering, each survey sheet was subdivided with the creation of five Caris fieldsheets to reduce to processing time and power required to generate CUBE surfaces. The fieldsheets were created to keep the number of nodes under the recommended limit 25 million for each CUBE surface. All CUBE surfaces were created at a 1 meter resolution which more than adequately represented the sea floor. CUBE surfaces of varying resolutions were not required since 1 meter resolution exceeded the 2 meter minimum resolution for *Complete Multibeam Coverage*. Separate grids for coverage demonstration and seafloor depiction were not required for these surveys.

The default HIPS CUBEParams.xml file was modified before the project in order to meet the maximum propagation distance values and to use more appropriate values for the estimate offset and horizontal error scale values. The CUBEParams.xml is included.

Verified zoned tides were applied to the data prior to depth editing or CUBE creation. Data from the subordinate station installed on the Rappahannock Front Range Light (863-2837) were compiled, reduced to MLLW and applied to the survey data through the use of a HIPS zone definition file (ZDF) was then built for use for data from 863-2837. This file was included with the HIPS deliverables.

All data were reviewed in HIPS 2D subset with the 1m CUBE reference surface visible. Fliers making the CUBE surface shoaler than expected by more than the allowable IHO Order 1 error were rejected. Any legitimate sounding that was not incorporated into the CUBE surface and shoaler than the surface by more than half the allowable IHO Order 1 error was flagged as a critical sounding. Data processors had a table of allowable IHO Order 1 error relative to depth at their station while processing. Subset tiles were used to track the progress of processing activities. In addition, data processors reviewed data sounding data and CUBE surfaces for excessive motion artifacts or systematic biases.

Significant side scan contacts were displayed in the background in HIPS (as a DXF file) and reviewed for multibeam coverage. In addition contact least depths were queried in subset editor and entered into the contact database with additional multibeam information such as ping, beam, and time. Contacts over the same feature were correlated in the database by entering contact identification numbers of matching contacts into the “Correlate” field of the database.

B5. Side Scan Processing

Final review and editing of the side scan data was performed in the DEA Portland office using Triton Isis and Delphmap software. The data processor performed an additional review of all imagery for contacts (third review), created TIF images of all contacts, and generated 100 and 200 percent side scan mosaics at 50cm resolution. During mosaic creation in Delphmap each 100 percent coverage was broken into four sections to facilitate reprocessing a mosaic if necessary without having to generate a new mosaic for the entire sheet.

Side scan images were imported into ESRI ArcView and reviewed for data gaps or holidays and for problematic data that would warrant reprocessing the data or resurvey of an area. After review of the mosaics SSS fill plans were generated and sent to the survey vessel.

B6. Data Export

After data editing was complete all CUBE grids were finalized. Preliminary product surfaces and associated contours and selected soundings were created for chart comparison which is discussed in the Descriptive Report for each survey. BAGs for each CUBE surface were exported from HIPS for delivery.

Each of the four TIF images making the 100 and 200 percent mosaics were merged using Lizardtech GeoExpress 6.1. A single TIF image per 100 percent coverage was created for delivery.

C. CORRECTIONS TO ECHO SOUNDINGS

C1. Static Draft

With the vessel out of the water, markings were surveyed and painted on the port and starboard sides of the hull directly abeam with the multibeam sonar providing a means to monitor vessel draft (Figure 8). Static draft readings from the port and starboard side were recorded at the start and end of each survey day, while the ship was alongside the pier and where an accurate draft reading could be obtained. The start and end of day draft values for the sonar were calculated from the average of the port and starboard draft readings. The vessel’s fuel and ballast levels were maintained to control the vessel draft. An average of the start and end of day draft values was calculated daily and entered into the waterline field in the Caris HVF. The average draft value best approximates the true draft value during acquisition due to loading changes from fuel consumption during transit to and from the survey area at the start and end of each day.

C2. Dynamic Draft

A settlement and squat test using Real-time Kinematic (RTK) GPS observations for the *R/V Sealth* was performed in the vicinity of the Rappahannock Front Range Light on May 10, 2006 (Day Number 130). Data from these measurements are displayed graphically in Figure 10 and are included in Appendix V of the Descriptive Report for each survey.

The settlement and squat values were obtained by computing one minute GPS height averages at different ship speeds, measured in knots and revolutions per minute (RPM) during transects near the range light where the RTK base station was installed. Transects were run twice at each RMP interval; once at a westerly heading and once at an easterly heading.

Ship speeds in increments of 100 RPMs were observed from 700 to 1500 RPM with GPS height recorded at 1 HZ. With the vessel at rest static RTK height observations were recorded between each RPM interval in order to have a baseline GPS height value not affected by tide changes during the test. One minute running averages of GPS height were calculated to remove any heave bias from the calculations. Each transect was run for approximately three minute resulting in three average GPS height measurements per transect. Three dynamic draft correctors were then calculated from the difference between the GPS height and an interpolated static GPS height (to account for changing tide) at the time of the average height value. An average dynamic draft corrector was then calculated from the average of the six values for each RPM interval. The average speed for each RPM interval and the average dynamic draft corrector were entered into the HIPS vessel file. TPE values for dynamic draft were calculated by taking the average of the standard deviation for all dynamic draft calculations per transect.

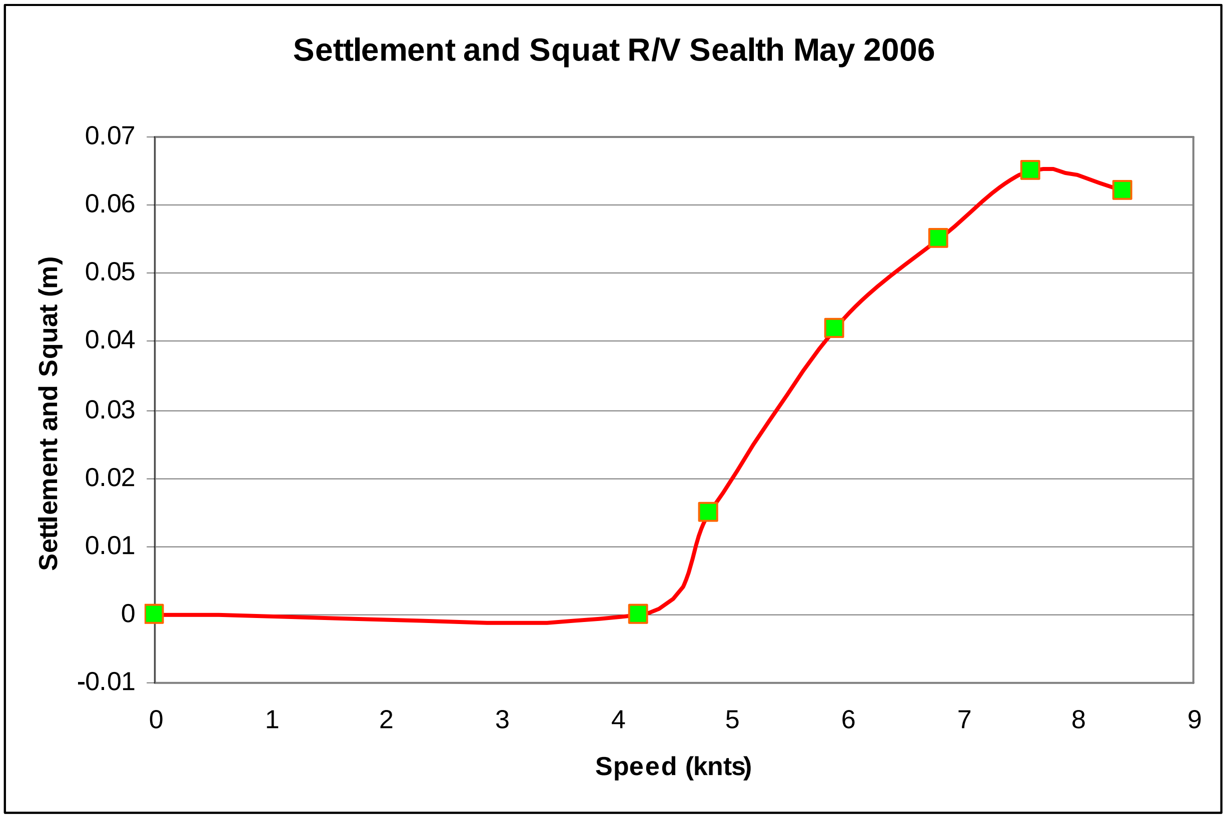

Figure 8. Settlement and squat of *R/V Sealth*.

C3. Lead Line Comparisons

Lead line checks were performed against the multibeam echosounder at the start of each week to confirm that the system was working properly. While the vessel was alongside its berth in the marina lead line readings were taken on the starboard side and port sides of the vessel adjacent to the multibeam sonar transducer. Lead line depth was compared to the multibeam depth recorded in the Triton Isis beam confidence check dialog window using a beam number, which reflected the known 3.0-meter offsets to port and starboard. Lead line observations were recorded in a lead line comparison log. The standard deviation between the lead line and multibeam measurements was 0.02 meters with a maximum deviation of 0.05 meters. The maximum deviations were attributed to the soft and irregular bottom. Tabulated lead line comparisons may be found in the Lead line Comparison log included in Appendix V of the Descriptive Report.

C4. Heave, Roll and Pitch Corrections

An Applanix POS/MV 320 version 4 integrated DGPS and inertial reference system was used for the motion sensor for this survey. The POS/MV 320 is a six-degree of freedom motion unit, with a stated accuracy of 0.05-meter or 5 percent for heave, 0.02 degrees for roll and pitch and heading. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the POS/MV controller program. If any of the vessel motion accuracy degraded to greater than 0.05 degrees, survey operations would be suspended until the inertial unit was able to regain the higher degree of accuracy. Manufacturer reported accuracies as published on the Caris HIPS TPE website (http://www.caris.com/tpe/) were entered into the HIPS HVF and used for TPE computations. A schematic of the vessel and sensor set-up is shown in Figure 9.

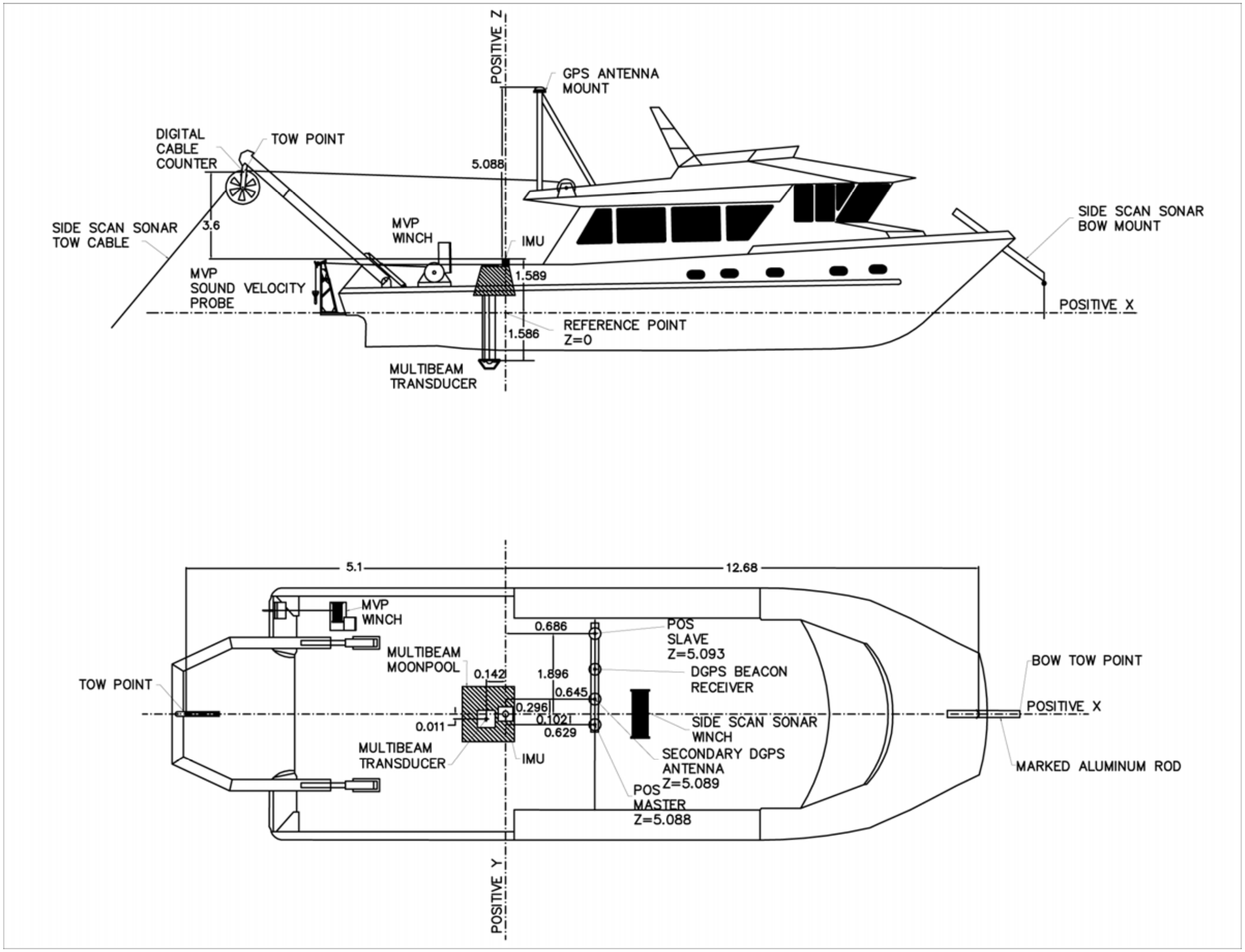

Figure 9. Schematic of *R/V Sealth* and sensor setup.

Installation bias was applied to all the data, along with results obtained from the patch test at the start of the survey. These values were stored in the Caris "NOAA_R/V Sealth.hvf" vessel configuration file.

C5. Patch Tests

A patch test was conducted at the beginning of the project to confirm alignment of the IMU sensor with the sonar transducer, and to verify delay times applied to the time-tagged sensor data. The patch test consisted of a series of lines run in a specific pattern, which were then used in pairs to analyze roll, pitch and heading alignment bias angles as well as latency in the time tagging of the sensor data. The patch test was conducted in accordance with NOAA standards on May 19, 2006 (Day Number 139) on the Rappahannock River.

A precise timing latency test was performed by running reciprocal lines 700 meters long over a flat bottom, in a water depth of 17 meters. The lines were then opened in the HIPS calibration editor (after applying tide and svp corrections) and a small along track slice of data was evaluated in the outer swath of the line. Incremental changes to the roll time offset were made to evaluate the performance of the precise timing setup and to determine if a latency correction was needed. No latency was found in the system. These lines were also used to evaluate the roll bias.

Roll alignment was determined by evaluating the reciprocal lines run over a flat bottom used for the latency test. The pitch test consisted of set of reciprocal lines 750 meters in length up a steep slope on the north side of the Rappahannock River. The heading error was determined by running parallel lines over the same area. All lines were run at approximately 6 knots.

Selected pairs of lines were then analyzed in HIPS Calibration editor to measure the angular sensor bias values. Visual inspection of the data confirmed each adjustment. Two sets of lines were run and analyzed for each of the mounting biases with the second set was used to confirm the results of the data. Bias correction values are displayed in Table 3.

Table 5. Biases applied when using the POS/MV for pitch and roll.

Alignment	Bias
Roll	-0.17°
Pitch	-0.65°
Yaw	0.30°
Latency	0.00s

C6. Tide and Water Level Corrections

Tide data from the subordinate station installed on the Rappahannock Front Range Light by DEA specifically for this project were compiled, reduced to MLLW and applied to the survey data. The Rappahannock Front Range light is a meteorological station for CO-OPS (863-2837) but does not provide water level data. Preliminary CO-OPS zoning files tied to Windmill Point, Virginia (863-6580) were adjusted for use from the DEA installed subordinate gauge (863-

2837). Zone boundaries were not modified, but new time and range correctors were calculated. Time correctors were calculated by adjusting the average time corrector (ATC) for zone SCB67 which surrounds gauge 863-2837 from -54 minutes (zoned from 863-6580) to zero minutes. Similarly, the range corrector was adjusted from 1.47 to 1.00. From this average time correctors were calculated for each zone relative to 863-2837 by calculating the difference between the ATC relative to 863-6580 for the zone in question and -54 (the ATC for SCB65). Range correctors were calculated by dividing the range corrector for the zone in question by 1.47 (the rage value for SCB65 relative to 863-6580).

The Rappahannock Front Range Light station (863-2837) experienced no down time during periods of hydrographic survey. A HIPS tide file and zone definition file are included.

C7. Sound Velocity Correction

While underway during data acquisition the MVP-30 was deployed as needed to attain an adequate number of sound velocity profiles to properly correct the multibeam data during data processing. At the start of each survey day a cast was taken right before coming online with additional casts being taken on a periodic basis, usually every 15 to 20 minutes unless there was a chance of entangling the SSS towfish and the MPV; typically when in strong currents or when surveying in deeper area where extra SSS cable was payed out. Casts were taken more frequently if refraction artifacts were visible in the SSS record or if large changes in sound speed were observed between casts. One deep cast (extending to 95% of depth) was taken per day.

After each cast the sound speed data was reviewed for outliers or anomalies such as a sharp thermocline which could impact data quality. The sound speed at 1.5 meters from the MVP was also compared to the Reson head velocity to ensure that both systems were working properly. In addition to these periodic comparisons, weekly check casts were taken to verify proper performance of the MVP 30. For this check a SeaCat SBE 19*plus* was attached to the MVP fish and the two probes were simultaneously deployed at the deepest end of the survey area for that day's operations. Corrections for the speed of sound through the water column were computed for each sensor and imported into an Excel file where sound speed profiles were created and overlaid for comparison. Each sensor had been calibrated prior to the start and at the end of the survey. Factory calibration results are included in the Separates Section II of the Descriptive Report for the survey.

The sound speed correction was applied to each line using the nearest in distance within time (2 hours) option in the HIPS SVP correct routine. All casts were concatenated into a daily HIPS svp file for each survey day. Time, position, and sound speed for each profile were included in the HIPS file.

D. LETTER OF APPROVAL

DAVID EVANS AND ASSOCIATES INC.

LETTER OF APPROVAL

OPR-E349-KR-06

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of OPR-E349-KR-06 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Jonathan L. Dasler, PE (OR) , PLS (OR,CA)
Lead Hydrographer

Jason Creech
Lead Hydrographer

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September 2006

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