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-10**
Contract No	**DG133C08CQ0006**
Task Order No	**T005**
Time Frame	**July 2010 - November 2010**

LOCALITY

State	**Maryland and Virginia**
General Locality	**Central Chesapeake Bay, MD and VA**

2010

CHIEF OF PARTY

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

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DATE

NOAA FORM 77-28 (11-72)

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

HYDROGRAPHIC TITLE SHEET

REGISTRY No
H12238
H12239
H12240
H12241
H12242

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

FIELD No
David Evans and Associates, Inc.

State: Maryland and Virginia

General Locality: Central Chesapeake Bay, MD and VA

Sub-Locality: East of Pt Look-in, Maryland to 3nm SW of Smith Island, Virginia

Scale: 1:10,000

Date of Survey: July 3, 2009 to November 15, 2010

Instructions dated: July 1, 2010

Project No.: OPR-E349-KR-10

Vessel: R/V *Theory* and R/V *Chinook*

Chief of party: Jonathan L. Dasler, PE (OR) , PLS (OR,CA)

Surveyed by: David Evans and Associates, Inc.

Soundings by echo sounder, hand lead, pole: RESON 7125, R2Sonic 2042, EdgeTech 4200-FS, EdgeTech 4200-HFL

Graphic record scaled by: N/A

Graphic record checked by: N/A

Automated Plot: N/A

Verification by:

Soundings in: Meters at MLLW

REMARKS: All times are UTC.

The purpose of this contract is to provide NOAA with modern, accurate hydrographic survey data with which to update nautical charts of the assigned area.

SUBCONSULTANTS: Zephyr Marine, P.O. Box 1575, Petersburg, AK 99833

John Oswald and Associates, 2000 E. Dowling Road, Suite 10, Anchorage, AK 99507

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537

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Acronyms and Abbreviations

AML	Applied Microsystems, Ltd
AWOIS	Automated Wreck and Obstruction Information System
BAG	Bathymetric Attributed Grid
CO-OPS	Center for Operational Oceanographic Products and Services
CORS	Continuously Operating Reference Systems
CUBE	Combined Uncertainty and Bathymetry Estimator
DEA	David Evans and Associates, Inc.
DGPS	Differential Global Positioning System
DN	Day Number
DTON	Danger to Navigation
DXF	Drawing Exchange Format
ERS	Ellipsoidal Referenced Survey
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HSD	Hydrographic Surveys Division
HSX	Hypack Hysweep File Format
HVF	HIPS Vessel File
IAKAR	Inertially-Aided Kinematic Ambiguity Resolution
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
MVP	Moving Vessel Profiler
NAD83	North American Datum of 1983
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OPUS	On-line Positioning User Service
PHB	Pacific Hydrographic Branch
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per Second
R/V	Research Vessel
RMS	Root Mean Square
RPM	Revolutions per Minute
SBET	Smooth Best Estimate and Trajectory
SSS	Side Scan Sonar
SVP	Sound Velocity Profiler
TWF	TIF World File
TIF	Tagged Image File Format
TPE	Total Propagated Error
UTC	Universal Time Coordinated
XTF	Extended Triton Format
ZDA	Global Positioning System Timing Message

Data Acquisition and Processing Report
Project OPR-E349-KR-10
Central Chesapeake Bay, MD and VA
July 2010 – November 2010
R/V *Theory*, R/V *Chinook*

David Evans and Associates, Inc.
Lead Hydrographer, Jonathan Dasler, P.E., P.L.S.
ACSM/THSOA Certified Inshore Hydrographer

INTRODUCTION

This report applies to surveys H12238, H12239, H12240, H12241 and H12242 located in the Central Chesapeake Bay, Maryland and Virginia. These contract surveys were performed under OPR-E349-KR-10 as specified in the *Statement of Work* (April 2010) and *Hydrographic Survey Project Instructions* (July 2010). All survey methods meet or exceed requirements as defined in the National Ocean Service (NOS) *Hydrographic Surveys Specifications and Deliverables* (April 2010). The project instructions required 200% side scan sonar coverage with concurrent multibeam to the inshore limit. The inshore limit is defined as the most seaward of either the surveyed 18-foot contour or the survey polygon *OPR-E349-KR-10_Sheets_region.shp*, which was included with the *Hydrographic Survey Project Instructions* (July 2010). Significant side scan contacts and Automated Wreck and Obstruction Information System (AWOIS) investigations were acquired to meet object detection coverage requirements for multibeam surveys.

On October 26, 2010 David Evans and Associates, Inc. (DEA) was directed to use Ellipsoidal Referenced Survey (ERS) methods for the reduction of survey data to chart datum via a signed memo from the Chief, Hydrographic Surveys Division (HSD). Approval of these methods was granted based on recommendations included with DEA's interim deliverables (submitted September 23, 2010) for the ERS / VDatum / Tide Buoy Validation components of OPR-E349-KR-10 specified in the *Hydrographic Survey Project Instructions (*July 2010*)*. A copy of this memo was included in Appendix V *Supplemental Survey Records and Correspondence* of each survey's *Descriptive Report*.

All references to equipment, software, or data acquisition and processing methods were valid at the time of document preparation. Any deviations from these data acquisition and processing methods will be specifically addressed in the Descriptive Reports of the project surveys.

A. EQUIPMENT

For this project DEA implemented state-of-the-art data acquisition systems aboard the Research Vessels (R/V) *Theory* and *Chinook*, in accordance with National Oceanic and Atmospheric Association (NOAA) standards and modern remote sensing techniques. Operational systems used to acquire survey data and redundant systems that provided confidence checks are described in detail in this section and listed in Tables 1 and 2 on the following pages.

Table 1. R/V *Theory* Hardware

Instrument	Manufacturer	Model	Serial No.	Function
Side Scan Sonar				
Deck Unit	**EdgeTech**	701-DL	35323	Topside interface side scan sonar (SSS) and digital sensors.
Towfish	**EdgeTech**	4200 HFL	37844	600 kHz Digital SSS imagery with towfish heading and depth sensors.
Side Scan Sonar Cable Counter				
Cable Counter	**Measurement Technology Northwest**	LCI-90	350	Continuous digital output of deployed side scan tow cable length for layback calculations.
Multibeam Echosounder				
	RESON	SeaBat 7125-SV multibeam sonar system		Dual frequency multibeam sonar
Deck Unit	**RESON**	7-P Processor Unit	2009002	7-P processor running Feature Pack 1 (FP1)
Receiver	**RESON**	EM 7200	1816020	
Projector	**RESON**	TC 2160	2405064	400kHz Transmitter
Sound Speed				
Surface Sound Speed	**RESON**	SVP 70	2007080	Beam formation and steering
Sound Speed Profiler	**Brooke Ocean Technology, Ltd.**	AML MVP 30 Smart SVP+	5111	Primary SV profiler
Sound Speed Profiler	**Applied Microsystems**	AML SVP+ V2	3592	Secondary SV profiler
Sound Speed Profiler	**Seabird Electronics**	SV19plus	4962	Secondary SV profiler
Navigation				
Deck Unit	**Applanix**	POS MV 320 V4	3038	Integrated Differential Global Positioning System (DGPS) and inertial reference system for position, heading, heave, roll and pitch data.
IMU	**Applanix**	POS MV V4	750	
Starboard Antenna	**Trimble**	Zephyr	60186994	
Port Antenna	**Trimble**	Zephyr	60222755	
Receiver	**Trimble**	DSM 132	224094182	Secondary positioning system with integrated DGPS radio. Used as primary DGPS radio from DN319-327.
Antenna	**Trimble**		220360424	
Receiver	**Trimble**	Pro-Beacon	220014495	Differential radio for primary position system.
Antenna	**Trimble**	MD MGL-3	No number	
Deck Unit	**Applanix**	POS MV 320 V4	3588	Installed on DN270 to replace failed system
Deck Unit	**Applanix**	POS MV 320 V4	3038	Installed on DN275 after repair.

Table 2. R/V *Chinook* Hardware

Instrument	Manufacturer	Model	Serial No.	Function
Side Scan Sonar				
Deck Unit	**EdgeTech**	701-DL	35324	Topside interface SSS and digital sensors.
Towfish	**EdgeTech**	4200 FS	35482	410 kHz Digital SSS imagery with towfish heading and depth sensors.
Towfish	**EdgeTech**	4200 HFL	38461	600 kHz Digital SSS imagery with towfish heading and depth sensors. Installed on DN222.
Side Scan Sonar Cable Counter				
Cable Counter	**Measurement Technology Northwest**	LCI-90	No Number	Continuous digital output of deployed side scan tow cable length for layback calculations.
Multibeam Echosounder				
Deck Unit	**R2Sonic**	Sonar Interface Module (SIM) Sonic 2000 Series	100063	Multiple frequency (200 to 400 kHz) multibeam sonar with 128° swath and 1.0° beams.
Transducer	**R2Sonic**	2024	10000023	
Sound Speed				
Surface Sound Speed	**Applied Microsystems**	MicroSVX	7561	Beam formation and steering
Sound Speed Profiler	**Applied Microsystems**	AML SVPlusV2	3592	Primary SV profiler
Sound Speed Profiler	**Seabird Electronics**	SV19plus	4962	Primary SV profiler
Sound Speed Profiler	**Brooke Ocean Technology, Ltd.**	AML MVP 30 Smart SVP+	5111	Secondary SV profiler
Navigation				
Deck Unit	**Applanix**	POS MV 320 V4	3588	Integrated Differential Global Positioning System (DGPS) and inertial reference system for position, heading, heave, roll and pitch data.
IMU	**Applanix**	POS MV V4	898	
Starboard Antenna	**Trimble**	Zephyr	30939211	
PORT Antenna	**Trimble**	Zephyr	30942877	
Receiver	**Trimble**	DSM132	224092892	Secondary positioning system with integrated DGPS radio.
Antenna	**Trimble**	Zephyr	220415991	
Receiver	**CSI Wireless**	MBX-3S	0716-1600-0009	Differential radio for primary position system.
Antenna	**Trimble**	MD MGL-3	0716-3582-0008	

Table 3. GPS Base Station Hardware

RTK Base Station Equipment						
Item/ Manufacturer	**Model**	**P/N**	**S/N**	**Antenna Type**	**Firmware Version**	**Comments**
Receiver						Dual Frequency/ data logging capable
Trimble	**NetR5**	62800-10	4750K11594		4.14	
Trimble	**NetR5**	62800-10	4750K11589		4.03	
Antenna						
Trimble	**Zephyr-Geodetic**	41249-00	12237025	TRM41249.00		
Trimble	**Zephyr-Geodetic**	41249-00	12338039	TRM41249.00		

A1. Survey Vessels

A1.a R/V *Theory*

The R/V *Theory*, which is owned and operated by Zephyr Marine (Figure 1), was used as the primary survey vessel for the project.

Figure 1. R/V *Theory*

The R/V *Theory*, hull registration number IAR34CATA808 is a 36-foot, 13-gross ton, aluminum catamaran with 13-foot beam and a draft of 3 feet. The vessel is equipped with twin Hamilton jets, a starboard side custom multibeam pole mount, stern mount A-frame, air-cushioned server station and acquisition station. No unusual sensor setup configurations were used aboard R/V *Theory*.

A1.b R/V *Chinook*

The R/V *Chinook*, which is also owned and operated by Zephyr Marine (Figure 2), was the second survey vessel configured for acquisition.

Figure 2. R/V *Chinook*

The R/V *Chinook* hull registration number IAR28CATJ607 is a 28-foot, aluminum catamaran with 10.5-foot beam and a maximum draft of 2 feet. The vessel is equipped with twin 225 HP outboard motors, 12-foot pilot house, a starboard side custom multibeam pole mount, stern mount A-frame, air-cushioned server station and acquisition station. No unusual sensor setup configurations were used aboard R/V *Chinook*.

A2. Multibeam Systems

A2.a R/V *Theory*

A Reson SeaBat 7125-SV multibeam sonar with dual frequency configuration and integrated SVP-70 sound velocity profiler (SVP) was pole mounted on the starboard side on the R/V *Theory*. The Reson 7125-SV, which is designed specifically for installation aboard surface vessels, operates at either 400 kHz or 200 kHz producing a 128°-swath of 256 uniform beams with a beam width of 0.5° x 1.0° in equiangle mode. The 7125 also has options for 512 beams per ping and equidistant beams, neither of which was used during this project. Range adjustments were made during acquisition as dictated by changes in the depth.

All multibeam data were acquired using equiangle beam spacing (256 beams) at the frequency of 400 kHz with the Normal Standard Bracket (PN85001559) selected in the Hardware configuration. All multibeam data were output using the 7006 datagram which references all soundings with respect to the 7125 sonar reference point.

Hypack HYSWEEP was used to acquire multibeam data in Hypack Hysweep File Format (HSX).

Over the course of the project a bug in the Hypack acquisition software corrupted the multibeam header of some HSX files. To enable conversion of these files in CARIS HIPS the header was restructured into the expected format. The suffix "_EDIT" was added to the filename to denote this modification.

A2.b R/V *Chinook*

An R2Sonic Sonic 2042 multibeam echosounder sonar integrated with a Applied Microsystems microSV was poled mounted on the starboard side on the R/V *Chinook*. The R2Sonic 2042 operates at frequencies ranging from 200 kHz to 400 kHz producing a user selected swath from 10° to 160° of 256 uniform beams with a beam width of 0.5° at 400 kHz and 1.0° at 200 kHz across track; and 1.0° at 400 kHz and 2.0° at 200 kHz along track.

All data were acquired using a frequency setting of 340 kHz with a 128° swath width and default ping rate, which ensures the maximum ping rate at any given depth range.

On August 9, 2010 (DN 221) the firmware on the R2Sonic was updated to version "July 26 2010" to optimize swath coverage by reducing noise as well as to remove a bug in the controller software which periodically sent incorrect absorption values to the sonar head. A patch test was acquired after the upgrade.

Hypack HYSWEEP was used to acquire multibeam data in HSX format.

A3. Side Scan Sonar Systems

Daily checks were performed to ensure the side scan sonar (SSS) 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 ranger 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.

Side scan sonar imagery was acquired with the Edgetech 4200-FS (120/410 kHz) and the Edgetech 4200-FSL (300/600 kHz) side scan sonar systems. The sonars were operated in High Frequency, High Speed mode in the 410 kHz setting or the 600 kHz setting. The sonars were operated at the 50-meter range scale on 80-meter main scheme lines and the 75-meter range scale on 130-meter main scheme lines, depending on depth, for each 100% coverage. Imagery was logged using the Triton Isis extended Triton format (XTF) (16 bit, 2048 pixels/channel) along with ancillary data including: towfish heading, pitch, roll, depth, ship position and computed towfish position from layback calculations. Side scan sonar data was acquired with the towfish deployed from the stern. Layback was computed in the Isis system by using the measured tow points, digital cable out and digital towfish depth. A LCI-90 Cable Payout Meter was used to provide a continuous digital cable length of deployed side scan tow cable to the Isis system. For shallow water operations, a close-to-stern setup was used aboard both survey vessels with a manually entered fixed layback distance.

A4. Position, Heading and Motion Reference Systems

Both survey vessels were outfitted with an Applanix position and orientation system for marine vessels (POS/MV) 320 v4 with Differential Global Positioning System (DGPS) and inertial reference system which was used to measure attitude, heading, heights, and position. Each system was comprised of an inertial motion unit (IMU), dual frequency (L1/L2) Global Positioning System (GPS) antennas, and a data processor.

Differential beacon receivers installed onboard the R/V *Theory* (Trimble Pro-Beacon) and R/V *Chinook* (CSI Wireless MBX-3S) acquired corrections from the U.S. Coast Guard beacon located at Annapolis, Maryland (301 kHz) and provided differential corrections to the POS M/Vs onboard each survey vessel. The POS/MV and inertial reference systems were used to measure attitude, heading, height, and position for the survey. In addition, Trimble DSM 132 DGPS receivers were used as redundant positioning systems onboard both the R/V *Theory* and R/V *Chinook* to provide secondary differential GPS positions for quality control purposes. These systems both used intergraded beacon receivers and acquired differential corrections from the same beacon used by the primary system.

Positions from all systems were displayed in real-time using Hypack and compared while online. The CSI Wireless MBX-3S status was displayed in the Configuration Display.

A weekly comparison between all positioning systems was observed and documented while the vessel was stationary in port. Logged position data was imported into Excel and a difference computed. Position Check Reports can be found in Separate I *Acquisition and Processing Logs* of the survey's *Descriptive Report*.

Position, timing, heading and motion data were output to the Hypack acquisition system using the POS/MV real-time ethernet option at 25 Hz.

The POS/MV provided time synchronization of sonar instruments and logging computers using a combination of outputs. The Reson processors and Hypack logging computers were provided both a pulse per second (PPS) and a National Marine Electronics Association (NMEA) GPS timing message (ZDA) to achieve synchronization with the POS/MV. The Isis logging computers synchronized their time using the proprietary Trimble coordinated universal time (UTC) message provided by the POS/MV. All messages contained time strings and caused the clocks of the computers and sonars to synchronize to the time contained within the message. Time offsets between the instruments and computers, relative to the times contained in POS/MV network packets, were typically sub-millisecond.

Using the ethernet logging controls, each POS/MV was configured to log all of the raw observable groups needed to post process the real-time sensor data. Each POS/MV logged 64 megabyte (MB) .000 files which resulted in multiple files created per day. The TrueHeave™ data group was also logged to these files.

A5. Sound Speed Measurement Systems

Sound speed sensors were calibrated prior to the start of acquisition. Factory calibration results are included in Separate II *Sound Speed Data* of the survey's *Descriptive Report*. All sound speed calculations from the Sea-Bird conductivity, temperature, and depth profiler used the Chen-Millero equation.

A5.a R/V *Theory*

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 in real-time during acquisition for beam forming on the 7125's flat array. A Brooke Ocean Technology Moving Vessel Profiler (MVP) 30 was mounted on the stern of the R/V *Theory* and used as the primary sound speed sensor to correct multibeam data collected onboard. The MVP towfish was lost on November 4, 2010 (DN 308). A Sea-Bird Electronics 19 SEACAT profiler was used to acquire sound speed profiles for the remainder of the project.

A5.b R/V *Chinook*

The integrated Applied Microsystems MicroSV supplied real-time surface sound speed correction for beam forming on the R2Sonic 2042's flat array. A proprietary cable and software were installed between the SVP sensor and R2Sonic 2042 processor which filtered erroneous values caused by vessel cavitations and bubble sweep down. The SV Sensor (S/N 132653) failed in the Applied Microsystems MicroSV probe (S/N 7561) and was replaced with SV Xchange sensor (S/N 200264) on September 16, 2010 (DN 259).

An Applied Microsystems, Ltd (AML) SV Plus V2 was used to acquire sound speed profiles collected onboard the R/V *Chinook* from the beginning of the project until the probe failed on July 26, 2010 (DN 207). Thereafter, a Sea-Bird Electronics 19 SEACAT profiler was used until the end of the project.

When possible the R/V *Chinook* worked in tandem with the R/V *Theory* in order to increase operational efficiency by using the sound speed profiles acquired by the R/V *Theory's* MVP-30. These instances are noted in the R/V *Chinook's* survey acquisition logs.

A6. Acquisition and Processing System

Acquisition stations were custom-installed and integrated on the R/V *Theory* and R/V *Chinook* by DEA and consisted of a Triton Isis side scan sonar data acquisition system, Hypack multibeam acquisition and navigation software, and 'Notes' workstation. In addition, an MVP station was installed aboard the R/V *Theory*. During acquisition, data were logged locally on acquisition PCs and transferred to the field office in Ridge, MD via external hard drive. Data were temporarily archived in the field office and prepared for shipment to DEA's Vancouver, WA office where processing and creation of deliverables were performed. The software and version numbers used throughout the survey are listed in Table 4.

Table 4: Acquisition and Processing Software

Description	Manufacturer	Version	Upgrade Date
Acquisition			
Hypack	Hypack, Inc.	10.0.0.21	
Isis	Triton Imaging, Inc.	7.3.548.51	
		7.3.623.51	7/20/2010 R/V Theory
		7.3.623.51	8/2/2010 R/V Chinook
LineLog	David Evans and Associates	1.0.6	
MV-POSView	Applanix Corporation	5.1.0.2	
POS MV V4 Firmware	Applanix Corporation	5.01	
Smart Talk	Applied Microsystems Ltd.	N/A	
Reson 7125	Reson	FP1	
R2Sonic Sonic 2042	R2Sonic, LLC	1.1.2	
		July 26, 2010	8/9/2010
ODIM MVP Control	Brooke Ocean Technology, Ltd.	2.27	
Seaterm	Seabird	1.59	
Seabird Data Processing	Seabird	5.37e	
Velociwin	NOAA	8.96	
Processing			
HIPS	CARIS	7.0 SP1 HF5	
		7.0 SP2 HF3	9/29/2010
Notebook	CARIS	3.1 SP1 HF1	
Bathy DataBASE	CARIS	2.3 HF5	
		3.0 HF9	12/28/2010
HYPACK	Hypack, Inc.	10.0.0.21	
ArcMap	ESRI	9.3 SP1	
POSPac MMS	Applanix Corporation	5.2.3317.24501	
Isis	Triton Imaging, Inc.	7.2.118.331	
Target Pro	Triton Imaging, Inc.	2.8.118.331	
SonarWiz	Chesapeake Technology, Inc	4.04.0054	
Photoshop	Adobe	10.0.1	
Convert to Rinex	Trimble	2.02.0	
Velociwin	NOAA	8.96	
Other			
Microsoft Office Suite	Microsoft	2007	
Beyond Compare	Beyond Compare	3.0.13	

A7. GPS Reference Station Network

Prior to the start of hydrographic survey operations, GPS base stations were established by DEA in order to log raw dual frequency observables necessary for GPS post-processing of survey vessel navigation data using either single base or SmartBase modes within Applanix POSPac MMS. With the exception of a 450-meter section along the western boundary of H12238, GPS base stations were installed no greater than 20 kilometers from the survey areas in order to keep the maximum possible range from survey vessel to base station within the published limits for post-processing using POSPac MMS in single base mode. Table 5 indicates the locations of the GPS base stations established for the project.

Table 5. GPS Base Station Positions

Station Name	Latitude (DMS North)	Longitude (DMS West)	NAD 83 Ellipsoid Height (m)
AIRD	38 07 10.22946	76 20 53.79559	-22.567
Ewell	37 59 46.25232	76 01 59.09814	-31.911

GPS Base station antennas were mounted on 5/8" bolts that were temporally fixed to stable structures in locations that provided the clearest access to the sky with limited obstructions above 10° from the horizon. All obstructions were located at each base station using an inclinometer and plotted on base station obstruction diagrams oriented to magnetic north.

A North American Datum of 1983 (NAD83) (CORS96) (Epoch 2002.0000) position of each base station was determined by acquiring and submitting a 24-hour observation with one second epoch data to the On-line Positioning User Service (OPUS) operated by the National Geodetic Survey (NGS). Due to the time delay in the availability of precise orbits (up to 19 days); base station positions were computed using rapid orbits. Once precise orbits were posted base stations positions were recomputed in order to validate the rapid orbit positions and to evaluate the need for using positions computed with precise orbits rather than with the rapid orbits. Differences between the positions were negligible with a maximum horizontal deviation of 2 millimeters and a maximum vertical difference of 8 millimeters. The positions for base stations AIRD and Ewell computed using rapid orbits (Table 5) were used during all GPS post-processing sessions.

Base stations AIRD and Ewell were added to a network of publicly available GPS reference stations to enable GPS post-processing of the POS/MV sensor data using the SmartBase option within Applanix POSPac MMS. This option creates a virtual reference station from a network of GPS base stations. GPS reference stations from the National Geodetic Survey's (NGS) Continuously Operating Reference Stations (CORS) were used during each SmartBase post-processing session. Table 6 indicates the NGS reference stations used in the network.

Table 6: Continuously Operating Reference Stations

NGS	
Station ID	**Station ID**
CORB	VAGP
DEDS	VAWI
HNPT	VIMS
MDSI	

More information on the GPS base stations, including site reports, and positions, are included in the OPR-E349-KR-10 *Horizontal and Vertical Control Report*.

A8. Survey Methodology

A8.a Mobilizations

Mobilization, sensor installation, and calibration of the R/V *Theory* and R/V *Chinook* occurred at Point Lookout Marina in Ridge Maryland from June 25, 2010 (DN 176) to July 6, 2010 (DN 187). Vessel offsets and associated measurement uncertainties for the R/V *Theory* were calculated from a vessel survey using a terrestrial land survey total station on August 5, 2008 undertaken for project OPR-N338-KR-08 Columbia River, Oregon. A similar vessel survey of the R/V *Chinook* was performed on July 20, 2009 prior to the start of OPR-E349-KR-09. No modifications have been made to the sensor configurations or mounts since the surveys were performed. Vessel offsets and uncertainties were used in the Hydrographic Information Processing System (HIPS) vessel files (HVF).

The vessel and sensor surveys involved the use of a land survey total station to position the sonar mount, all GPS antennas, the IMU, the location for draft measurements; and to create a general outline of the survey vessel. All survey points were positioned from a minimum of two locations which allowed a position uncertainty to be determined.

Once installations were completed and the hydrographer was confident that all sensors were operational, the survey vessels underwent system calibration tests, including settlement and squat and patch tests.

A8.b Survey Coverage

The Central Chesapeake Bay (OPR-E349-KR-10) was surveyed with line orientation appropriate for each of the survey boundaries. The side scan sonars were operated at 50-meter and 75-meter range scales with 80-meter and 130-meter survey line spacing, to attain each 100% side scan coverage and allow for a 10-meter offline tolerance. Multibeam echosounder data was acquired concurrently with side scan sonar operations. Additional multibeam coverage was acquired over significant features found in the side scan data record to obtain a least depth at object detection requirements.

Survey coverage was based on the survey limits depicted by the file *Chesapeake2010_SurveyArea.shp* which was created by DEA and accepted by HSD during negotiations and survey planning to better define the contract survey area. It is a modified version of *OPR-E349-KR-10_Sheets_region.shp* which was provided with the *Hydrographic Survey Project Instructions* (July 2010). Survey coverage extends to the either the modified file's polygon limit or the surveyed 18-foot depth curve. As discussed with the Chief of the Operations Branch, additional multibeam cross lines were run on the edges of the H12240, H12241, and H12242 survey areas in order to better define the 18-foot depth curve in some areas where the modified survey coverage did not fully capture the 18-foot depth curve. Files *Chesapeake2010_SurveyArea.shp* and *OPR-E349-KR-10_Sheets_region.shp* are included with the digital deliverables of each survey. A copy of correspondence related to the acquisition of additional multibeam cross lines is included in Appendix V *Supplemental Records and Correspondence* of the impacted surveys' Descriptive Reports.

A8.c Side Scan Sonar Operations

Side scan imagery was collected using the sonar's high frequency settings (410 kHz or 600 kHz) in the multi-pulse high-speed mode at a range of 75 meters for deep areas or 50 meters for shoal areas (Figure 3).

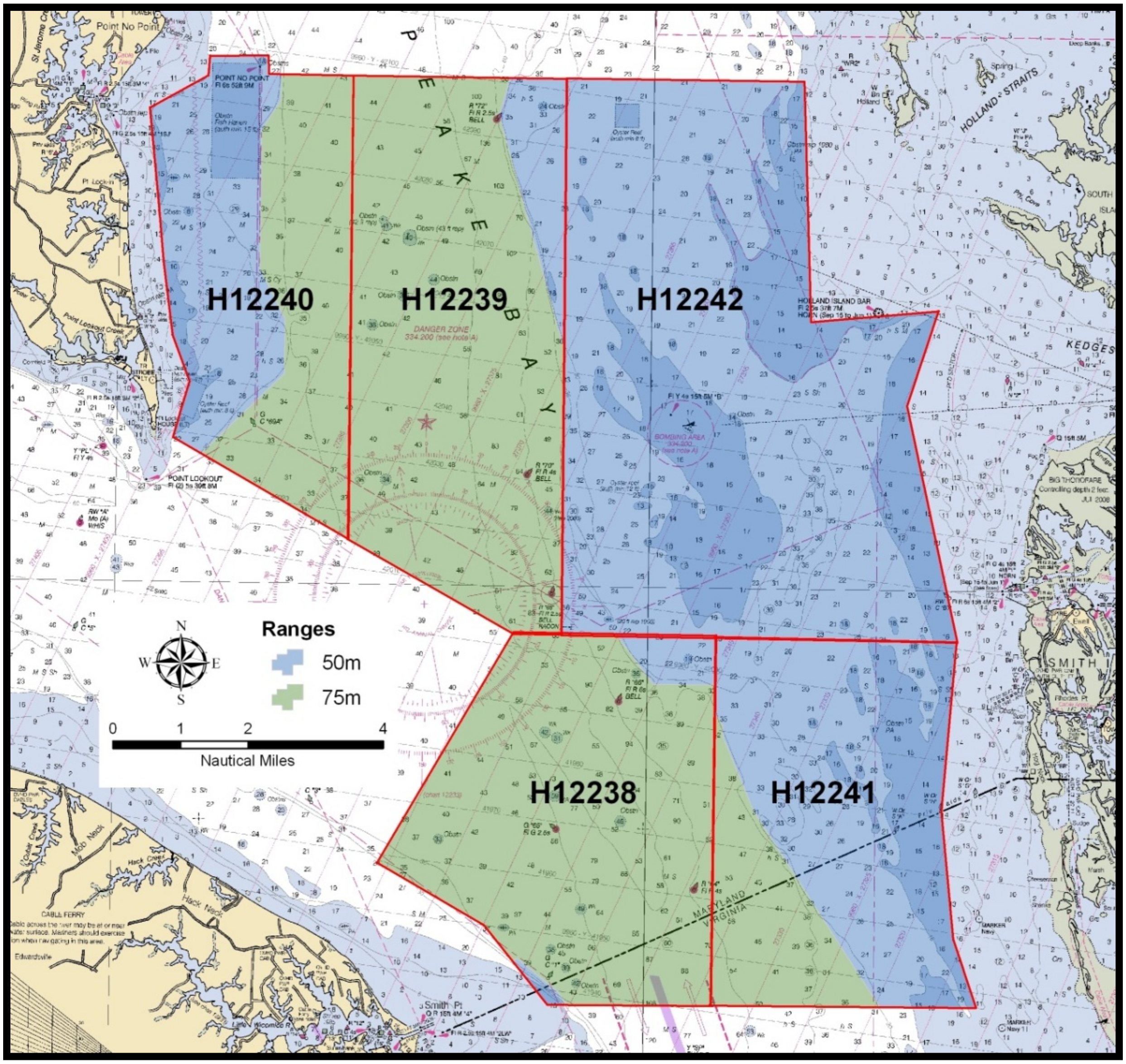

Figure 3. Side Scan Sonar Range Scale Use by Survey Area

The EdgeTech 4200 series sonar has a ping rate of 20 Hz at 75-meter range and a ping rate of 30 Hz at 50-meter range, while operating in the high speed mode which places additional pings in the water. In accordance with the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010), vessel speed was monitored to ensure three pings per meter to ensure detection of a 1m x 1m x 1m object on the seafloor. The side scan was towed from the stern of the vessels during acquisition.

The SSS 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 weather or sea conditions degraded SSS imagery, operations were suspended. All acquisition occurred during daylight hours with the vessel leaving port in the morning and returning in the evening.

Side scan sonar coverage was obtained by using Technique 2 under 6.1 of the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). This technique allows for two separate 100% 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 allowed for a minimum of three pings per meter for the range scale being used. In addition, the SSS operator monitored towfish height, ensuring a height of 8% to 20% of the range above the bottom and coverage displays to ensure 100% coverage was obtained.

A8.d Multibeam Sonar Operations

Multibeam operations occurred concurrently with SSS acquisition using the Set Line Spacing coverage technique as stated in the OPR-E349-KR-10 *Hydrographic Survey Project Instructions*, (July 2010) and defined by the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). Full multibeam coverage was not a requirement for this survey. 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.

Tables 7 and 8 list the typical sonar settings for the survey.

Table 7. Reson 7125 Sonar Settings

7125 Parameter	Value
Range	Variable, depth dependent
Gain	15-125 dB
Power	208-220 dB
Spreading	30-35 dB
Absorption	20 or 90 dB/km
Ping Rate	21-30 p/s
Pulse Width	31-60 µs

Table 8. R2Sonic 2024 Sonar Settings

2024 Parameter	Value
Range	Variable, depth dependent
Gain	9-11 dB
Power	211 dB
Spreading	60 dB
Absorption	30 dB/km
Ping Rate	Variable, range dependent
Pulse Width	20 or 30 µs

A8.e Bottom Sampling

Based on the new bottom sample specifications included in the 2010 NOS *Hydrographic Surveys Specifications and Deliverables* bottom samples were not required for project OPR-E349-KR-10. Interpretation of these new specifications was verified by the Chief of the Data Acquisition and Control Branch.

A8.f GPS Base Stations

GPS Base stations logged one second epoch GPS observables in the Trimble .T00 format with one file created every 24 hours. The Trimble Convert to RINEX utility was used to convert Trimble .T00 files to RINEX format in order to be ingested into Applanix POSPac post-processing software.

A9. Quality Assurance

Acquisition and processing methods followed systematic and standardized workflows established by DEA. These systems include but are not limited to staff training and mentoring, a formalized project management program, record and log keeping standards, software version management, and a multilevel review process.

MBES survey data were converted and processed in Caris HIPS version 7.0 with modifications to the default Combined Uncertainty and Bathymetry Estimate (CUBE) Parameters.XML and Device Models.XML files, both of which have been included with the deliverables for each survey. As part of the routine software maintenance cycle Caris HIPS was upgraded from version 7.0 Service Pack 1 Hotfix 5 to Service Pack 2 Hotfix 3 over the course of the survey. Processing methodology followed the standard Caris HIPS CUBE (Combined Uncertainty Bathymetric Estimator) workflow with integration of post-processed sensor data through the HIPS Load Attitude and Navigation Tool.

The default *CUBE Parameters.XML* was replaced with a file issued to DEA by the Pacific Hydrographic Branch (PHB) and also issued to all NOAA hydrographic field units and processing branches in Hydrographic Surveys Technical Directive 2009-2. This updated XML file uses the resolution dependent maximum propagation distance values required in the *Hydrographic Surveys Specifications and Deliverables* (April 2010).

The *Device Models.XML* was modified to include a device model for the R2Sonic 2024 sonar for multiple frequencies, including 340 kHz which was used during all survey acquisition.

Side scan contacts were reviewed during multibeam processing to ensure that contacts were fully developed and no further investigation was required (Figure 4). Additional investigations were run when necessary.

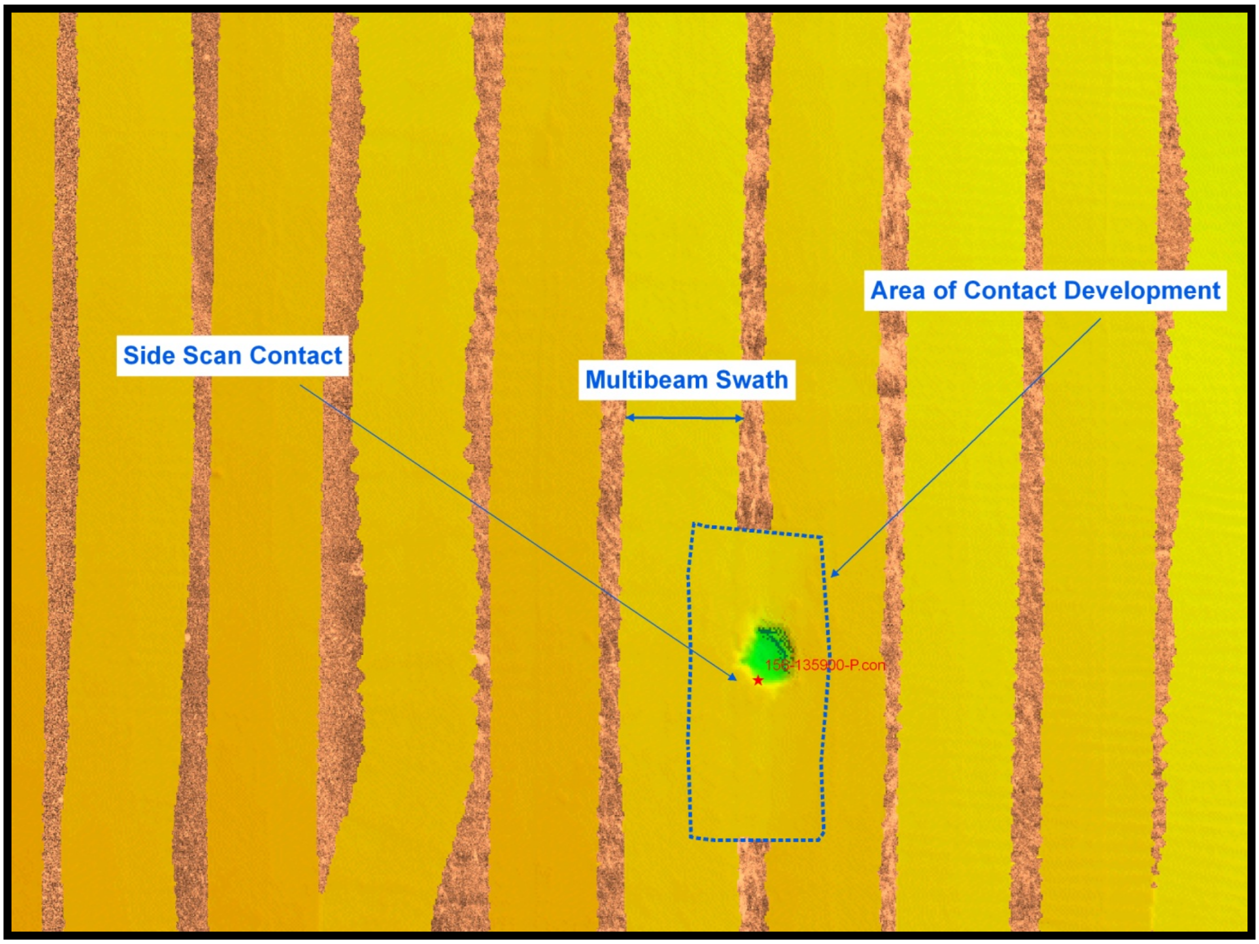

Figure 4. Graphic of side scan mosaic overlaid with contacts and multibeam swath coverage

B. QUALITY CONTROL

B1. Data Acquisition

B1.a Side Scan Sonar

Triton ISIS acquisition software was used to record side scan sonar data in XTF format. Adjustments to towfish height were made during data acquisition as necessary, and logged in ISIS to meet specifications and provide the best image quality possible. Layback values and changes were recorded in the daily acquisition log. Typical windows for monitoring raw sensor information included a waterfall display for the sonar imagery, graphs of tow fish motions, a sonar signal voltage display and I/O port monitor. Data were displayed on a 30-inch LCD flat panel monitor mounted vertically at the acquisition station. The large format display allowed for increased time to analyze contacts prior to the display scrolling from view. Contacts were selected in real-time and during post-processing. Additionally, vessel speed was adjusted in accordance with the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010) to meet the required along track coverage requirements.

To aid in the consistency of contact identification, a table was posted listing slant range and towfish altitude to determine minimum shadow heights for 1 meter contacts at 75-meter and 50-meter ranges. Contacts were classified as significant if their estimated height was 1 meter or more. Maintaining towfish altitude at 8% to 20% of the range (6 meters to 15 meters 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 10-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 and during deployment of the towfish.

B1.b Multibeam

Multibeam data were acquired in Hypack HSX format. Adjustments to the sonar, including changes in range and gain were made, as necessary, to acquire the best bathymetric data quality. Additionally, vessel speed was adjusted in accordance with the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010) to meet the required along track coverage. Typical windows for monitoring raw sensor information included timing synchronization, surface sound velocity, vessel motion, GPS quality, and satellite coverage. Raw attitude and nadir depth is also recorded in HYPACK Hysweep (RAW) format, as a supplementary backup.

The HYPACK acquisition station operator monitored the multibeam sonar, monitored the surface sound velocity to determine the frequency of sound velocity casts and maintained the digital line log. Operators monitored primary and secondary navigation systems to verify quality position data were acquired at all times.

B2. Methodology Used to Maintain Data Integrity

The acquisition systems 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. Position confidence checks and multibeam bar checks were conducted weekly to confirm required accuracy was being maintained. Weekly comparison checks were performed by lashing the R/V *Chinook's* SBE 19 or AML to the R/V *Theory's* MVP and simultaneously lowering them to the bottom. Sound speed profiles were computed for each of the sensors and compared to confirm instrumentation was functioning within survey tolerances.

Contacts were tracked while online using the ISIS cursor log as well as noted in the digital line log. All significant contacts were compiled into a sheet wide Drawing Exchange Format (DXF) file displayed onscreen during survey as well as during multibeam data processing.

A flow diagram of the data acquisition and processing pipeline is presented in Figure 5 on the following page. This diagram graphically illustrates the data pipeline and processing workflow from acquisition to delivery.

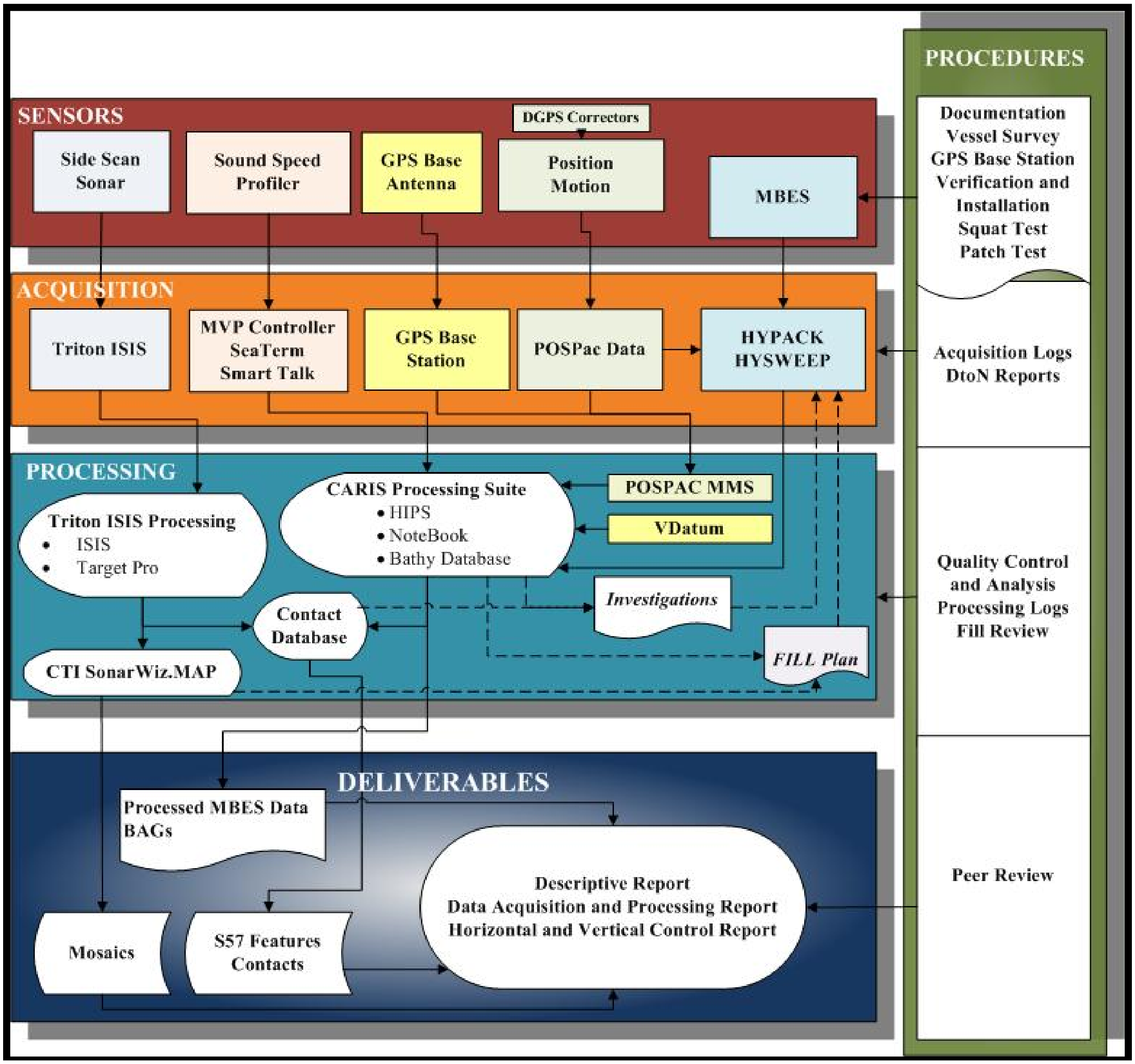

Figure 5. Flowchart of data acquisition and processing pipeline

B2.a HIPS Conversion

Multibeam data were converted from HSX format to Caris HDCS format using the Hypack conversion wizard. Ground coordinates (UTM NAD 83 18N) were selected in the Conversion Wizard dialogue and the device numbers fields were left blank since there were no duplicate sensors logged in the HSX files. No data were rejected based on quality flags during conversion.

The Caris output window was reviewed for failures during conversion.

B2.b Vessel Files

Two (2) HIPS vessel files (Table 9) were created to correspond to each survey vessel configuration used during the survey. The vessel file contains all offsets and system biases for the survey vessels and its systems, as well as error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements.

In addition vessel files were created to facilitate the review of side scan sonar data by the processing branch. The side scan sonar vessel files were not used during data processing. Instructions for conversion of side scan data into Caris HIPS using these vessel files are included in Appendix I *CARIS SIPS Side Scan Processing Guidance* of this document.

Table 9. HIPS Vessel Files

HIPS Vessel File	HIPS Converter	Sonar Type	Comment
OPRE349-KR-10_MBES_TH	Hypack 7.0.1.0 Hypack 7.0.2.1	Multibeam	MBES hvf
OPRE349-KR-10_MBES_CH	Hypack 7.0.1.0 Hypack 7.0.2.1	Multibeam	MBES hvf
OPRE349-KR-10_SSS_TH	N/A	Side scan	SSS hvf
OPRE349-KR-10_SSS_CH	N/A	Side scan	SSS hvf

Sensor offsets values were calculated from the vessel surveys which were conducted prior to the start of field operations. Draft (water line) was measured and entered daily from draft marks on the port and starboard side of each vessel's hull. Morning and evening, port and starboard draft readings were averaged to obtain the vessel draft. Draft changes relative to the vessel reference point were entered into the multibeam vessel configuration files. Dynamic draft (settlement and squat) values were calculated through the use of post-processed GPS observations. These offsets are listed in tabular format in Section C of this document. Both dynamic draft and waterline values were used to properly position the multibeam in the water column for the sound velocity correction. GPS Tides were computed using the "apply dynamic draft" and "apply waterline offset" options, which subtract the waterline height and dynamic draft values from the final signal. Therefore, the dynamic draft and waterline values are not used as correctors in the sounding reduction, other than their role in the sound velocity correction.

Best estimates for total propagated error (TPE) values were entered into the vessel file based on current knowledge of the TPE/CUBE processing model. The manufactures' published values were entered into the static sensor accuracy fields. Other values were either calculated or estimated. Real-time error values created during the POSPac post-processing sessions were loaded for position, heading, height, and attitude and used during TPE computation. Navigation and transducer separation distances from the motion sensor were computed relative to the phase center, vice the top hat, of the motion sensor therefore the vessel file standard deviation offsets will not exactly match the sensor offset values. No error values were entered for draft and loading since the use of GPS referenced tides includes those error sources in the vertical uncertainty.

Table 10 represents HVF TPE values for each vessel.

Table 10. Hydrographic Vessel File TPE Values

Manufacturer Accuracy Values for Total Propagation Error Computation		
HIPS Vessel File (HVF)*		
Vessel	***R/V Theory***	***R/V Chinook***
Motion Sensor	POS/MV	POS/MV
Position System 1	POS/MV Model 320 V 4	POS/MV Model 320 V 4
Position System 2	DSM132	DSM132
Gyro - Heading		
Gyro (°)	0.02	0.02
Heave		
Heave % Amplitude	5	5
Heave (m)	0.05	0.05
Roll and Pitch		
Roll (°)	0.02	0.02
Pitch (°)	0.02	0.02
Navigation		
Position Navigation (m)	1.0	1.0
Latency		
Timing Trans (s)	0.005	0.005
Nav Timing (s)	0.005	0.005
Gyro Timing (s)	0.005	0.005
Heave Timing (s)	0.005	0.005
Pitch Timing (s)	0.005	0.005
Roll Timing (s)	0.005	0.005
Measurement		
Offset X (m)	0.005	0.009
Offset Y (m)	0.005	0.005
Offset Z (m)	0.005	0.008
Speed		
Vessel Speed (m/s)	0.030	0.030
Draft and Loading		
Loading	0.000	0.000
Draft (m)	0.000	0.000
Delta Draft (m)	0.000	0.000
Physical Alignment Errors*		
Alignment		
MRU align Stdev gyro	0.104	0.118
MRU align roll/pitch	0.117	0.053
*All values given as 1 sigma.		

The estimated uncertainty of the ellipsoid to MLLW separation model was computed from values published on NOAA's VDatum website[1]. This estimate is the cumulative uncertainty of the source data and transformation uncertainties required to convert an ellipsoid height to MLLW in VDatum. The model uncertainty was introduced into the HIPS TPU computation by entering the 1 sigma uncertainty into the Tide Zoning field since HIPS does not currently allow for the application of a separation model uncertainty. Table 11 lists the published source and transformation uncertainties used to compute the separation model uncertainty.

Table 11. Estimated VDatum Model Uncertainty

Virginia/Maryland - Chesapeake Bay	
Transformation Uncertainty	**1-Sigma (cm)**
ITRF to NAD83	Does Not Apply
NAD83 to NAVD88	5.0
NAVD88 to LMSL	5.6
LMSL to MLLW	3.1
Total Transformation Uncertainty	*8.12*
Source Uncertainty	
NAD83	2.0
NAVD88	5.0
LMSL	1.6
MLLW	1.6
Total Source Uncertainty	*5.84*
MODEL Uncertainty	**10.00**

Sound speed and tide TPE values are listed in Table 12.

Table 12. TPE Values for Tide and Sound Speed

Total Propagation Error Computation in CARIS HIPS	
Tide Values	**Uncertainty**
Tide Value Measured	0.000
Tide Value Zoning	0.100
Sound Speed Values	
Sound Speed Measured	1.000
Surface Sound Speed	0.500

*All values given as 1 sigma.

[1] http://vdatum.noaa.gov/docs/est_uncertainties.html

B2.c Static Draft

Static draft marks were surveyed and painted on the port and starboard sides of the R/V *Theory* and R/V *Chinook* as well as on the multibeam pole mounts. Port and starboard draft readings were averaged to obtain the draft in relation to the reference point at the center of the vessel.

During survey operations, vessel 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 return from the survey area. The start and end of day draft values for port and starboard were calculated daily, averaged, and entered into the ”Waterline Height” field in the HVF.

B2.d Sound Velocity

Sound speed profiles were applied to each line using the nearest in distance within time (one hour) option in the Caris SVP correct routine. Velocity casts were taken at frequent intervals through the use of the MVP-30 or manually with the AML SVP Plus or SBE 19Plus. 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 and recorded in the acquisition log.

B3. Multibeam 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 were rejected and critical soundings not incorporated in the CUBE surface were designated. Baring point features, such as beacons or piles associated with pound nets were rejected and flagged “Examined” at the shoalest and seaward-most point. The use of the “Examined” status flag enabled DEA hydrographers to denote baring items during processing and then resolve their charting status during review.

Below is the list of correctors and filters applied to the bathymetric data in HIPS. Several of the steps are interim processes (such as the water levels) and were re-applied as needed. The TPE was re-computed for the multibeam data as needed to reflect changes in the correctors.

1. Apply true heave
2. Load post-processed attitude, height, navigation, and heading
3. Load post-processed error for altitude, navigation, height and heading
4. Compute GPS Tide using VDatum-derived separation model
5. Apply sheet wide concatenated sound speed profiles
    - “Nearest in distance within time 1 hour”
6. Merge, apply GPS Tides
7. Compute TPE via values listed in Table 12
8. Filters applied based on the following criteria:
    - Reject soundings with poor quality flags (0 for Reson)
    - Reject by swath width 45/45

9. Data reviewed and fliers removed in Swath Editor and/or Subset Editor
10. Add data to field sheet:
    - CUBE" weighted surface of appropriate resolution for water depth
        - International Hydrographic Organization (IHO) S-44 Order 1
        - Density & Local Disambiguation method
        - Advanced configuration using the 2009 NOAA field unit parameters of the appropriate resolution surface
11. Review data in subset using tiles with reference surface on

Navigation, attitude, height, heading, and their corresponding error estimates were applied during post-processing in HIPS. Data were post-processed using POSPac MMS software. The POSPac SmartBase routine was used to generate a virtual base station from a network of continuously operating GPS stations. In generating the virtual base station, the published NAD83 (CORS96) Epoch 2002.0 coordinates were used for the control station. The virtual base station was used to generate a tightly coupled post-processed Inertial-Aided Kinematic Ambiguity Resolution (IAKAR) navigation and attitude solution. The resulting Smooth Best Estimate and Trajectory (SBET) and POSPac smrmsg dynamic error files were applied in HIPS with the Load Attitude/Navigation data and Load Error data tools.

One field sheet was created to correspond to each survey sheet. CUBE surfaces were created over the entire survey area using grid-resolution thresholds and resolution dependent maximum propagation distances for complete coverage surveys as specified in the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). CUBE surfaces using object detection resolution were created over each multibeam investigation of a significant side scan sonar contact. Survey coverage was reviewed to ensure that there were no holidays spanning the entire survey swath greater than 3 nodes or that there were no data gaps present over significant contacts. The HIPS density layer of each grid was reviewed to ensure that the minimum sounding density of five soundings per node was achieved for 95% of nodes populated by mainscheme survey lines and that all multibeam investigations over significant features had either a designated sounding from a nadir beam or the node overlying the least depth had a density of at least five soundings.

All data were reviewed in HIPS 2D subset with the CUBE reference surface visible. Soundings rejected by quality filters were displayed during editing, and any feature removed by a filter was manually reaccepted. 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 designated sounding. Subset tiles were used to track the progress of processing activities. In addition, data processors reviewed sounding data and CUBE surfaces for excessive motion artifacts or systematic biases. All crosslines were manually reviewed to ensure high internal consistency between the datasets and comparison statistics were also computed using the HIPS crossline QC tool.

Contacts derived from the daily cursor logs and target files were displayed in the background in HIPS as a DXF file and reviewed for multibeam coverage and significance. Designated soundings were created to denote the least depth of each significant feature.

B4. GPS Post-processing

POSPac processing followed the workflow recommended by Applanix. The only deviation from standard procedures was the use of the NAD83 coordinate system which is required by NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). Since POSPac only works with real-time sensor navigation using the WGS-84 coordinate system, the software's default settings for WGS-84 real-time input and post-processed output were used. NAD83 coordinates of the GPS reference stations were used during post-processing even though the software assumed the coordinates were relative to WGS-84. This processing configuration resulted in a post-processed navigation solution (SBET file) relative to NAD83 without the need of a transformation. Prior to the start of processing the NAD83 (CORS96) (2002) coordinates of all base stations were imported into the POSPac coordinate manager on each processing computer.

Applanix POSPac MMS software was used to post-process the vessel navigation data. The majority of the processing used the Applanix SmartBase technique to generate a virtual reference station from a network of continuously operation reference stations (CORS) to create a post-processed Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) navigation solution. During POSPAC processing, the NAD83 coordinates from the coordinate manager file were assigned to all base stations used in the network. As a quality assurance measure the SmartBase Quality Check was run during each processing session. This process performs a minimally constrained adjustment of the entire network from the designated control station. The results were used to ensure the correct coordinates had been assigned to all base stations, and no abnormal base station performance was included in the network. All adjusted positions were reviewed to ensure they fell within 10 centimeters of the set coordinate. Any base station not meeting this requirement was then disabled. Once the overall stability of the network was verified, the adjusted positions were discarded and the original NAD83 coordinates from the CSV file were used for all further processing.

A primary station was selected based on its proximity to the survey area and its overall data quality. A SmartBase virtual reference station was generated by translating the observations from the primary station to the survey area using the SmartBase network. Prior to generating a post-processed navigation solution, all lever arms and offsets were manually reviewed and validated. With the relatively short lever arms on the survey vessels and high accuracy of the vessel surveys, lever arm uncertainty was set at 3 centimeters. Once the virtual reference station was generated and all lever arms and settings were reviewed, the POSPAC GNSS processor was used to post-process a tightly coupled PPK navigation and attitude solution.

The GPS receiver at the DEA installed base station, Ewell, was incorrectly configured to log only the L2C signal rather than the full L2 signal from the start of acquisition until August 12, 2010 (DN 224). During these days it was not possible to use Ewell as the primary control station so the next closest station, typically MDSI, was used.

At times the SmartBase height solution was found to be unstable. These instances were identified by abnormal height RMS as reported by POSPac, or by swath to swath offsets after applying GPS tide in HIPS. In these situations, reprocessing the entire day in SingleBase mode significantly improved the height solution. Single base processing was limited to survey H12240 which used AIRD as the primary station and H12241 which used Ewell.

This post-processed solution included new position, height, heading and attitude measurements which used reference station observables to mitigate atmospheric and satellite biases and to resolve integer ambiguities. The software also used a forward and backward smoother to blend the inertial position and sensor data into a smoothed best estimate trajectory (SBET).

After the post-processed solution was created it was reviewed to insure that the optimum solution was achieved. Processing review included graphical review of the vessel track while color coded by position Root Mean Square (RMS) and the creation of a NAV-DIFF graph which showed the difference between the real-time and post-processed solutions in the X, Y, and Z coordinates.
POSPac processing logs were kept for each survey sheet. The logs were used to record POSPac project information, vessel and base station used, and major processing steps. These logs have been included in Separate I *Acquisition and Processing Logs* of the *Descriptive Report*.

B5. Final Bathymetric Processing

Upon the completion of editing multibeam data in HIPS, finalized CUBE grids were generated using the “greater of the two” option for the final uncertainty value. Depths and contours were generated from the surfaces and used for chart comparison purposes, but are not included with the deliverables. Finalized surfaces were reviewed in the HIPS 3D graphics window with an extreme vertical exaggeration to verify that all fliers have been removed from the surfaces. Bathymetric Attributed Grids (BAGs) for each CUBE surface were exported from HIPS for submittal.

Designated soundings were used as a starting point for S-57 feature creation. Designated soundings that were determined to be obstructions, rocks wrecks, or other significant features were imported into the S-57 feature files and attributed. S-57 objects were created for all new and incorrectly charted baring features. Many items included in the S-57 feature file have already been submitted as Dangers to Navigation (DtoNs). In some cases an obstruction that is depicted in an S-57 feature file was not reported as a DtoN because it was found to be deeper than currently charted soundings.

All mandatory attributes of features have been populated. In addition, the INFORM and TXTDSC fields of some features have been used to supply supplemental information. The feature file also includes required meta-objects (M_COVR and M_QUAL).

B6. Side Scan Processing

After acquisition, the side scan bottom track was reviewed in Chesapeake Technologies SonarWiz and loss of bottom or incorrect bottom track areas were re-digitized. The newly bottom tracked files were exported to XTF and two independent reviews were performed in Triton Isis to identify significant contacts. Contacts in depths less than or equal to 20 meters were classified as significant if their estimated height was at least one meter. In depths greater that 20 meters, contacts with heights greater than 10% of the depth were classified as significant.

In most cases side scan contacts were determined to be significant if the measured height was within 25 centimeters of the significant height requirement to allow for contact measurement error. Also contacts with minimal shadow heights were classified as significant if there were areas deemed to be critical to navigation or if they appeared to be mounds or other geologic structures which cast little or no shadow. Towfish altitude was reviewed to verify the height was maintained between 8% and 20% of the range.

Sonar contacts were processed using Triton Isis Target Pro software. Management of the high volume of side scan sonar contacts was accomplished by utilizing an in-house created utility for contact tracking that would meet the requirements of the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2010). The database was maintained and stored in Microsoft Access using the .MDB file format. Contacts were added into the database on a daily basis upon completion of the side scan review and contact identification. The use of the .MDB format allowed direct geographic display of contacts and spatial queries within ESRI ArcGIS where contacts were correlated and compared to the chart and other survey data.

Side scan mosaics were created using Chesapeake Technologies SonarWiz. Bottom track and layback from the previously processed XTF files were applied during generation of mosaics. Some signal processing was performed during the mosaic creation in order to improve the overall appearance of the final images. An empirical gain normalization table was generated for each sonar from a subset of lines from each survey and then applied to all the appropriate survey lines. User defined gains were applied on a line by line basis in some cases. Minor adjustments were then made to the final empirical gain normalization intensity of individual survey lines to enhance the mosaic. Georeferenced mosaics were generated in Tagged Image File Format (TIF) with an associated world file (TWF) at 50-centimeter resolution for each 100% survey coverage.

C. CORRECTIONS TO ECHO SOUNDINGS

C1. Static Draft

With the vessels out of the water, markings were surveyed and painted on the port and starboard sides of the hull providing a means to monitor vessel draft. 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 draft marks were directly abeam of the vessel reference point in the center of the vessel and the multibeam head pole mounted on the side of the vessel.

The vessel's fuel and ballast levels were maintained to minimize extreme changes in 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. Ultimately, the daily draft values were used to calculate daily draft relative the HIPS reference point which was entered into the waterline field in the Caris HVF files.

C2. Dynamic Draft

Settlement and squat tests for the R/V *Theory* and R/V *Chinook* were conducted after the vessels were mobilized using post processed GPS height observations. Dynamic draft correctors were added to the Caris HVFs and applied during the HIPS merge operation. Figure 6 graphically represents settlement and squat results for both vessels.

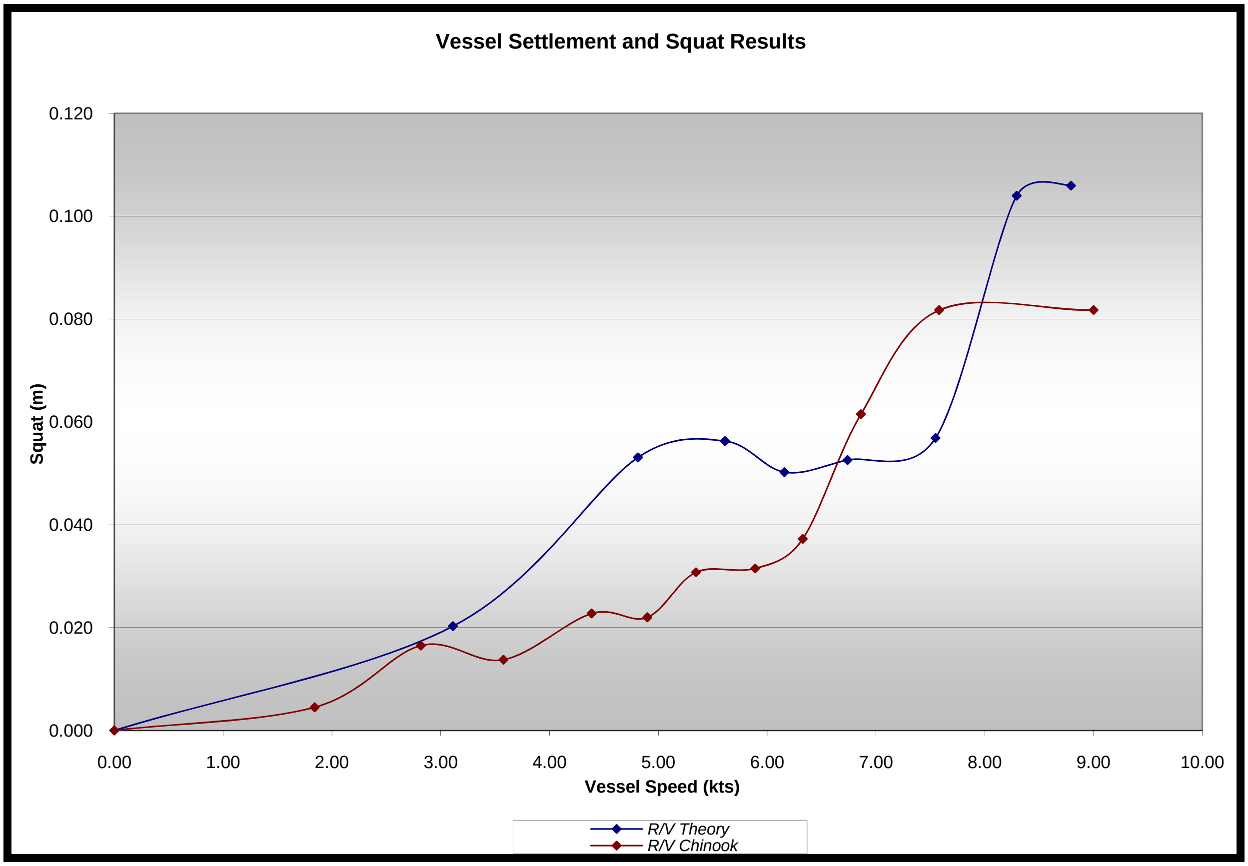

Figure 6. Vessel settlement and squat results

Dynamic draft values for both survey vessels are presented in Table 13.

Table 13. Dynamic Draft Values

R/V *Chinook*		R/V *Theory*	
Speed (kts)	**Squat (m)**	**Speed (kts)**	**Squat (m)**
0.00	0.000	0.00	0.000
1.85	0.005	3.11	0.020
2.82	0.017	4.81	0.053
3.58	0.014	5.61	0.056
4.39	0.023	6.16	0.050
4.90	0.022	6.74	0.053
5.35	0.031	7.55	0.057
5.89	0.031	8.29	0.104
6.32	0.037	8.79	0.106
6.86	0.061		
7.58	0.082		
9.00	0.082		

Results from settlement and squat tests using post-processed GPS height observations performed for OPR-E349-KR09 were used for this project. The settlement and squat test for the R/V *Theory* occurred on June 20, 2009 (DN170) and for the R/V *Chinook* on August 6, 2009 (DN218) and August 22, 2009 (DN234). No modifications, which would impact the settlement and squat curves of these survey vessels, were made since the tests were performed. Data from these measurements are displayed graphically in Figure 6, in tabular format in Table 13 and are included in Appendix V *Supplemental Survey Records and Correspondence* of the *Descriptive Reports*.

The settlement and squat values were obtained by computing a three minute GPS height average for transects run at different ship speeds and measured in both knots and revolutions per minute (RPM). Transects were run twice at each RPM interval; once at a northerly heading and once at a southerly heading.

Vessel speeds in increments of 200 RPMs were observed from just above each survey vessel's idle RPM to just beyond the survey vessel's maximum survey speed. GPS heights were recorded at 25 Hz. With the vessel at rest static GPS 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. Three minute running averages of GPS height were calculated to remove any heave bias from the calculations. Each transect was run for approximately three minutes. 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 were used to calculate the dynamic draft for each transect. An average dynamic draft corrector was then calculated from the average of the two values for each RPM interval.

The settlement and squat profile of the R/V *Chinook* was modified to remove values at speeds where the vessel was on plane. Due to differences between speed over ground (used by HIPS) and speed over water it may be possible to achieve a higher speed over ground when running with currents which would use settlement and squat correctors achievable only when the vessel was on plane. No survey data was acquired while the survey vessels were on plane. When vessel speeds exceed the maximum value in the HVF HIPS still uses the dynamic draft corrector for the maximum speed.

C3. Bar Check Comparisons

Weekly bar checks were performed to ensure that sonars were functioning properly and static drafts were accurately documented. Two (2) bar check plates were constructed using a 20-inch diameter, 0.25-inch thick steel discs. Checks enabled depths to be read to within 5 millimeters.

Each bar check device was lowered to a point above the natural bottom where it could be clearly ensonified. The depths of the devices reported on the tape were compared to the depth of the disc or bar reported by the sonar. Observations were recorded in a comparison log. Table 14 below details the average difference, standard deviation, and maximum deviations for each vessel. Maximum deviations were attributed to strong currents inhibiting the 20-inch steel disc from sitting completely flat due to increased surface area.

Table 14. Vessel Bar Check Summary

	R/V *Chinook*	R/V *Theory*
Average Difference	-0.006	-0.001
Standard Deviation	0.007	0.007
Maximum Deviation	-0.020	-0.013

Tabulated bar check comparisons may be found in the Weekly Bar Check logs included in Separate 1 *Acquisition and Processing Logs* of the *Descriptive Report*.

C4. Heave, Roll and Pitch Corrections

An Applanix POS/MV 320 version 5.01 integrated dual frequency GPS 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% for heave, 0.01° 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° RMS, 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/tpu/) were entered into the HVF and used for TPU computations.

As previously discussed, attitude and heading were reapplied after post-processing navigation and inertial sensor data in POSPac. SBET files were applied in HIPS with the Load Attitude/Navigation data tool.

Installation bias and patch test results were computed at the start of the survey. Additionally, patch tests were performed throughout the survey to monitor known values and account for changes due to sensor replacements. All values were stored in the Caris HVF files.

Schematics of the vessel and sensor set-up for the R/V *Theory* and the R/V *Chinook* are shown in Figures 7 and 8 on the following pages.

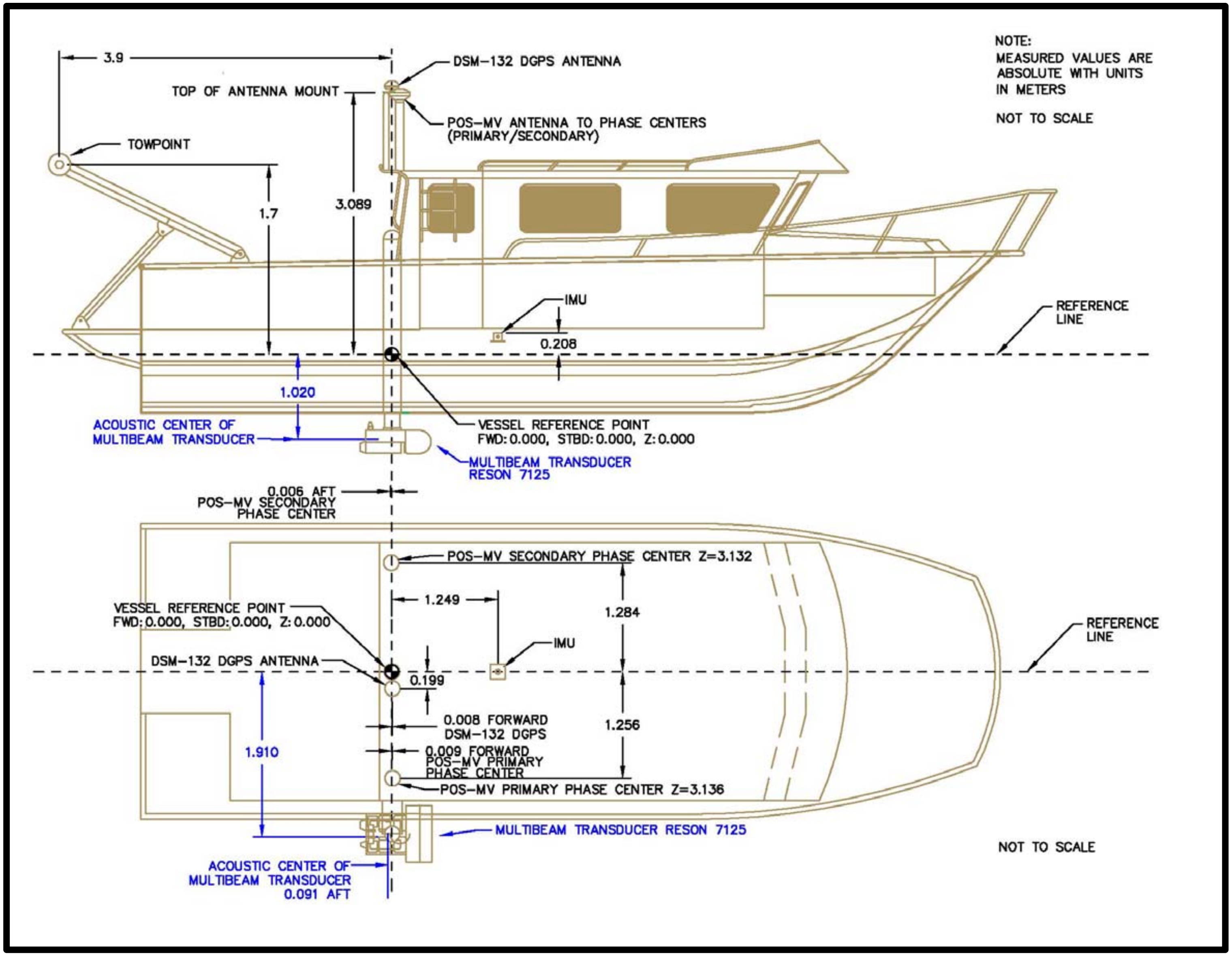

Figure 7. Schematic of R/V *Theory* and Sensor Setup

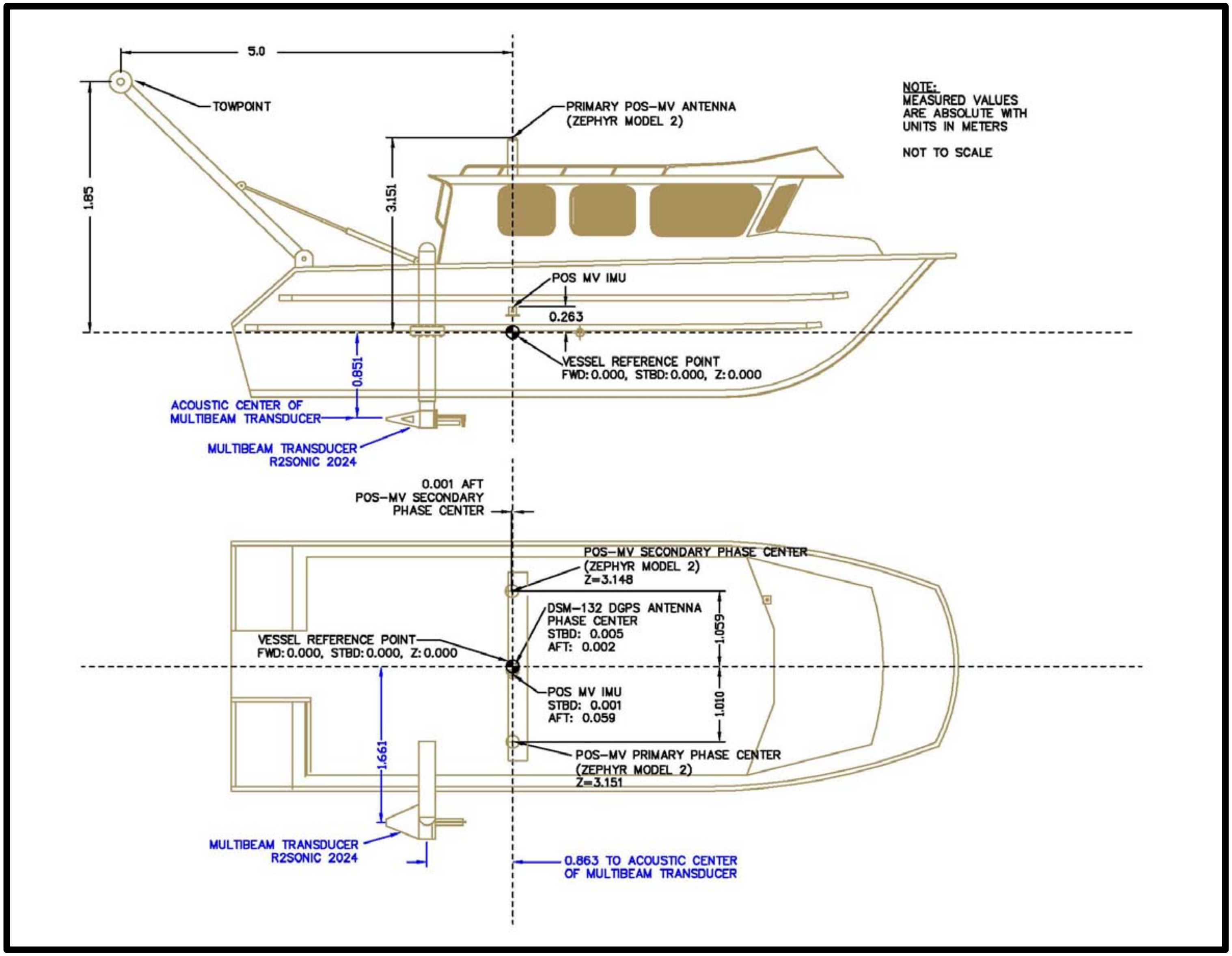

Figure 8. Schematic of R/V *Chinook* and Sensor Setup

C5. Patch Tests

Multibeam patch tests were conducted for the R/V *Theory* and R/V *Chinook* to measure alignment offsets between the IMU sensor and the multibeam transducer and to determine time delays between the time-tagged sensor data. Multiple patch tests were performed throughout the project to verify the adequacy of the system biases. Patch tests were performed at the beginning of the project, at the end of each month, after any system replacement, and at the end of the project. Each 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.

A precise timing latency test was performed by running a single line over a flat bottom with induced vessel motion. The line was 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 for motion artifacts. 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.

Roll alignment was determined by evaluating the reciprocal lines run over a flat bottom used for the latency test. The pitch tests consisted of set of reciprocal lines located on a steep slope. The yaw error was determined by running parallel lines over the same area. All lines were run at approximately 3 to 6 knots. Patch tests were run in the local survey area.

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 (2) 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.

The final yaw patch test values for the R/V *Theory* varied significantly from prior tests and also produced the greatest standard deviation between the three sets of test lines. The variation of the yaw alignment biases may actually be the result of a slight vertical and horizontal misalignment of the test lines due to poor GPS constellation geometry. These values were therefore not considered in the HVF. Offsets and biases for both vessels were entered into the HVF and also documented in Table 15.

Table 15. Vessel Offsets and Biases

R/V *Theory*							
DN	Latency	Pitch	Yaw	Roll	X (m)	Y (m)	Z (m)
183	0.000	-3.300	-0.000	-0.470	1.910	-0.091	1.020

R/V *Chinook*							
DN	Latency	Pitch	Yaw	Roll	X (m)	Y (m)	Z (m)
186	0.000	0.480	-0.300	1.057	1.661	-0.863	0.851

C6. Tide and Water Level Corrections

The application of SBET navigation positioned soundings vertically on the NAD83 (CORS96) ellipsoid. VDatum version 2.3 and the region file Maryland – Virginia – Chesapeake Bay (version 01) was used to reduce soundings from NAD83 to MLLW in CARIS using the model file *Potomac.bin,* which has been included with the survey's digital deliverables. To generate the model file, a three-second grid was created which encompassed the entire survey area. The elevation value of the grid was populated with the NAD83 elevation of MLLW using GEOID09 at each point from the VDatum model. The grid model was then converted to the same binary format as geoid grid models generated by NGS, which can be used by Hypack (using a GenGeo.exe utility provided by Hypack) and Caris HIPS to convert ellipsoid heights directly to a mapping datum. In order to provide a check to the grid values, at a select point the MLLW to NAD83 separation was independently computed by using VDatum to transfer from MLLW to NAVD88, and then Corpscon to transfer from NAVD88 orthometric elevations to NAD83 ellipsoid heights. The resulting elevations compared to the original grid points within 0.0003m. The model file, *Potomac.bin,* has been included with the survey's digital deliverables. When the model file was used in the tide reduction process in CARIS HIPS for surveys H12238, H12239, and H12240 it was inadvertently misspelled. A query of the GPS Tide Datum in HIPS will show the file *Potamic.bin*.

As a confidence check on the GPS tide computation, GPS tide readings were recorded for one hour while the survey vessel floated adjacent to tide station Lewisetta, Virginia (863-5750). GPS measurements were processed using techniques identical to processing for all collected survey data and then compared to verified tide data. The resulting GPS-derived water level at Lewisetta had a mean difference of -0.047 meters with a standard deviation of 0.012 meters with the water level recorded by the gauge being greater than the water level recorded by GPS.

C7. Sound Velocity Correction

While underway during data acquisition the MVP-30 on the R/V *Theory* was deployed as needed to obtain an adequate number of sound velocity profiles to properly correct the survey 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 20 minutes. At least one deep cast (extending to 95% of depth) was taken per day.

A sound speed cast using either the Applied Microsystems, Ltd. SV Plus V2 sound velocity sensor or SBE 19 V2 SEACAT Profiler was taken at approximately one hour intervals during R/V *Chinook* survey operations. Sound velocity profiles obtained from the MVP-30 were applied to multibeam data collected by the R/V *Chinook* when the vessel was operating in close proximity to the R/V *Theory.* Due to a failure of the MVP-30 onboard the *R/V Theory*, the survey vessels worked in close proximity to one another on July 13, 2010 and July 14, 2010 (DN 194-195) order to share sound velocity profiles obtained from the R/V *Chinook.*

After each cast the sound speed data was reviewed for outliers which could impact data quality. The sound speed measured by the MVP at 1 meter depth was also compared to the Reson 7125 head velocity for agreement to ensure that both systems were working properly. In addition to these periodic comparisons, weekly comparison checks were performed by lashing the SBE 19 or AML to the R/V *Theory's* MVP and simultaneously lowering them to the bottom. Both of these comparison sensors were used by the R/V *Chinook*. These weekly checks were completed to verify pressure sensor and SV instrument performance. Corrections for the speed of sound through the water column were computed for each sensor. Sound speed profiles were imported and overlaid for comparison into an Excel file. All comparisons were well within survey specification. Factory calibration results are included in Separate II *Sound Speed Data* of the *Descriptive Report*.

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

D. APPROVAL SHEET

The letter of approval for this report follows on the next page.

DAVID EVANS AND ASSOCIATES INC.

LETTER OF APPROVAL

OPR-E349-KR-10
DATA ACQUISITION AND PROCESSING REPORT

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of OPR-E349-KR-10 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 OPR-E349-KR-10 *Statement of Work* (April 2010) and *Hydrographic Survey Project Instructions* (July 2010).

Digitally signed by Jon Dasler
DN: cn=Jon Dasler, email=jld@deainc.com, o=David Evans and Associates, Inc., c=US
Date: 2011.01.17 09:15:06 -08'00'

Jonathan L. Dasler, PE (OR), PLS (OR,CA)
ACSM/THSOA Certified Hydrographer
Chief of Party

Digitally signed by Jason Creech
DN: cn=Jason Creech, email=jasc@deainc.com, o=David Evans and Associates, Inc., c=US
Date: 2011.01.17 09:15:38 -08'00'

Jason Creech
Lead Hydrographer

David Evans and Associates, Inc.
November 2010

APPENDIX I
CARIS SIPS SIDE SCAN PROCESSING GUIDE

CARIS SIPS Side Scan Processing Guidance

As described in Section B6 of this document, side scan sonar contacts were selected in Triton ISIS and mosaics of the survey area were created using Chesapeake SonarWiz. XTF data were bottom tracked and towfish layback was applied in SonarWiz. These “Processed” XTFs, were used for the conversion procedures listed below.

The following diagram outlines a basic processing sequence to facilitate the review of the side scan sonar data in CARIS HIPS and SIPS. Though generic, mosaics created though this process will be sufficient to verify coverage requirements.

Conversion

- Convert XTF
- Ground
  - UTM
    - NAD83 Zone18N
- Ship Navigation
  - Raw
- Attitude
  - Raw datagram
- Convert Side Scan
  - Sonar Channels
    - 1,2
  - Navigation data field
    - Ship
- Convert layback
  - from Layback field

Recompute Towfish Navigation

- No sensor smoothing

Slant Range Correction

- Resolution
  - 0.10m
- Sound Speed
  - 1500 m/s
- Keep 16 Bit Data

Mosaic Editor-Create GeoBaR

- Resolution
  - 0.500 m
- Color Map
  - SSS_Mosaics
- Correct Side Scan Data

Mosaic Editor-Advance

- Side
  - Both
- Intensity Range
  - -40.0 to -5.00 db
- Interpolate
- Extrapolate
  - 10 s
- Gyro from
  - Course Made Good

Field Sheet

- UTM- NAD83
  - UTM 18N-NAD83

Create Mosaic

- Resolution
  - 0.5000 m
- Method
  - Underlay
- Color Map
  - SSS_Mosaics