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-09**
Contract No	**DG133C08CQ0006**
Task Order No	**T0001 and T0002**
Time Frame	**June 2009 - December 2009**

LOCALITY

State	**Virginia**
General Locality	**Southern Chesapeake Bay**

2009

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	REGISTRY No
HYDROGRAPHIC TITLE SHEET	H12040 H12041 H12042 H12043 H12044 H12045
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: **Virginia**

General Locality: **Southern Chesapeake Bay, VA**

Sub-Locality: **South of Smith Point to 3nm South of Tangier Island**

Scale: **1:10,000**

Date of Survey: **June 21, 2009 to December 7, 2009**

Instructions dated: **June 1, 2009**

Project No.: **OPR-E349-KR-09**

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**

Geomatics Data Solutions, 4128 Ingalls Street, San Diego, CA 92103

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

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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
CUBE	Combined Uncertainty and Bathymetry Estimator
DEA	David Evans and Associates, Inc.
DGPS	Differential Global Positioning System
DN	Day Number
DXF	Drawing Exchange Format
DTON	Danger to Navigation
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HSX	Hypack Hysweep File Format
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IAKAR	Inertially-Aided Kinematic Ambiguity Resolution
IMU	Inertial Motion Unit
MVP	Moving Vessel Profiler
NAD83	North American Datum of 1983
NATSUR	Nature of Surface
NATQUA	Nature of Surface Qualifying Terms
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
RPM	Revolutions per Minute
RMS	Root Mean Square
SBDARE	Seabed Area
SBET	Smooth Best Estimate and Trajectory
SSS	Side Scan Sonar
SVP	Sound Velocity Profiler
TPE	Total Propagated Error
TIN	Triangular Irregular Network
UTC	Universal Time Coordinated
XTF	Extended Triton Format
ZDA	Global Positioning System timing message

OPR-E349-KR-09
Data Acquisition and Processing Report
Southern Chesapeake Bay, Virginia
June 2009 – December 2009
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 H12040, H12041, H12042, H12043, H12044 and H12045 located in Southern Chesapeake Bay, Virginia. These contract surveys were performed under OPR-E349-KR-09 as specified in the *Statement of Work* dated June 2009. All survey methods meet or exceed requirements as defined in the National Ocean Service (NOS) *Hydrographic Surveys Specifications and Deliverables* (April 2009) and the Draft NOS Skunk Stripe Specifications issued to David Evans and Associates, Inc. (DEA) via email by the Chief of the Data Acquisition and Control Branch. A copy of this email is included in Appendix IV - *Supplemental Records and Correspondence* of each survey's Descriptive Report. The project instructions required 200% side scan sonar coverage with concurrent multibeam to the inshore limit, defined as the 18-foot contour. Significant side scan contacts and Automated Wreck and Obstruction Information System (AWOIS) investigations were acquired to meet multibeam complete coverage requirements.

All references to equipment, software, or data acquisition and processing methods were valid at the time of document preparation. All changes to 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 detailed in this section and listed in Tables 1 and 2 on the following pages.

Table 1. *R/V Theory* Hardware

Instrument	Manufacturer	Model	Serial Number	Function
Side Scan Sonar				
Deck Unit	**EdgeTech**	701-DL	35323	Topside interface side scan sonar (SSS) and digital sensors.
Towfish	**EdgeTech**	4200 HFL	37844 38461	Installed 600 kHz Digital SSS imagery with towfish heading and depth sensors on DN191.
Towfish	**EdgeTech**	4200 FS	35482	410kHz Digital SSS imagery with towfish heading and depth sensors. Data acquisition DN170 to DN190.
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 (MR6)	57729	Used DN170-DN188
		7-P Processor Unit (MR6)	2009002	Used DN189-DN315
		7-P Processor Unit (MR6.3)	2708002	Used DN315 to end of project
Link Control Unit	**RESON**	LCU bottle	52007	Seabat transceiver system
Reciever	**RESON**	EM 7200	4105054	Used DN170-DN189
Reciever	**RESON**	EM 7200	3008253	Used DN189 to end of project
Projector	**RESON**	TC 2163	3905334	200kHz Used DN170-DN190
Projector	**RESON**	TC 2160	2405064	400kHz Used DN190 to end of project
Sound Speed				
Surface Sound Speed	**RESON**	SVP 70	3205687	Beam formation and steering.
Sound Speed Profiler	**Brooke Ocean Technology, Ltd.**	AML MVP 30 Smart SVP	5110	Primary SV profiler.
Sound Speed Profiler	**Seabird Electronics Inc.**	SV19	1919847-2691	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**	Zepher	60222755	
Port Antenna	**Trimble**	Zepher	60222895	
Port Antenna	**Trimble**	Zepher	12354270	Replaced antenna 60222895 on DN346
Receiver	**Trimble**	DSM 132	224094182	Secondary positoning system with integrated DGPS radio. Used as
Antenna	**Trimble**		220360424	
Receiver	**CSI Wireless**	MBX-3S	0647323510026	Differential radio for primary position system.
Antenna	**Trimble**	MD MGL-3	0716-3582-0006	
Receiver	**Trimble**	ProBeacon	220014495	Replaced MBX-3S on DN327

Table 2. *R/V Chinook Hardware*

Instrument	Manufacturer	Model	Serial Number	Function
Side Scan Sonar				
Deck Unit	**EdgeTech**	701-DL	35323	Topside interface SSS and digital sensors.
Towfish	**EdgeTech**	4200 FS	35482	410 kHz Digital SSS imagery with towfish heading and depth sensors.
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. Firmware 1.2.2
Transducer	**R2Sonic**	2024	10000023	
Sound Speed				
Surface Sound Speed	**Applied Microsystems**	MicroSV	7561	Beam formation and steering.
Sound Speed Profiler	**Brooke Ocean Technology, Ltd.**	AML SVPlusV2	3592	SV profiler.
Sound Speed Profiler	**Seabird Electronics Inc.**	SV19	1919847-2691	SV profiler.
Navigation				
Deck Unit	**Applanix**	POS MV 320 V4	2204	Integrated Differential Global Positioning System (DGPS) and inertial reference system for position, heading, heave, roll and pitch data.
IMU	**Applanix**	POS MV V4	72	
Starboard Antenna	**Trimble**	Zepher	60073610	
PORT Antenna	**Trimble**	Zepher	60080633	
Receiver	**Trimble**	MS 750	220382893	Secondary positoning system with integrated DGPS radio.
Antenna	**Trimble**	Zepher	39105-00 DC 4232	
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		3.5	
Trimble	**NetR5**	62800-10	4750K11589		3.5	
Antenna						
Trimble	**Zephyr-Geodetic Model-2**	57971-00DC4805	30765574	TRM55971.00		
Trimble	**Zephyr-Geodetic Model-2**	57971-00DC4805	30765531	TRM55971.00		

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.

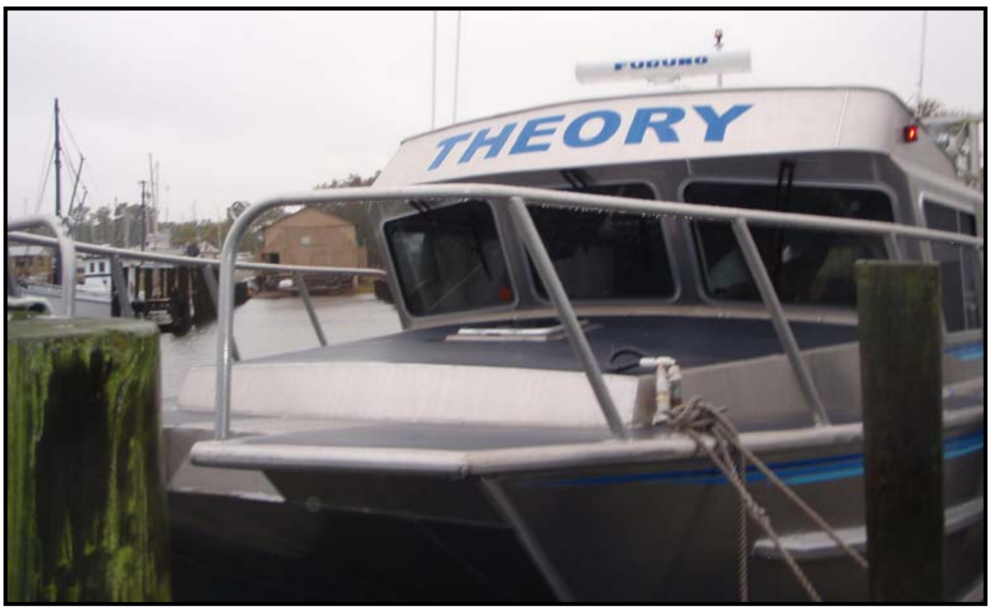

Figure 1. *R/V Theory*

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 three 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 two 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 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 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.

At the start of the project, artifacts were noted in both 200 kHz and 400 kHz frequencies of the Reson 7125 running. On July 8, 2009 (DN189) Reson engineers replaced the deck unit running MR6 with a new unit which was also running MR6 and installed a new receiver. These upgrades eliminated virtually all artifacts in the 400 kHz data and generally improved data quality and performance of both frequencies. A patch test was performed after these system changes were made. Data from June 19, 2009 (DN170) to mid-day July 9, 2009 (DN190) were acquired using the low frequency 200 kHz setting with equiangle beam spacing. Thereafter, all multibeam data were acquired using equiangle beam spacing at the frequency of 400 kHz. Due to failure of the 7-P processor, it was replaced with a new unit running MR6.3 on November 11, 2009 (DN315).

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

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.

With the exception of data collected on August 13, 2009 (DN225), all data were acquired using the low frequency setting of 200 kHz with a 128° swath width and default ping rate, which ensures the maximum ping rate at any given depth range. On August 13, 2009 (DN225) the frequency was adjusted from 200 kHz to 230 kHz during acquisition in an attempt to optimize data quality. Six survey lines were acquired at 230 kHz between 12:02 UTC and 14:53 UTC. The sonar frequency was then changed back to 200 kHz at 15:54 UTC.

On September 27, 2009 (DN 270) the firmware on the R2Sonic was updated to version 1.2.2 to improve the bottom detection algorithm and remove data artifacts at the junction between amplitude and phase detection. 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 (100/410 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 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 the *R/V Theory* 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 Global Positioning System (GPS) antennas, and a data processor.

CSI Wireless MBX-3S radios acquired corrections from the U.S. Coast Guard beacon located at Driver, Virginia (289 kHz) or 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, redundant positioning systems were installed onboard the *R/V Theory* (Trimble DSM 132) and *R/V Chinook* (Trimble MS 750) 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 Descriptive Reports Separate I *Acquisition and Processing Logs* of each survey.

Position, timing, heading and motion data were output to the Hypack acquisition system using the 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 universal time coordinated (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 M/V was configured to log all of the raw observable groups needed to post process the real-time sensor data. Under typical survey conditions a single POS M/V .000 file was logged by each survey vessel per day though periodic changes in operations or shut down of the POS M/V systems required the creation of several 0.000 files. 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 and will be calibrated again at the end of the survey. Factory calibration results are included in the Separates Section II *Sound Speed Data* of the *Descriptive Report* for the survey.

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 it was used as the primary sound speed sensor to correct multibeam data collected onboard.

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. On DN 232 (August 20, 2009) 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. Prior to DN 232, these erroneous sound speed values resulted in loss of beam formation and produced artifacts in the multibeam data. These bad pings were rejected which created small along track multibeam data gaps. The data gaps were left unfilled unless significant contacts were present in the underlying side scan sonar imagery.

A Sea-Bird Electronics 19 SEACAT profiler was used to acquire sound speed profiles collected onboard the *R/V Chinook* from the beginning of the project until DN 259 (September 15, 2009); thereafter an Applied Microsystems, Ltd (AML) SV Plus V2 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 processing office in Sunnybank, VA via external hard drive, where preliminary data processing was performed. Additional processing and creation of deliverables was performed in DEA's Vancouver, Washington office.

The software and version numbers used throughout the survey are listed in Tables 4 and 5 on the following pages.

Table 4. Acquisition Software

Acquisition Software						
Software	**Manufacturer**	**Program**	**Office Version**	***R/V Chinook* Version**	***R/V Theory* Version**	**Comment**
HYPACK	HYPACK, Inc	HYPACK 2008			8.0.1.2	
		HYPACK 2009 SP1		9.0.5.6	9.0.5.6	Upgraded on *R/V Theory* DN175
Isis	Triton Imaging,Inc	Isis Application		7.1.500.123	7.1.500.123	
LineLog	DEA, Inc	LineLog		1.0.0.6	1.0.0.6	
MV-POSView	Applanix Corporation	MV-POSView		3.4.0.0	3.4.0.0	
Smart Talk	Applied Microsystems Ltd.	Smart Talk		2.27	2.27	
Brook Ocean Technology MVP	Brooke Ocean Technology, Ltd.	Brook Ocean Technology MVP			2.27	
7k Control Center 7125	Reson	SeaBat-7125-MR6: 7KUI			3.7.2.5	
		7K Center			3.0.7.1	
		7K IO			3.3.0.7	
		FPGA0			16370103	
		SeaBat-7125-MR6.3: 7KUI			3.7.2.5	Upgraded DN315
		7K Center			3.0.7.3	Upgraded DN315
		7K IO			3.3.0.19	Upgraded DN315
		FPGA0			16370103	Upgraded DN315
R2Sonic, Sonic 2024	R2 Sonic LLC	Sonic 2024 Firmware		V 1.2.2		Upgraded DN270
SeaTerm	SeaBird Electronics, Inc.	SeaTerm	1.30	1.30	1.30	
SBE Data Processing-Win32	SeaBird Electronics, Inc.	SBE Processing, SBE19	5.27a	5.27a	5.27a	

Table 5. Processing Software

Processing Software						
Software	**Manufacturer**	**Program**	**Office Version**	***R/V Chinook* Version**	***R/V Theory* Version**	**Comment**
CARIS		HIPS	6.1 SP2 HF7			
		Add on	Cube Parameters XML			Installed DN181
		Add on	R2Sonic Device Model			Installed DN217
		NoteBook	3.1			Upgraded from 3.0 SP1 HF1 DN293
		Bathy DataBASE	3.1 HF5			Upgraded from BDB 2.1 HF7 DN293
HYPACK	Hypack, Inc.	Hypack Lite	8.0.1.2			
ArcMap	ESRI	ArcGIS	9.3 SP1			
Applanix	Applanix Corpora	POSPac MMS	5.2.3247.12881			Daily POSPac processing
			4.40			Base station verification
Triton Isis	Triton Imaging	Isis Application	7.2.118.331			Bottom tracking and contact selection
	Triton Imaging	Isis Application	7.1.428.53			Mosaicking
	Triton Imaging	TargetPro	2.8.118.331			
PhotoShop	Adobe	CS3 Extended	10.0			Contact image presentation
Convert2Rinex	Trimble	Convert2RINEX	1.0.1.32			Base data conversion
Velocwin	NOAA	Velocwin	8.8.0.0			
Other						
Microsoft Office	Microsoft	Word SP2	2003 SP2			
		Access	2003 SP2			
		Excel	2003 SP2			
Beyond Compare		Beyond Compare	3.0.13			Data transfer

A7. GPS Reference Station Network

Prior to the start of hydrographic survey operations, GPS base stations were established in order to log raw dual frequency observables necessary for GPS post-processing. 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 processing post-processed kinematic solutions. Table 6 indicates the locations of the GPS base stations used for the project.

Table 6. GPS Base Station Positions

Station Name	Latitude (DMS North)	Longitude (DMS West)	NAD 83 Ellipsoid Height (m)
SUN	37 53 08.35738	76 15 59.41330	-23.933
SMITH	37 46 50.05899	76 19 01.22290	-26.347
TANGIER	37 49 10.00603	75 59 48.41756	-31.290

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 compass set to a declination of 11° west and plotted on base station obstruction diagrams.

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 NGS. Base station positions were computed using precise orbits.

More information on the GPS base stations, including site reports, and positions, are included in the OPR-E349-KR-09 *Horizontal and Vertical Control Report*.

A8. Survey Methodology

A8.a Mobilizations

Initial mobilization of the *R/V Theory* occurred at DEA's Marine Services headquarters in Vancouver, Washington. Vessel offsets and associated measurement uncertainties 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. These values were reconfirmed with hand tape measurements prior to the start of OPR-E349-KR-09 survey operations and used in the Hydrographic Information Processing System (HIPS) vessel file for the *R/V Theory*. On site mobilization, sensor installations, and calibrations occurred at Smith Point Marina in Sunnybank, Virginia from June 17, 2009 through June 20, 2009.

The *R/V Chinook* was mobilized at DEA's Marine Services headquarters in Vancouver. A vessel survey was performed using a terrestrial land survey total station on July 20, 2009 and values from this survey were used to calculate sensor offsets and uncertainty estimates used in the *R/V Chinook* HIPS vessel file. On site mobilization, sensor installation, and calibration occurred at Fairport Marina, Fairport, Virginia on August 4, 2009.

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 Southern Chesapeake Bay (OPR-E349-KR-09) 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 complete coverage detection requirements.

Survey coverage was based on the survey limits depicted by the file *OPR-E349-KR-09_region.shp* provided with the Project Instructions. Survey coverage extends to the most seaward of either the file's polygon limit or the surveyed 18-foot contour. With the approval of the COTR, the survey boundaries of H12043 and H12044 were modified by shifting the junction of the two survey areas westward to accommodate single base GPS post-processing requirements. While this modification impacted the survey coverage of these two surveys it did not change the total OPR-E349-KR-09 project survey coverage.

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 the majority of the project. Shallow portions of surveys H12040, H12041, H12042, H12044 and H12045 were collected with the same configuration with an adjustment to the range of 50 meters (Figure 3). 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 2009), 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 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 vessels during acquisition.

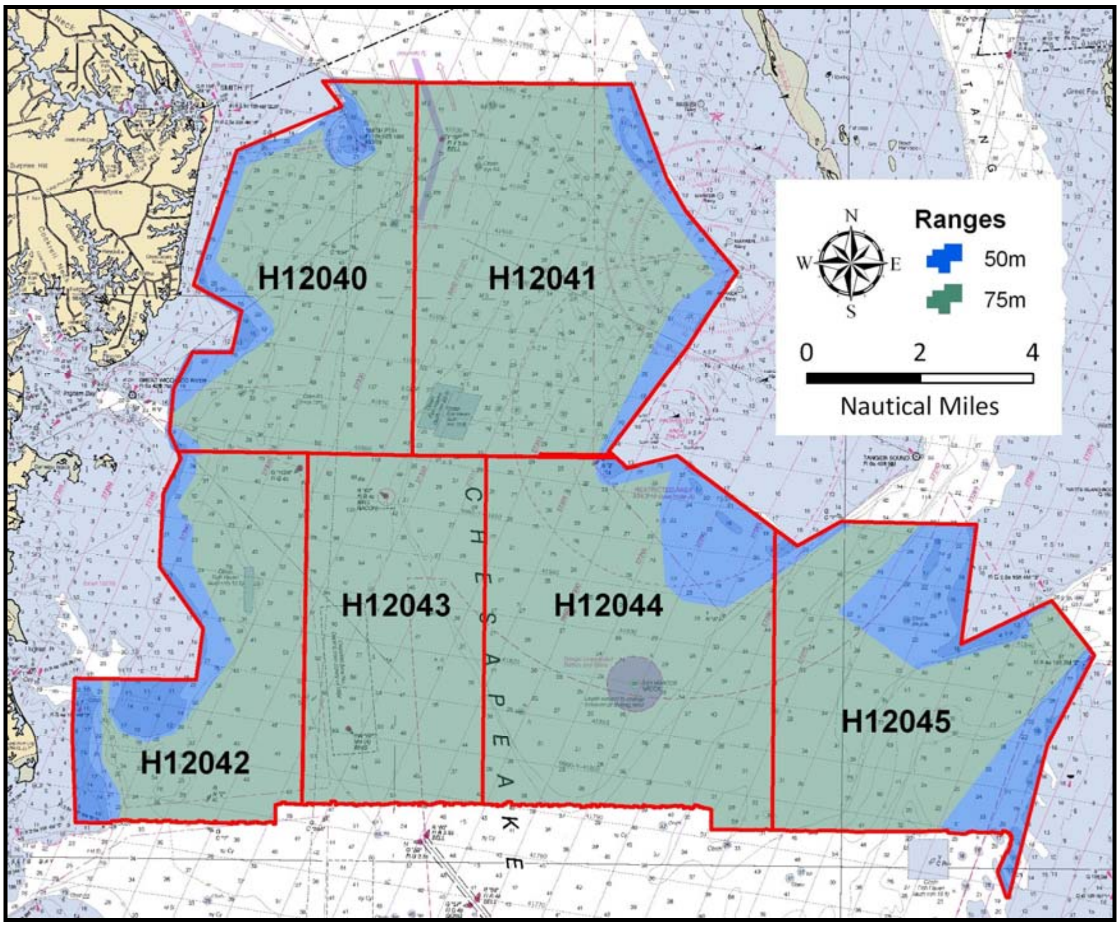

Figure 3. Side Scan Sonar Range Scale Use by Survey Area

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 2009). 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 did not exceed 8.5 knots thus allowing a minimum of three pings per meter. 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-09 *Hydrographic Survey Project Instructions*, (June 17, 2009) and defined by the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2009). 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	20 dB
Power	220 dB
Spreading	30 dB
Absorption	60 dB/km
Ping Rate	18 p/s
Pulse Width	33-68 µs

Table 8. R2Sonic 2024 Sonar Settings

2024 Parameter	Value
Range	Variable, depth dependent
Gain	Variable, depth dependent
Power	Variable, depth dependent
Spreading	30 dB
Absorption	60 dB/km
Ping Rate	Variable, range dependent
Pulse Width	42 µs

A8.e Bottom Sampling

A total of 133 bottom-sediment grab samples were obtained every 2,000 meters across all six 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 International Hydrographic Organization (IHO) S-57 requirements for Seabed Area (SBDARE) features with attribution of COLOUR, Nature of Surface Qualifying terms (NATQUA), and Nature of Surface (NATSUR).

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 v6.1 SP2 Hotfix 7 with modifications to the default CUBE Parameters.XML and Device Models.XML files, both of which have been included with the deliverables for each 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 used new resolution dependent maximum propagation distance values required in the HSSD 2009.

The Device Models.XML was modified to include a device model for the R2Sonic 2024 sonar for multiple frequencies, including 200 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.

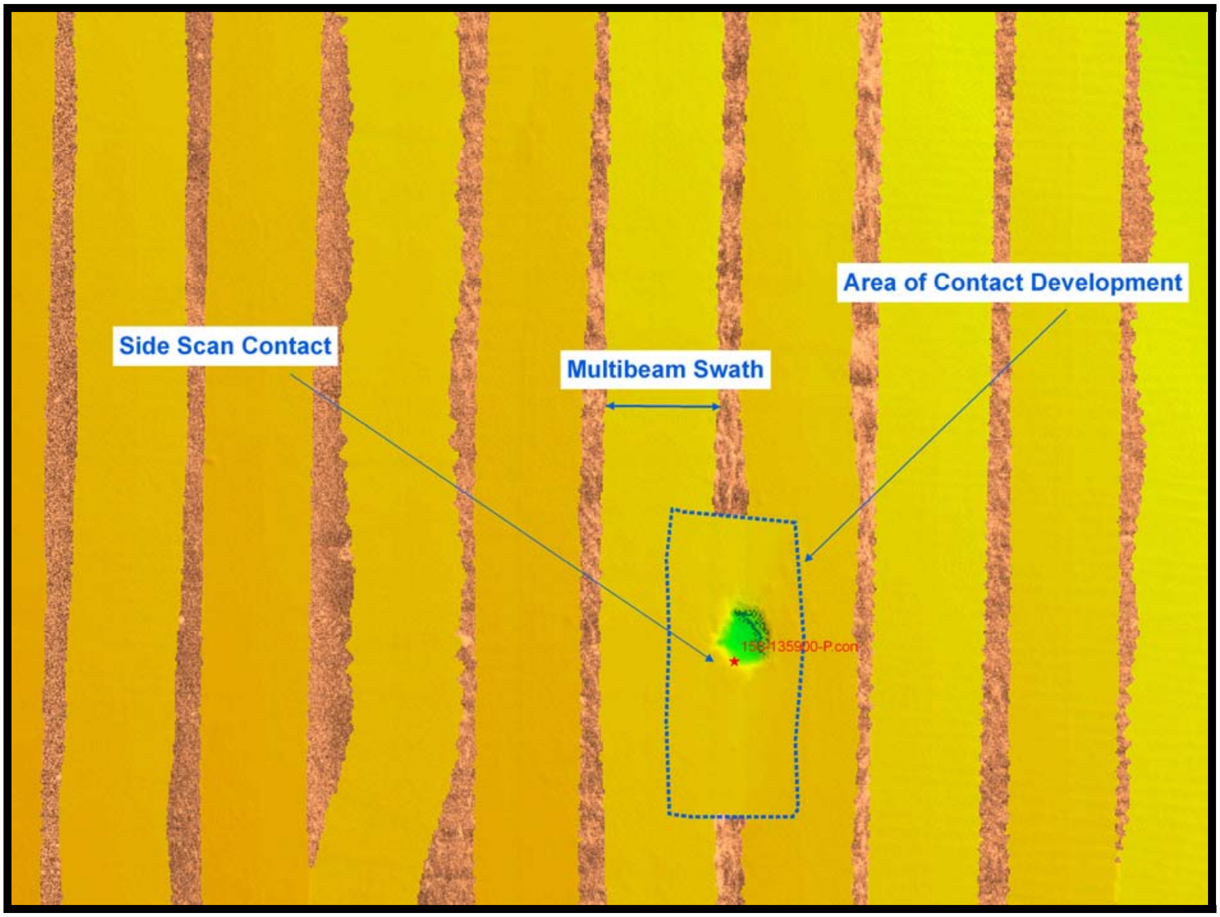

Figure 4. Graphic of side scan mosaic overlaid with contacts and multibeam swath coverage

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 as necessary during data acquisition and logged in ISIS to ensure the best image quality. 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 2009) to ensure the required along track coverage.

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-meter and 50-meter ranges. Contacts were classified as significant if their estimated height was one 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 deploying 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, during acquisition to ensure the best bathymetric data quality. Additionally, vessel speed was adjusted in accordance with the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2009) to ensure 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. Both operators monitored primary and secondary navigation systems to ensure 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. On *R/V Chinook* the AML was occasionally lashed to the SBE19 for comparison as another redundant observation in addition to the weekly comparison with the MVP. Sound speed profiles were computed for each of the sensors and compared to confirm instrumentation was functioning within survey tolerances.

Contacts were classified as significant if their estimated height was at least one meter in water depths less than or equal to 20 meters. In water depths greater that 20 meters contacts with heights greater than 10 percent of 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 the were areas deemed to be critical to navigation or if they appeared to be mounds or other geologic structures which cast no shadow. Towfish altitude was maintained at 8% to 20% of all ranges.

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.

In order to manage the high volume of side scan sonar contacts DEA created a custom database that would meet the contact tracking requirements of the *Specifications and Deliverables*. 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.

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.

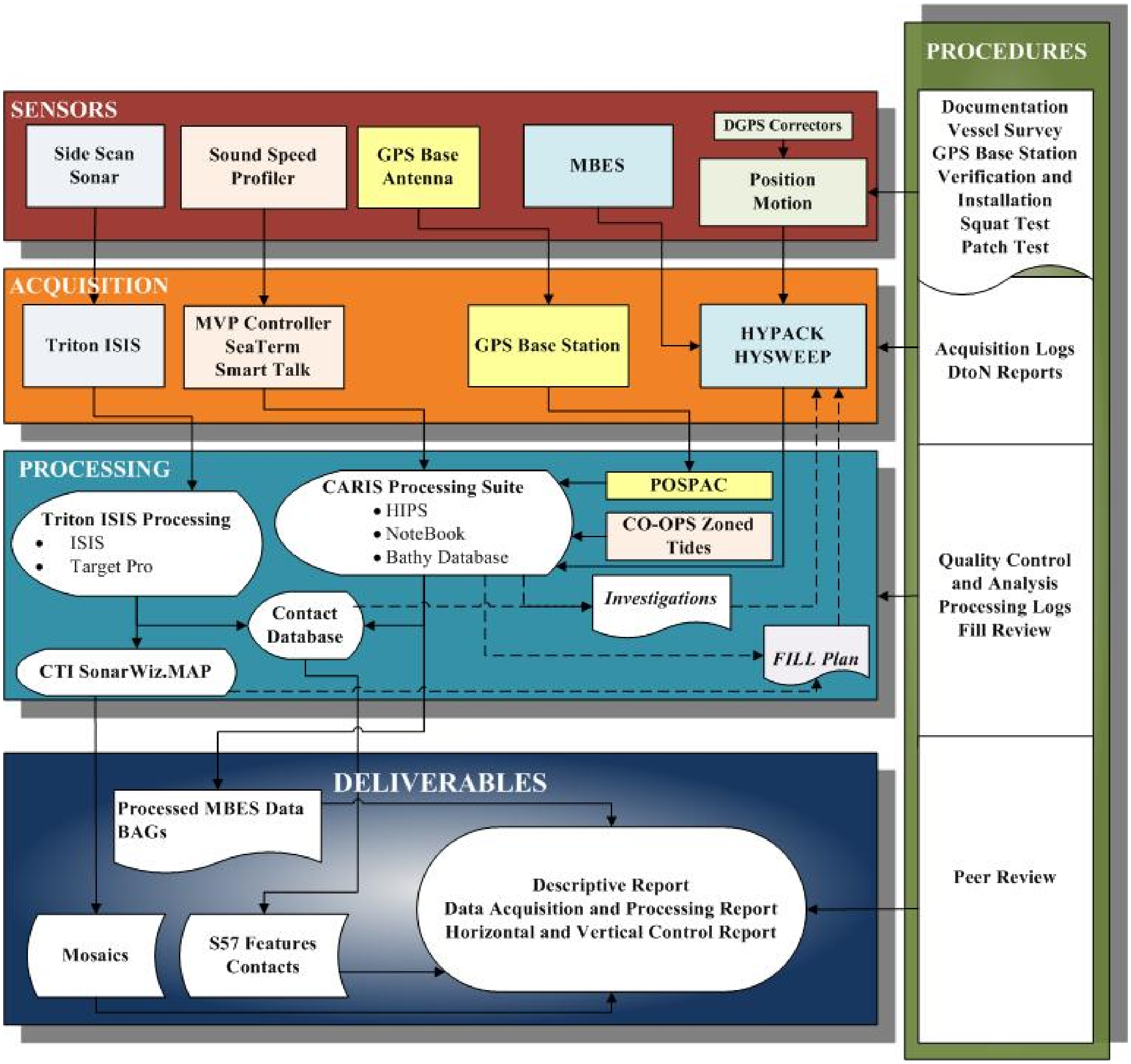

Figure 5. Flowchart of data acquisition and processing pipeline

B2.a HIPS Conversion

Multibeam data were converted from HSX format to Caris HDCS format using the Hypack conversion wizard (Hypack converter 6.1.2.2). 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 (HVF) (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. When converting side scan data using these vessel files, layback values should be imported using the “from Layback field” in the CARIS XTF converter. Towfish navigation can then be recomputed to generate corrected positions

Table 9. HIPS Vessel Files

HIPS Vessel File	HIPS Converter	Sonar Type	Comment
OPRE349-KR-09_MBES_TH	Hypack 6.1.2.2	Multibeam	MBES hvf
OPRE349-KR-09_MBES_CH	Hypack 6.1.2.2	Multibeam	MBES hvf
OPRE349-KR-09_SSS_TH	N/A	Side scan	SSS hvf
OPRE349-KR-09_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.

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 and attitude and used during TPE computation.

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 4.00	POS/MV Model 320 V 4.00
Position System 2		DSM132	MS 750
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	0.050
	Nav Timing (s)	0.005	0.050
	Gyro Timing (s)	0.005	0.050
	Heave Timing (s)	0.005	0.050
	Pitch Timing (s)	0.005	0.050
	Roll Timing (s)	0.005	0.050
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)	0.010	0.010
	Delta Draft (m)	0.026	0.029

Physical Alignment Errors*			
Alignment			
	MRU align Stdev gyro	0.096 (DN167)	0.118
	MRU align Stdev gyro	0.104 (DN190)	0.053
	MRU align roll/pitch	0.100 (DN167)	
	MRU align roll/pitch	0.117 (DN190)	

*All values given as 1 sigma.

A single tidal uncertainty incorporating measurement error, zoning error, and processing error was provided by CO-OPS at the 95% confidence interval. This value was scaled to 1 sigma and entered into the Tide Zoning field during HIPS TPE computation. Zero was entered into the Tide Measured value since the value used in the Tide Zoning field represented the total propagated uncertainty of all the known tide errors.

Sound speed and tide TPE values are listed in Table 11.

Table 11. TPE Values for Tide and Sound Speed

Total Propagation Error Computation in CARIS HIPS	
Tide Value	**Uncertainty**
Tide Value Measured	0.000
Tide Value Zoning	0.089
Sound Speed Values	
Sound Speed Measured	1.000
Surface Sound Speed	0.500
*All values given as 1 sigma.	

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* and 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 1 (one) hours 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. 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. Caris Data Processing

Multibeam data processing followed the standard HIPS workflow for Combined Uncertainty and Bathymetry Estimate (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 single piles 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, and heading
4. Apply sheet wide concatenated sound speed profiles
   - "Nearest in distance within time"
5. Merge
6. Compute TPE via values listed in Table 9
7. Filters applied based on the following criteria:
   - Reject soundings with poor quality flags (0 and 1 for Reson)
   - Add data to CUBE surface
     1. Resolution dependent on depth
        - IHO S-44 Order 1
        - Density & Local Disambiguation method
        - Advanced settings specific to surface resolution
8. Surface Filter
   - Errors from Standard Deviation
   - 2.6 (99.06%) Confidence Interval

After filtering, each survey sheet was subdivided by creating multiple Caris field sheets to reduce processing time and the computer power required to generate the CUBE surfaces. The field sheets were created to fall within the recommended 25 million node limit for each CUBE surface. 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 2009). Survey coverage was reviewed to ensure that there were no substantial holidays spanning the entire survey swath or that there were no data gaps present over significant contacts. In addition survey coverage and density were reviewed to ensure that the Draft NOS Skunk Stripe Specifications were met. The HIPS density layer of each grid was reviewed to ensure that the minimum sounding density of three 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 three soundings.

All data were reviewed in HIPS 2D subset with the CUBE reference surface visible. Soundings rejected by quality and surface 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 critical sounding. Data processors used an IHO Order 1 Error Calculator macro developed by David Evans and Associates, Inc. to determine the acceptable error relative to depth. 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 for each contact least depth.

Post-processed GPS heights were loaded to each HIPS survey line and a GPS tide computed using a NAD83 ellipsoid to MLLW separation file created using VDatum. Though present for each survey line GPS Tides were not applied to the survey data during the merge process and are for reference only. Further discussion on the computation of GPS tides and the separation model can be found in the OPR-E349-KR-09 Ellipsoid Referenced Survey Deliverables.

B4. GPS Post-processing

Applanix POSPac MMS was used to create a post-processed Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) navigation solution. This post-processed solution included new position, heading and attitude measurements which used the 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).

POSPac processing followed the workflow recommended by Applanix with each .000 file processed independently. Base RINEX files were loaded from the appropriate base station for the day being processed. 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 2009). 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 even though the real-time input navigation was relative to NAD83. NAD83 coordinates of the DEA installed GPS reference stations were used 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. A POSPac station database file with the NAD83 project coordinates for each

base station was created and distributed to all processing computers in order to remove the need to manually enter the coordinates during each processing session.
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 each survey.

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 or wrecks 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.

The feature file also includes bottom samples (SBDARE) and required meta-objects (M_COVR and M_QUAL).

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 directly abeam with the multibeam sonar 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 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. 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

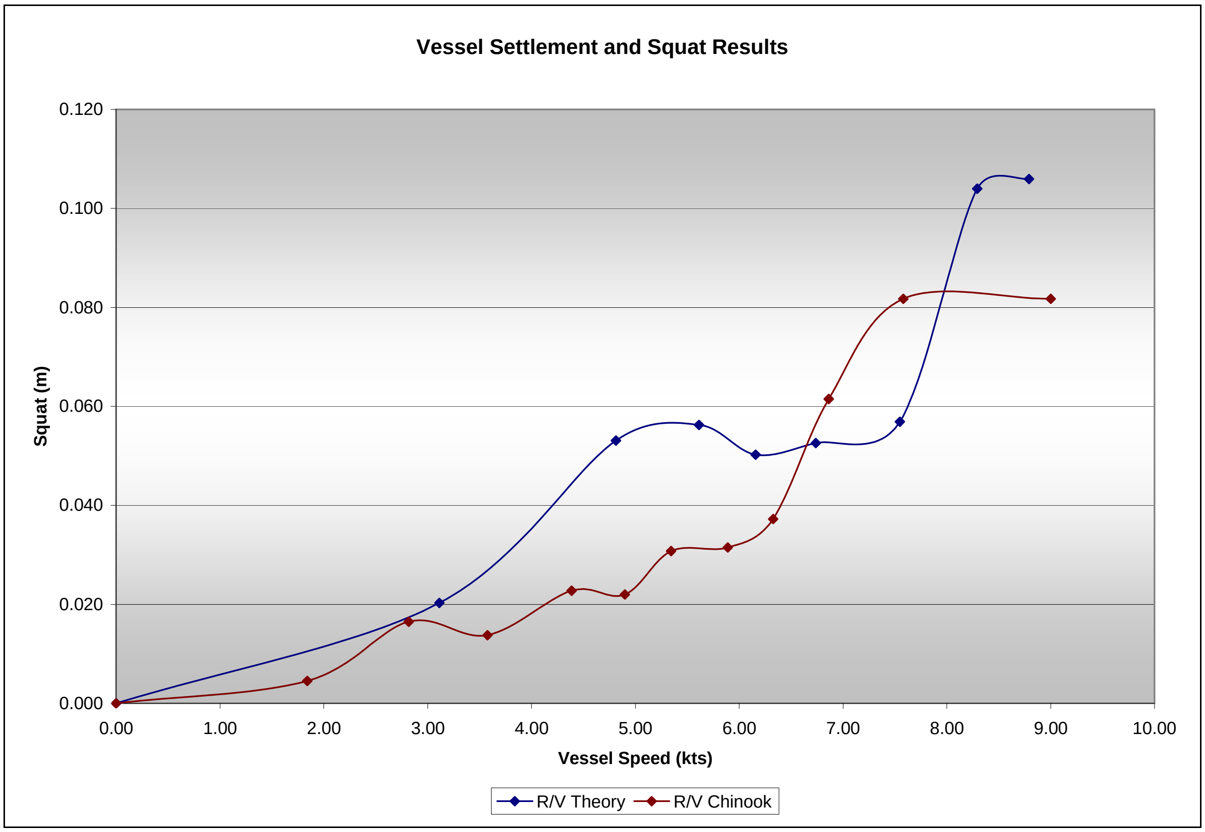

Figure 6. Vessel settlement and squat results

Dynamic draft values for both survey vessels are presented in Table 12.

Table 12. 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		

A settlement and squat test for the *R/V Theory* using post-processed GPS height observations was performed on the Chesapeake Bay just west of Fleeton Point on June 20, 2009 (DN170). Settlement and squat tests for the *R/V Chinook* were performed on August 6, 2009 (DN218) and August 22, 2009 (DN234) within the H12042 and H12043 survey limits. Data from these measurements are displayed graphically in Figure 6 and in tabular format in Table 11 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 five 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 13 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 13. Vessel Bar Check Summary

	R/V Chinook	***R/V Theory***
Average Difference	-0.011	-0.013
Standard Deviation	0.021	0.019
Maximum Deviation	-0.060	0.040

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

C4. Heave, Roll and Pitch Corrections

An Applanix POS/MV 320 version 4 integrated dual frequency GPS and inertial reference system was used for the motion sensor for this survey. The POS/MV 320 is a 6° of freedom motion unit, with a stated accuracy of 0.05-meter or five percent 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/tpe/) were entered into the HVF and used for TPE 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.

An error of 0.173m in the reference to IMU Lever Arm "Z" for the POS/MV on *R/V Chinook* was discovered and corrected on September 15, 2009 (DN 259). The correct value was entered into the POS/MV and a GAMS calibration was conducted. The offset was corrected in data collected prior to DN259 by adjusting the Swath1, SVP1, and waterline height offsets in the HVF by -0.173 meters.

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.

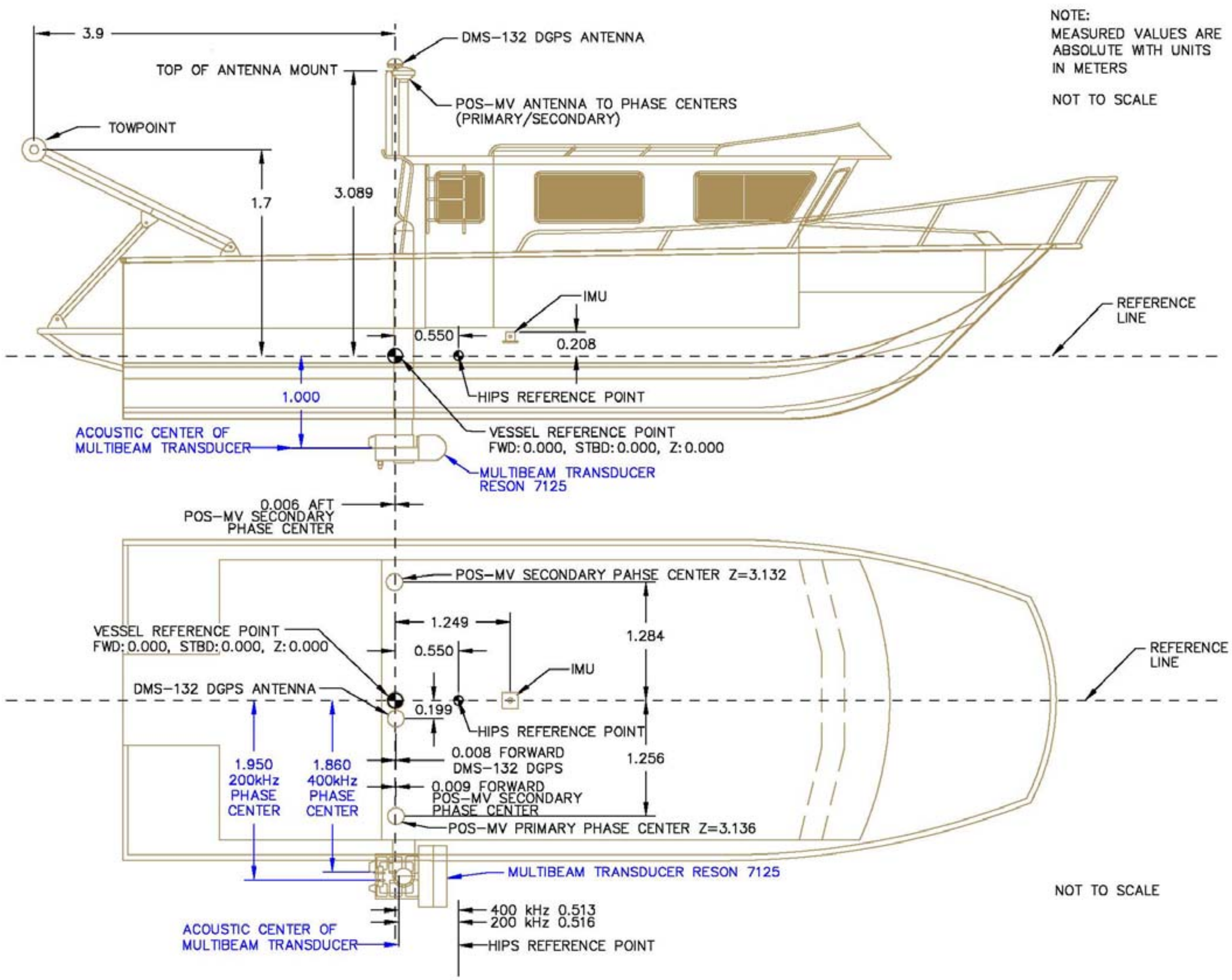

Figure 7. Schematic of *R/V Theory* and Sensor Setup

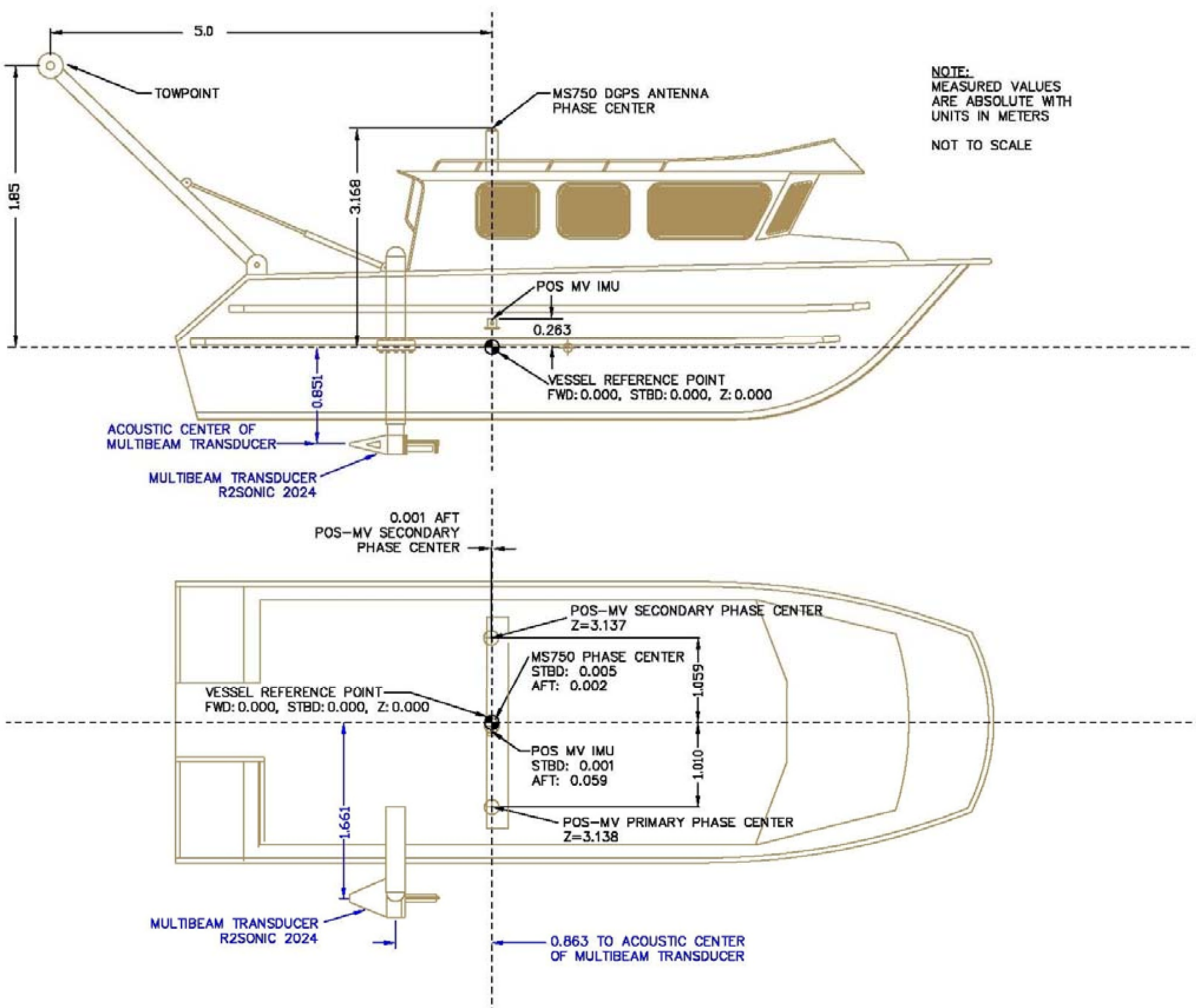

Figure 8. Schematic of *R/V Chinook* and Sensor Setup

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 knots 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.

Changes for both vessels are also documented in Tables 14 and 15 on the next page.

Table 14. *R/V Theory* biases applied when using POS/MV

DN	Latency	Pitch (°)	Yaw (°)	Roll (°)	X (m)	Y (m)	Z (m)	Comments
167	0.000	-3.300	-0.550	-0.900	1.950	-0.516	1.000	200 kHz, Patch values are from DN337 of NOAA11
170	0.000	-3.800	-0.300	-1.100	1.950	-0.516	1.000	200 kHz, Confidence Checks
170	0.000	-4.300	-0.600	-1.500	1.860	-0.513	1.000	400 kHz, Confidence Checks
170	0.000	-3.800	-0.300	-1.100	1.950	-0.516	1.000	200 kHz, Confidence Checks - Wreck Test
170	0.000	-4.300	-0.600	-1.500	1.860	-0.513	1.000	400 kHz, Confidence Checks - Wreck Test
171	0.000	-3.800	-0.300	-1.100	1.950	-0.516	1.000	200 kHz, Patch Test
171	0.000	-4.300	-0.600	-1.500	1.860	-0.513	1.000	400 kHz, Patch Test
172	0.000	-3.800	-0.300	-1.100	1.950	-0.516	1.000	200 kHz, Start of Survey
189	0.000	-2.629	-0.574	-1.279	1.860	-0.513	1.000	400 kHz, Patch Test - New Reson Rx Installed
189	0.000	-3.043	-0.405	-1.000	1.950	-0.516	1.000	200 kHz, Patch Test - New Reson Rx Installed
190	0.000	-2.629	-0.574	-1.279	1.860	-0.513	1.000	400 kHz, Restart Survey
262	0.000	-2.586	-0.588	-1.320	1.860	-0.513	1.000	400 kHz, Patch Test
294	0.000	-2.588	-0.532	-1.400	1.860	-0.513	1.000	400 kHz, Boat pulled (Patch Values from Day 304)
304	0.000	-3.150	-0.344	-1.540	1.950	-0.516	1.000	200 kHz, Patch Test
305	0.000	-2.588	-0.532	-1.400	1.860	-0.513	1.000	400 kHz, Patch Test
315	0.000	-2.650	-0.539	-1.200	1.860	-0.513	1.000	400 kHz, Patch Test - Reson 7P upgraded from MR6 to MR6.3
324	0.000	-2.944	-0.522	-1.400	1.860	-0.513	1.000	400 kHz, Patch Test
338	0.000	-3.085	-0.499	-1.370	1.860	-0.513	1.000	400 kHz, Patch Test

Table 15. *R/V Chinook* biases applied when using POS/MV

DN	Latency	Pitch (°)	Yaw (°)	Roll (°)	X (m)	Y (m)	Z (m)	Comments
216	0.000s	1.100	-0.060	1.066	1.661	-0.863	1.024	Adjusted Z value by 17.3cm.
256	0.000s	0.875	0.325	1.104	1.661	-0.863	1.024	Patch Test
259	0.000s	0.875	0.325	1.104	1.661	-0.863	0.851	Offset in POS Changed by 17.3cm
270	0.000s	1.067	0.490	1.080	1.661	-0.863	0.851	Patch Test
324	0.000s	1.038	0.052	1.102	1.661	-0.863	0.851	Patch Test - close out

C6. Tide and Water Level Corrections

The primary water level stations for this project were Lewisetta, Virginia (863-5750) and Windmill Point, Virginia (863-6580). A modified of the HIPS Zone Definition File (ZDF) *E349KR2009_RevisedCORP* provided by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) was used to apply zoned tides to the multibeam data. The modified file, named *E349KR2009_RevisedCORP*_1s, used a HIPS Interval value of 1 second rather than the default value of 360 seconds which was used in the file received by CO-OPS. The interval value controls the frequency of tide zoning interpolation. The default value of 360 seconds is too infrequent to properly correct for the assigned zoning boundaries where it would be possible for the survey vessel to pass through a zone without a zoned tide corrector being applied if the vessel was not within the zone boundary for longer than 359 seconds.

The primary and subordinate stations experienced no down time during periods of hydrographic survey.

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. The boat remained stationary and casts were taken in the deepest area near the lines acquired within the previous 2-hour time frame. 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.

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 measured by the MVP at 1.0 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*. On *R/V Chinook* the AML was occasionally lashed to the SBE19 for comparison. These weekly checks were completed to verify 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* of the Descriptive Reports.

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. Daily HIPS SVP files were concatenated into a sheet wide file. Time, position, depth, 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-09
DATA ACQUISITION AND PROCESSING REPORT

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of OPR-E349-KR-09 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-09 *Statement of Work* (June 2009).

Digitally signed by Jon Dasler
DN: cn=Jon Dasler, email=jld@deainc.com, o=David Evans and Associates, Inc., c=US
Date: 2009.12.18 13:48:13 -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: 2009.12.18 13:59:11 -08'00'

Jason Creech
Lead Hydrographer

David Evans and Associates, Inc.
December 2009

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