U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Data Acquisition and Processing Report

Type of Survey *Shallow Water Multibeam Hydrographic and Side Scan Sonar Survey*

Project No. *OPR-J364-KR-09*

Locality

State *Florida*
General Locality *Gulf of Mexico*
Sub-locality *Entrance and Approaches to Pensacola Bay*

2010

George G. Reynolds

CHIEF OF PARTY

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HYDROGRAPHIC TITLE SHEET	REGISTRY NOs. *H12060,H12061* *H12062, H12157*

State	*Florida*
General Locality	*Gulf of Mexico*
Sub-Locality	*Entrance and Approaches to Pensacola Bay*
Scale	*1:10,000*
Date of Survey	*October 23, 2009 – May 11, 2010*
Instructions Dated	*September 21, 2009*
Project No.	*OPR-J364-KR-09*
Vessel	*R/V Able II - Registration Number CT4788BB* *R/V Ferrel – Official Number 1182802*
Chief of Party	*George G. Reynolds*
Surveyed By	*John G. Wetmur, Robert M. Wallace, Matthew T. Grennan, Bonnie L. Johnston, Michael D. Lincoln, Andrew W. Payson, Kerry H. Cutler, Alexander G. Unrein, John R. Bean, John R. Ayer, Joseph V. Tyler*
Soundings by echo sounder	*Reson Seabat 7101*
Verification by	*Michael J. Engels*
Soundings in	*Meters (MLLW)*

REMARKS: *All Times Recorded in UTC*

Data Recorded and Presented relative to UTM Zone 16 North

Original SOW modified by January 21, 2010 Amendment of Solicitation (Refer to Separate III of the Descriptive Report).

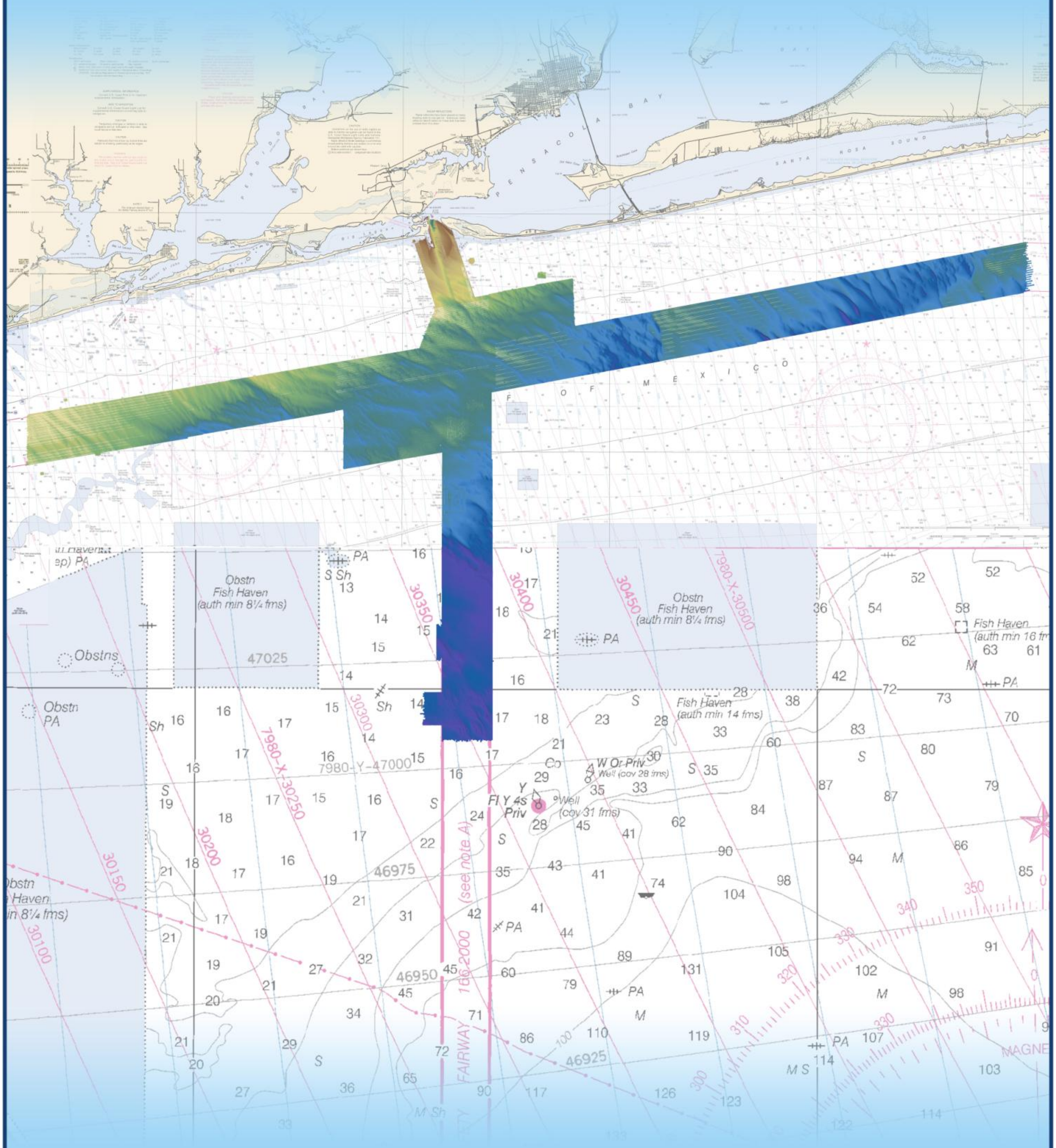
Contractor: *Ocean Surveys, Inc.*
91 Sheffield St.
Old Saybrook, CT 06475

OPR-J364-KR-09

Entrance and Approaches to Pensacola Bay

Registry Nos. H12060, H12061, H12062, H12157

OSI Report #09ES056-DAPR



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A. EQUIPMENT

A.1 Survey Vessels

All survey operations were conducted from OSI's *R/V Able II* (Figure 1) and from Reservoir Geophysical's *R/V Ferrel* (Figure 2). *R/V Able II*, Connecticut Registration Number CT 4788 BB, is a 7.6-meter fiberglass vessel, with a 2.9-meter beam and 0.8-meter draft. *R/V Able II* is powered by twin 150 HP outboard engines. *R/V Ferrel*, O.N. 1182802, is a 44.5-meter steel vessel, with a 9.8-meter beam and 1.8-meter draft. *R/V Ferrel* is powered by two 750 HP CAT D 353 diesel engines.

Figure 1. *R/V Able II* configured for hydrographic survey operations.

The following is a summary of the customized survey support hardware and reference points installed aboard the R/V Able II:

1. An indexed Inertial Measurement Unit (IMU) mounting plate is permanently installed on the starboard side of the vessel at the approximate pitch center of rotation. The POS-MV IMU was installed on this plate which resides at the plane of the vessel's waterline.
2. A retractable multibeam transducer pole is installed on the starboard side of the vessel at the approximate pitch centerline. The pole is fabricated from thick-walled stainless

steel pipe and attached to the hull and cabin with a rigid 3-position mount that facilitates transducer draft adjustment. The mounting system employs precision machined index pins and alignment holes to allow repeatable, accurate alignment for multiple draft settings. A transducer pole "stiffener bracket" is permanently installed near the chine of the vessel allowing the operator to clamp the multibeam pole to the boat at the waterline, helping to eliminate pole movement.

3. A hydraulically actuated A-frame is installed on the stern of the vessel allowing the SSS towfish to be flown and handled aft of the outboard engines. An electric/hydraulic multi-purpose slip ring winch was used to control the SSS.
4. A davit and capstan utilized for CTD casts and bottom sample collection are installed on the port side of the cabin.
5. Reference points were established on the vessel to define a fixed reference frame, vessel reference point (RP), draft measurement locations and sensor mounting locations. These points were "surveyed" using a precision total station optical theodolite and electronic distance meter. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file. Refer to Section C.1 Vessel Configuration and Offsets for additional details.

Figure 2. *R/V Ferrel* configured for hydrographic survey operations.

The *R/V Ferrel* was modified by OSI to support hydrographic survey operations. The following summarizes the major adaptations and/or custom survey support hardware installed on the *R/V Ferrel*:

1. An ISO office container was installed on the main deck to house acquisition and processing computer stations along with major survey system control modules and computer systems.
2. A measured and indexed Inertial Measurement Unit (IMU) mounting plate was installed on the ship's fore-aft (roll) centerline at the approximate pitch center of rotation. The POS-MV IMU was installed on this plate which resides just below the plane of the ship's waterline on the lower deck.
3. A retractable multibeam transducer pole, constructed of thick-wall steel pipe, was attached to the starboard side of the vessel at the approximate pitch centerline. The pole was attached at two points; a "saddle plate" on the deck of the vessel and a "receiver plate" at the chine of the vessel. The transducer pole is forced, by means of a wire rope winch connection, into the V-notch receiver plate at the chine of the ship, thereby eliminating pole movement. The transducer pole was fitted with fairings on the trailing edge to minimize cavitation. The transducer was not moved or adjusted after completion of the initial system alignment calibration (patch test).
4. A Hazen tide gauge was installed within the transducer pole to monitor static draft.
5. A hydraulically actuated A-frame was installed on the starboard quarter of the ship. The SSS towfish was flown from the A-frame. Two (2) electric/hydraulic multi-purpose slip ring winches (SSS primary and spare) were installed on the main deck. A moving vessel profiler (MVP) was installed on the port quarter of the ship.
6. Reference points were established on the vessel to define a fixed reference frame, vessel reference point (RP), draft measurement locations and sensor mounting locations. These points were "surveyed" using a precision total station optical theodolite and electronic distance meter. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file. Refer to Section C.1 Vessel Configuration and Offsets for additional details.

A.2 Acquisition Hardware

Major data acquisition system components employed on this survey are summarized in Table 1 below. A brief description of the equipment follows.

Table 1
Acquisition Hardware

System	Data	Manufacturer	Model/ Version No.	Firmware Ver.	Serial Number (s)
Multibeam Echo Sounder	Soundings	Reson	7101	MR 7.1	3707078
Side Scan Sonar	Imagery/Contacts	Klein	3000	11.2	575
Side Scan Sonar	Imagery/Contacts	Klein	5000	11.3	357
Sound Speed Profiler (2)	Sound Speed	Sea-Bird	SeaCAT SBE 19 CTD	3.1	1801 2864
Sound Speed Profiler (2)	Sound Speed	Sea-Bird	SeaCAT SBE 19+ CTD	2.1	6513 6107
Sound Speed Sensor (Real-Time Surface Water Sound Speed) (2)	Sound Speed	Sea-Bird	MicroCAT SBE37	2.2	6372 7531
Moving Vessel Profiler	Sound Speed	ODIM	MVP-30	1.0	10648
Primary Navigation DGPS	Position	Applanix/ Trimble	POS MV 320 V.4	HW 2.5-6 SW 03.42	TPU 2149 IMU 390
Secondary Navigation DGPS (Position Integrity Alarm)	Position	Trimble	MS750	1.58	220209817
Vessel Attitude and Heading	Pitch, Roll, Heave, Heading	Applanix/ Trimble	POS MV 320 V.4	HW 2.5-6 SW 03.42	TPU 2149 IMU 390
U.S.C.G. Differential Beacon Receivers (2)	GPS correctors	Trimble	ProBeacon	3	0220033958 0220181939
Lead Line	Soundings	OSI	Lead Disk	N/A	1
Stadia Rod	Sounding	Crain	CR-4.0M	N/A	OSI SR-02
SSS Cable Payout Indicator	SSS Fish Layback	Hydrographic Consultants	SCC16”	2	1603
Land Survey GPS	Position	Trimble	5700	V3.01	220332818
Ponar Grab Sampler	Bottom Samples			N/A	NA
Tide Gauge	Static Draft	Hazen	HTG5000	N/A	363764R

A.2.1 Multibeam Echo Sounder System - Reson SeaBat 7101

The SeaBat 7101 is a 240 kHz Multibeam Echo Sounder (MBES) System, which measures the relative water depths across a 150º wide swath perpendicular to a vessel's track. The 7101 system illuminates a swath of the seafloor that is 150º across track by 1.5º along track. The system can be configured to collect 239 or 511 equidistant beams or 101 equiangular beams with a depth resolution of 1.25 cm. The installed system was equipped with the Extended Range projector and designed to comply with International Hydrographic Organization (IHO) standards to measure seafloor depths to a maximum range of 500 meters.

Digital data were output through the Ethernet data port and displayed in real time on a high-resolution color monitor. Power and gain settings were monitored and adjusted to optimize bottom detection for the inner 140 degrees of swath coverage. Range settings were monitored and adjusted for observed depths to maximize ping rates.

UTC date and time information from the POS MV was used to accurately time stamp the Reson output data string. The Reson 71P processor also received a pulse-per-second (PPS) and a serial $ZDA NMEA timing string from the POS MV.

Transducer offsets and mounting angles, relative to the vessel frame and a vessel reference position (RP), were measured using standard optical survey equipment and techniques. Residual alignment and calibration offsets were documented in the patch test results. Refer to Section C.1 Vessel Configuration and Offsets for additional details.

A.2.2 Vessel Navigation Systems

A.2.2.1 Primary Positioning: Applanix POS MV

An Applanix POS MV 320 V.4 system was installed on the survey vessels to provide position and attitude data. The POS MV (Position and Orientation System for Marine Vessels) consists of a rack mountable POS Computer System (PCS), a separate Inertial Measurement Unit (IMU) and two GPS receivers.

The POS MV combines the IMU and GPS sensor data into an integrated and blended navigation solution. There are two navigation algorithms incorporated into the system, namely tightly coupled and loosely coupled inertial/GPS integration. Tightly coupled inertial/GPS integration involves the processing of GPS pseudorange, phase and Doppler observables. In this case, the GPS receiver is strictly a sensor of the GPS observables and the navigation functions in the GPS receiver are not used. With loosely coupled inertial/GPS integration, the GPS position and velocity solution are processed to aid the inertial navigator.

The POS MV received United States Coast Guard differential beacon corrections (DGPS). In all cases, dockside navigation system accuracy testing demonstrated that the POS-MV, employing USCG correctors, had an accuracy of better than 1.5 meters. DGPS outages were infrequent. The real-time position accuracy alarm was set at 1.5 meters and monitored during data acquisition using the MV-POSView controller software. Despite the infrequent outages, at no time did the field team observe real-time accuracy degradation greater than two meters.

IMU and antenna offsets and mounting angles, relative to the vessel frame and a vessel reference position (RP), were measured with precise optical survey methods. For each vessel, the primary GPS antenna position, with respect to the IMU and RP, was confirmed using the MV POSView controller calibration procedure. Residual alignment and calibration were derived during the patch test procedure. Refer to Section C.1 Vessel Configuration and Offsets for additional details.

A.2.2.2 Secondary Positioning: Trimble MS750

A secondary or "position integrity alarm" GPS system consisted of a Trimble MS750 GPS operating in DGPS mode. The secondary system position was compared to the primary position system and monitored continuously in HYPACK during survey operations.

A.2.2.3 Differential GPS Correction: Trimble Pro Beacon DGPS Receivers

Trimble Pro Beacon DGPS beacon receivers were manually tuned to local USCG differential beacon stations and interfaced to each of the aforementioned GPS systems. Refer to the Vertical and Horizontal Control Report for additional details of DGPS position correctors.

A.2.2.4 Precise Positioning: Trimble 5700 GPS

Prior to and during the course of the survey the accuracy of the primary positioning system was verified by means of a physical measurement to a project temporary horizontal control/navigation checkpoint located at the vessel's berth. The checkpoint was established using a Trimble 5700 GPS system configured with a Trimble Zephyr Geodetic antenna. The Geodetic antenna was installed over the project horizontal checkpoint and three (3) static position observations were made. The recorded GPS data files were submitted to the National Geodetic Survey (NGS) On-line Positioning User Service (OPUS) and processed to determine the position of the temporary control point. Each data file that was submitted was processed with respect to at least 5 CORS sites. NGS provided an OPUS Report which included both ITRF and NAD83 coordinates along with position accuracy information. These reports are provided in the Vertical and Horizontal Control Report.

Position confidence checks were accomplished daily on *R/V Able II* and at least bi-weekly, during fuel or weather stops, for the *R/V Ferrel*. The distance between the vessel reference point and the horizontal control point computed by the navigation system was compared to the distance between the vessel reference point and the horizontal control point measured with a steel tape. Details of the horizontal control points are included with the Vertical and Horizontal Control Report. A tabulation of navigation system performance checks is included with the Survey Descriptive Report (DR) Separate I.

A.2.3 Attitude and Heading Measurement System - Applanix POS MV

The POS MV generates attitude data in three axes (roll, pitch and heading) within 0.02 degree accuracy. Heave measurements supplied by the POS MV maintain an accuracy of 5-centimeters or 5% of the measured vertical displacement for movements that have a period of up to 20 seconds. The heave bandwidth filter was configured with a dampening coefficient of 0.707. The cutoff period of the high pass filter was determined by estimating the swell period encountered during the survey. A heave bandwidth filter of 10 seconds was employed on the *R/V Able II* and *R/V Ferrel*.

Applanix "TrueHeave" data were acquired and recorded during survey operations. The TrueHeave algorithm uses a delayed filtering technique to increase heave measurement accuracy, reducing error caused by IMU drift and long-period ocean swell. The TrueHeave data corrections were applied to soundings during post processing in CARIS HIPS.

The GPS Azimuth Measurement Subsystem (GAMS) allows the POS MV system to achieve high-accuracy heading measurement. The GAMS subsystem uses two GPS receivers and antennas to determine a GPS-enhanced heading that is accurate to 0.02° or better (using a two-meter antenna baseline) when blended with the inertial navigation solution. POS MV uses this heading information as aiding data together with the position, velocity and raw observations information supplied by the primary GPS receiver. GAMS operation was employed for all survey data acquisition and GAMS status was monitored continuously during survey operations using the MV-POSView controller software.

IMU and antenna offsets and mounting angles, relative to the vessel frame and a vessel reference position (RP), were measured with a precise survey. An Applanix-specified GAMS calibration procedure was conducted prior to survey data acquisition.

A.2.4 Side Scan Sonar System - Klein 3000/Klein 5000

Side scan sonar imagery was acquired employing a Klein 3000 dual-frequency sonar operating at 100 and 500 kHz on the *R/V Able II*, and a Klein 5000 single-frequency sonar operating at 455 kHz on the *R/V Ferrel*. Both systems consist of a Transceiver Processor Unit (TPU), coaxial double armored steel tow cable, winch, digital cable payout meter, and sonar towfish. System components are interfaced to the acquisition system and other ancillary devices, via a local network hub or serial cable connections.

Each towfish was equipped with an optional pressure sensor which was used to measure towfish depth. The pressure sensor was calibrated (depth zeroed) daily at the surface to account for changes in atmospheric pressure. The pressure sensor data were interfaced and converted to depth with Chesapeake Technologies, Inc. "SonarWiz" side scan sonar data acquisition system. The TPU was interfaced with the primary navigation system through SonarWiz. Depth and cable-out data were used by SonarWiz to determine the towfish position relative to the vessel reference point.

The waterfall display within the Klein "SonarPro" side scan sonar data acquisition system was employed in display mode only. Refer to Section A.3 Computer Hardware and Software for additional details of side scan sonar data processing.

A.2.5 Sound Speed Determination Systems

The surface sound speed sensor, the primary and secondary sound speed profilers, and the ODIM MVP were manufacturer calibrated before survey data acquisition. Instruments that required post-survey calibrations, due to the length of time deployed in the field, were post-deployment manufacturer calibrated. Copies of the calibration sheets are included with the DR in Separate II.

A.2.5.1 Water Column Profiles: Primary SBE 19 SEACAT Profiler CTD

Water column conductivity, temperature and pressure (depth) profiles were acquired using a Sea-Bird Electronics SBE 19 SEACAT Profiler CTD. Water sound speed profiles were calculated from raw CTD data using NOAA NOS Coast Survey Development Laboratory (CSDL) Velocwin software. All sound speed corrections were applied in post processing with CARIS HIPS software. Refer to section A.3 Computer Hardware and Software for additional details of sound speed data processing.

A.2.5.2 Water Column Profiles: Secondary SBE 19/19+ SEACAT Profiler CTD

On the *R/V Able II* weekly sound speed quality assurance (DQA) checks were performed using NOAA CSDL Velocwin software by comparing a primary SBE 19 SEACAT Profiler CTD sound speed profile to a secondary SBE 19 or 19+ Profiler CTD sound speed profile. A tabulation of sound speed casts and record of DQA results are included with the DR Separate II.

A.2.5.3 Surface Sound Speed: SBE37

The Sea-Bird Electronics SBE 37 is a high-accuracy conductivity and temperature sensor capable of calculating and transmitting sound speed via a standard RS232 serial data interface. The SBE 37 transmitted real-time surface sound speed data to the Reson 7101 multibeam system and the HYPACK acquisition computer (via the Reson 7101 interface).

The SBE 37 was installed behind the multibeam transducer at the draft of the phase center. Real-time surface sound speed values were transmitted to the Reson 71P topside unit and subsequently recorded with multibeam echo sounder data in the raw HYPACK .HSX data files. Sound speed data were also transmitted to the HYPACK acquisition software which was configured to display a visual alarm if the surface sound speed exceeded a threshold of +/- 3 m/s. Variations in surface sound speed were monitored and evaluated as an indicator of surface water temperature/salinity fluctuation and potential water column variation which would necessitate additional sound-speed profile measurements.

Daily sound velocity quality assurance (DQA) checks were performed using NOAA CSDL Velocwin software by comparing the SBE37 surface sound speed to the surface sound speed of the primary CTD sound speed profile. A tabulation of daily DQA results is included in DR Separate II.

Surface sound speed data were used by the Reson 7101 system for range determination. However, all sound speed corrections used to calculate depths from raw data were performed during post processing in CARIS HIPS using the full water column sound speed profile data.

A.2.5.4 Water Column Profiles: ODIM MVP30 Moving Vessel Profiler

The ODIM MVP30 Moving Vessel Profiler allows sound speed profiles to be collected while the vessel is underway. The ODIM MVP consists of a towfish sensor, a conductor cable and an electric winch. The MVP may be deployed manually using the winch controls or remotely using the ODIM MVP Controller Software. When operated in "FreeWheel" mode while underway, the MVP falls near-vertically to a preset depth off the bottom, collecting sound speed and temperature/depth measurements at a frequency of 10Hz. The ODIM MVP30 was only employed on the *R/V Ferrel*.

A manual MVP cast was acquired daily while the *R/V Ferrel* was at a full-stop. The manual cast data were compared with a simultaneously recorded CTD cast acquired with a SBE 19+ SEACAT Profiler CTD. The sound speed profiles from the MVP and CTD were compared using Velocwin's "Weekly DQA" tool. Daily comparisons were made between the surface sound speed of the stationary MVP (and CTD cast) and the surface sound speed recorded by the SBE37 at the time of the cast. The surface DQA comparisons were accomplished using Velocwin's "Daily DQA" tool. A listing of daily DQA results is included in DR Separate II.

A.2.6 Lead Line and Stadia Rod

Multibeam echo sounder accuracy checks were performed by means of a "bar check" or lead line measurement comparison. The lead line was constructed of a 9 kilogram, 0.3-meter round lead disk attached to a cable with permanent index markers established at measured 5-meter intervals. The bar check procedure consists of lowering the disk (acoustic target) to a measured depth directly below the multibeam transducer and recording the nadir depth value. A bar check was performed prior to survey data acquisition to confirm the transducer phase-center vertical offset with respect to the vessel reference point. Subsequent bar checks were performed at regular intervals, and after system draft changes (*R.V Able II*), to verify vertical offsets and system performance. All vertical offsets were recorded and updated in the CARIS vessel configuration files.

The lead line comparison procedure, or "spot check," consisted of sounding the seafloor directly below the multibeam transducer with the lead line while simultaneously observing the multibeam nadir depth.

Prior to survey data acquisition, the lead line was calibrated with a steel survey tape to verify index mark accuracy.

A fiberglass stadia rod was employed throughout the survey for various tasks requiring a rigid measuring tool. The rod was used to measure least depths on two of the Sheet B AWOIS items. Also, due to the relatively high freeboard of the *R/V Ferrel*, static draft measurements were accomplished employing the stadia rod. Prior to utilization, the rod graduations were compared to a steel tape measure to confirm its accuracy.

A.2.7 SSS Cable Out Indicator

Determination of SSS cable out values was accomplished by means of a Hydrographic Consultant, Ltd. SCC Smart Sensor Cable Payout Indicator. The payout indicator consists of a topside display/controller, deck cable, and 16-inch (0.4-meter) diameter block fitted with a magnetically triggered counting sensor.

The cable out indicator was calibrated according to manufacturer specifications before data acquisition by measuring the sheave circumference and entering a calibration value into the topside controller software. Cable out readings were verified daily at the beginning of survey operations, and at regular intervals throughout the day, by observing measured index marks on the towfish cable with respect to a reference position on the winch.

The cable out indicator was interfaced with Chesapeake Technologies, Inc. SonarWiz side scan sonar data acquisition system. The length of cable deployed, along with towfish pressure sensor information, were used to determine an accurate towfish position relative to the vessel reference point. Refer to Section A.3 Computer Hardware and Software for additional details of side scan sonar data processing.

A.2.8 Bottom Sampler

A Ponar Type grab sampler and a pipe dredge were employed to obtain seafloor sediment samples within the survey area. The Ponar sampler is a self tripping, modified Van Veen sampler constructed of stainless steel with zinc-plated steel arms and weights. The sampler was deployed from the *R/V Able II* using a davit and PowerWinch system. A pipe dredge sampler was utilized to obtain seabed samples from the *R/V Ferrel*. A PowerWinch system aboard the *R/V Ferrel* was employed to recover the unit.

A.2.9 Hazen Tide Gauge

A Hazen tide gauge was used on the *R/V Ferrell* to calculate daily vessel static draft levels. The instrument consists of a pressure transducer connected to a top-side transmitter. The transmitter is powered by a rechargeable battery pack and it communicates to a remote receiver via cable or a radio link. The receiver digitally displays the tide reading which can be logged to a hard copy or output digitally to a PC via an RS-232CA interface.

The Hazen gauge transducer was installed below the waterline in the multibeam transducer pole mount. It was configured to record a water level every 9 seconds. The receiver was interfaced with the acquisition computer through a serial port and the tide reading was logged in meters to a HYPACK .RAW file while the ship was at a full stop. See Section C.2.1 Static Draft for a more detailed explanation of the Hazen gauge utilization.

A.3 Computer Hardware and Software

Computer hardware and software utilized during this survey are itemized in Table 2 below.

Table 2
Computer Software

Manufacturer	Application	Platform	Version	Version Date
HYPACK	HYPACK SURVEY	WXP	9.0 9.1.0.0	Sept. 28, 2009
HYPACK	HYSWEEP SURVEY	WXP	9.0.26.0	Sept. 28, 2009
Chesapeake Technology, Inc.	SonarWiz 4	WXP	4.04.0061	Sept 8, 2009
Chesapeake Technology, Inc.	SonarWiz RT	WXP	1.0.8.0088	Jan 8, 2010
L3 Klein	SonarPro	WXP	11.2	Apr 24, 2007
L3 Klein	VX, Works	WXP	6.18	Feb 21, 2008
Universal Systems, Ltd.	CARIS HIPS/SIPS	WXP	6.1	June 1, 2008
Universal Systems, Ltd.	CARIS Notebook	WXP	3.0	June 5, 2008
Universal Systems, Ltd.	CARIS Easy View	WXP	2.0	2008
NOAA	NOAA Velocwin	WXP	8.92	May 8, 2008
Global Mapper Software LLC	Global Mapper	WXP	10	Aug 27, 2008
AutoDesk Inc.	AutoCAD	WXP	2004	Feb 14, 2003
Microsoft	Office (WORD, EXCEL)	WXP	2007	Oct 18, 2008
Sea-Bird Electronics	SeaTerm	WXP	1.59	Dec 22, 2008
Sea-Bird Electronics	SBE Data Processing	WXP	7.18b	2008
Applanix	MV POS View	WXP	4.0.2.0	Dec 1, 2008
Applanix	POSPac MMS	WXP	5.2	Aug 25, 2009
Hydrographic Consultants	CALLOAD	WXP	2.0	Dec 18, 2005
Trimble	MS Controller	WXP	1.1.0.0	May 21, 2002
Trimble	Pro Beacon PC Interface	DOS	5.0	March 5, 1991
ODIM Brooke Ocean	MVP Controller	WXP	2.430	2009

A.3.1 HYPACK

A.3.1.1 Vessel Navigation

Survey vessel trackline control and position fixing were accomplished by using a computer-based data-logging and navigation software package (HYPACK). Vessel position data were output from the POS MV at 50 Hz frequency and transmitted to the navigation computer system, which processed these data in real-time into the desired mapping coordinate system (UTM Zone 16 North, NAD 83). Raw and processed position data were continuously logged onto the computer hard drive and displayed on a video monitor, enabling the vessel's helmsman to guide the survey vessel accurately along pre-selected tracklines. Tracklines and survey features were displayed on the helm monitor with geographic reference data that included NOS raster nautical charts (RNC) and S-57 electronic nautical charts (ENC). Multibeam echo sounder data were monitored in real-time using 2-D and 3-D data display windows. Motion and predicted tide-corrected sounding data were displayed as HYPACK gridded depth models and coverage matrices. HYPACK "targets" were also recorded to mark the location and time of significant observations during data acquisition, such as CTD cast positions or detached positions on charted Aids to Navigation.

Raw, geographic position data (NAD83 degrees latitude and longitude) were time tagged with UTC time by the POS MV and recorded by HYPACK in .RAW format line files.

The HYPACK computer was also used for sensor monitoring and data quality review while data were acquired. Utilities in the acquisition module of HYPACK notify the operator with a visual alert in the event of a sensor malfunction or, in some cases, when a sensor parameter drifts out of operator-set limits (e.g. DGPS position comparison or sound speed change).

A.3.1.2 Multibeam Data Acquisition

A dedicated computer was used to record all multibeam sounding data as well as all associated vessel position, motion, and heading data. During *R/V Able II* operations, multibeam data were logged with HYPACK HYSWEEP software using a Windows XP computer which has a 3.4 GHz Pentium IV processor, 1.5 terabyte hard drive, and 2.0 gigabytes of RAM. This computer was also used to monitor the MV POSView controller and record POSPac data. During *R/V Ferrel* operations, multibeam data were logged with HYPACK HYSWEEP software using a Windows XP computer which has a 3.16 GHz Intel Core 2 Duo processor, a 320 gigabyte hard drive, a 2 terabyte hard drive and 4.0 gigabytes of RAM. This computer was also used to monitor the MV POSView controller and record POSPac data.

Multibeam raw beam ranges, intensities, and quality flags were time tagged with UTC time by the Reson 71P processor and recorded by HYPACK in HSX format line files.

Motion and attitude data (heave, pitch, roll, and heading) were time tagged with UTC time by the POS MV and recorded by HYPACK in HSX format line files.

During *R/V Able II* operations, data were copied at the end of every survey day from the acquisition computer onto a removable hard drive and archived locally. Raw multibeam data and supporting data (acquisition logs, svp profiles) were transferred to Ocean Surveys' home office via high-speed internet connection or courier delivery.

During *R/V Ferrel* operations, data were copied onto processing computers located on the ship for editing. Raw, processed and supporting data (acquisition logs, svp profiles, etc.) were transferred to Ocean Surveys' home office via courier delivery.

A second computer was employed aboard the survey vessels to process water column sound speed data and maintain project and acquisition logs. On the *R/V Able II*, this computer was a Windows XP machine which had a 1.7 GHz Pentium M processor, 56-gigabyte hard drive and 1.99 gigabytes of RAM. On the *R/V Ferrel*, this computer was a Windows XP machine which had a 3.16 GHz Intel Core 2 Duo processor, a 320 gigabyte hard drive, a 2 terabyte hard drive and 4.0 gigabytes of RAM.

A.3.1.3 Multibeam Data Processing

The HYPACK HYSWEEP SURVEY calibration module was used to determine preliminary alignment correctors from multibeam sonar calibration patch tests. All patch test values were verified in CARIS HIPS and entered into the vessel configuration file. Refer to Section C.3 Motion, Timing Errors and Sensor Alignment.

A.3.2 Chesapeake Technologies, Inc. (CTI) SonarWiz

A.3.2.1 Side Scan Sonar Data Acquisition

A dedicated computer was used to record all side scan sonar data and display real-time side scan sonar (SSS) waterfall and mosaic imagery. During *R/V Able II* operations, side scan sonar data were logged with SonarWiz software using a Windows XP computer which has a 3.4 GHz Pentium IV processor, 1.5 terabyte hard drive and 2.0 gigabytes of RAM. During *R/V Ferrel* operations, side scan sonar data were logged with SonarWiz software using a Windows XP computer which has a 3.16 GHz Intel Core 2 Duo processor, a 320 gigabyte hard drive, a 2 terabyte hard drive and 4.0 gigabytes of RAM.

SonarWiz was configured to display slant-range corrected, scrolling waterfall displays of both the 100 and 500 KHz frequency side scan sonar data during *R/V Able II* operations and 455 kHz frequency side scan sonar data during *R/V Ferrel* operations. Scrolling imagery was monitored continuously for data quality and to identify significant features. Confidence checks observed across the full range (e.g. sand waves, bottom changes and buoy blocks) were recorded frequently to verify system operation and object detection capabilities. Confidence checks were recorded with line names, observation times, and comments in the daily acquisition log.

Significant side scan contacts were targeted in the SonarWiz waterfall window, simultaneously creating a target in HYPACK Survey. The HYPACK targets were tagged with a unique ID by SonarWiz and updated with a descriptive field comment. All potential side scan contacts selected from the real-time waterfall were saved to the daily HYPACK target file.

SonarWiz compiled side scan sonar data with vessel position, towfish position, layback and cable out values and recorded raw data in .XTF format line files. Two hundred percent (200%) SSS coverage was attained in the survey area employing line spacing and side scan sonar range scales tabulated in Table 3 below.

Table 3
SSS Line Spacing and Range Scales

Trackline Offset (meters)	SSS Range Scale (meters)
20	25
30	37.5
40	50
65	75
85	100

Vessel speed was maintained such that any $1m^3$ object would be ensonified more than three times per pass at the operating range scale. In general, the towfish height was maintained at 8-20 percent of the range scale. In very shallow water, it was not possible to maintain the towfish more than 2 meters above the bottom. Refraction effects were minimized in deep water by changing the depth/altitude at which the towfish was flown. Often this necessitated flying the towfish slightly lower or higher than specified to avoid thermoclines or haloclines encountered within the survey area.

During *R/V Able II* operations, data were copied at the end of every survey day from the acquisition computer onto a removable hard drive and archived locally. Raw side scan data and supporting data (acquisition logs) were transferred to Ocean Surveys' home office via high-speed internet connection or courier delivery.

During *R/V Ferrel* operations, data were copied onto processing computers located on the ship for editing. Raw, processed and supporting data (acquisition logs) were transferred to Ocean Surveys' home office via courier delivery.

A.3.2.2 Towfish Layback and Position Computation

SonarWiz was configured to receive navigation data from the POS MV, pressure sensor data from the towfish, and cable out from the topside cable counter controller. Towfish depth was calculated from the pressure sensor data. Towfish layback was calculated in SonarWiz from depth and cable out using Pythagorean's Theorem and a percentage of cable out value to correct for the catenary effect. The towfish position was calculated assuming that the towfish was directly behind the vessel relative to the navigation track.

A.3.3 L3 Klein SonarPro

L3 Klein SonarPro software was operated in “slave mode” to the side scan sonar TPU and configured to display an uncorrected, scrolling waterfall display of the side scan sonar data. Scrolling imagery was monitored continuously for data quality and to identify water column noise or interference (e.g. dolphins, boat wake, etc.).

A.3.4 CARIS Hydrographic Information Processing System (HIPS) and Sonar Image Processing System (SIPS)

All multibeam echo sounder data were converted from raw HYPACK format data files to HDCS format and processed using CARIS HIPS software Version 6.1 (Service Pack 2) for the Microsoft Windows XP environment.

All SSS data were converted from raw XTF format line files to HDCS format and processed using the CARIS SIPS software, Version 6.1 (Service Pack 2) for the Microsoft Windows environment.

Refer to Section B. PROCESSING AND QUALITY CONTROL.

A.3.5 CARIS Notebook

An S-57 attributed feature file was created in CARIS Notebook to emphasize navigationally significant objects discovered during the survey and to provide information for these objects that could not be portrayed in the BASE surfaces. New and updated chart features were included in the S57 feature file for submission with the hydrographic survey data.

Refer to Section B. PROCESSING AND QUALITY CONTROL.

A.3.6 CARIS Easy View

CARIS Easy View (Service Pack 1) was used to review multiple sources of data during processing, quality review and chart comparisons. Raster and vector reference data included CARIS soundings, BASE surfaces, contours, HOB format files, S-57 000 format files, ENC, RNC, and AutoCAD drawing exchange files (dxf).

A.3.7 AutoCAD 2004

AutoCAD drafting and geographic information system was employed for pre-survey planning, line file construction, hydrographic data QC and the production of presentation graphics.

A.3.8 Microsoft Office Word and Excel

MS Excel was used for log keeping (field and processing), sound velocity profile display and review, organization and preparation of field and office tasks, report table production and statistical data analysis. MS Word was used for report generation.

A.3.9 Adobe Acrobat

Adobe Acrobat was used to prepare final reports with digital signatures in accordance with the Statement of Work (SOW) and HSSD.

A.3.10 Global Mapper 10

This 3-D visualization software and geographic information system was employed to create detailed sun-illuminated Digital Terrain Model (DTM) images, display vector geographic data and convert file formats. These data were used for QC checks and presentation purposes.

A.3.11 Applanix MV POSView

The MV POSView controller software was used to configure and monitor the POS MV navigation and inertial motion unit system. IMU, navigation and GAMS status were monitored continuously at the navigation and acquisition stations. Visual alarms were configured to alert the operator in the event that attitude, position, velocity, heading or heave accuracy was degraded.

The MV POSView controller was also configured to record TrueHeave, navigation and motion correction data (POSPac).

A.3.12 Applanix POSPac MMS Post-Processing Data

POSPac data were acquired and logged during survey operations. POSPac MMS is a post-processing software module, which significantly increases the efficiency, accuracy, and robustness of mapping and surveying using GPS data. Using POSPac MMS in post processing, reliable decimeter level or better accuracy can be obtained from existing reference station networks without having a dedicated station located close to the project area.

In certain instances, POSPac data were post processed and evaluated for quality assurance and development purposes. These data were not used for final sounding positioning. Processed POSPac navigation data were internally implemented to confirm Coast Guard DGPS navigation solutions and to corroborate system offsets. The program was also employed to carry out limited water level QA/QC analysis.

A.3.13 Hydrographic Consultants, Ltd. CALLOAD

CALLOAD was installed on the side scan acquisition computer and used to calibrate and configure the SCC Smart Cable Counter. Sheave circumference, quantity of magnets and preset cable out values were input into CALLOAD to reset the cable counter.

A.3.14 Trimble MS Controller

The Trimble MS Controller Software was installed on the multibeam acquisition computer and used to configure and calibrate the Trimble MS750 Receiver. It is a simulated keypad and display that shows current position and a number of additional data fields, providing access to several status and system setup menus.

A.3.15 Trimble ProBeacon

The Trimble ProBeacon PC Interface program was installed on the multibeam acquisition computer and used to configure the Trimble ProBeacon to receive DGPS correctors from the selected USCG station. The PC Interface Program was run through a DOS command window to enter the receiver frequency, check the receiver status and monitor the RTCM messages arriving from the ProBeacon to the acquisition computer.

A.3.16 ODIM Brooke Ocean MVP Controller

On the *R/V Ferrel*, a dedicated laptop computer was used to operate the ODIM MVP30 Controller Software. The System Configuration Window was used to interface the MVP towfish, MVP winch and the navigation and depth data strings output from HYPACK. Position, depth and vessel speed data were received from HYPACK and sound speed profiles were export to HYSWEEP to be used for real-time correction of the multibeam waterfall display.

The deployment configuration, alarms and data logging options were set in the Configuration Window, including profile depth limit, max cable out and docked cable out. The deployment depth limit was set to 2 meters off bottom. Sound speed profiles (SV Files) were saved to the MVP laptop and the .CALC files were post processed and converted to CARIS .SVP files using Velocwin. During manual casts, completed once per day with the vessel at rest, the MVP fish was allowed to reach full water depth.

The Main Operator Window was used to remotely "cast" the towfish and to monitor the towfish parameters and alarms. Graphical tabs in the Main Operator Window were used to monitor towfish depth and surface sound speed. The "view profile" button was utilized to review the current sound speed profile. The manual logging option was toggled on during the acquisition of stationary MVP casts.

A.4 Acquisition Procedures

A.4.1 Project Management Overview

All data acquisition and processing were performed under the supervision of the Chief of Party. Field acquisition was performed under the supervision of a Lead Hydrographer and a Senior Hydrographer, each with at least 3 years of experience conducting hydrographic surveys.

A.4.2 Project Planning

Prior to the survey, a review of the current charted data was conducted to identify critical features and areas including ship channels, fish havens, disposal sites and questionable charted features (obstructions, wrecks, reported PA, ED charted features). General depth areas were delineated from current charted information or DTM of high-density sounding data from prior surveys (if available from the NGDC digital archive). A line plan was created to meet requirements specified in the SOW. Specific line plans and survey coverage are described in the individual survey Descriptive Reports.

A.4.3 Data Acquisition Quality Control

Data acquisition quality control was established and performed to ensure survey data met requirements specified in the SOW and HSSD. The following quality control checks were performed during survey operations:

- Position
    - Positioning system confidence checks were performed utilizing an NGS OPUS-derived temporary dockside reference point. During *R/V Able II* operations, positioning system checks were performed daily. During *R/V Ferrel* operations, positioning system confidence checks were performed at every refueling or weather delay stop (approximately every 9-14 days).
    - The POS/MV position accuracy status indicators were monitored in real time.
    - Position information from the primary and secondary DGPS receivers were continuously compared in HYPACK and status indicators were monitored in real time.
- Attitude
    - The POS/MV GAMS heading accuracy status indicator was monitored in real time.

  - The POS/MV heave, pitch and roll accuracy status indicators were monitored in real time.
  - TrueHeave and POSPac data were acquired at least 5 minutes prior to and after SWMB acquisition.

- Static Draft
  - Static draft measurements were conducted prior to SWMB acquisition and daily throughout the period of data acquisition.
  - Additional static draft measurements were conducted before and after fueling.

- Sound Speed Profile (SSP)
  - Sea-Bird CTD's were operated in accordance with Coast Surveys Development Lab (CSDL) guidance: 3 minutes of warm up at the surface, 2 minutes operation at the surface, 1 meter per second depth descent.
  - The moving vessel profiler was operated in accordance with the ODIM Brooke Ocean's MVP30 Operation and Maintenance Manual.
  - A CTD cast was acquired daily prior to SWMB acquisition in the relative location of operations. Daily CTD confidence checks were performed and logged in Velocwin by comparing the CTD surface sound speed to the SWMB sound speed probe.
  - Weekly confidence checks were performed and logged in Velocwin by comparing casts from the primary CTD with the secondary CTD.
  - During *R/V Able II* operations, CTD data were acquired at a minimum interval of 1 cast per 4 hours; more frequent casts were acquired if variable sound speed (SS) was observed in either profile or surface data.
  - During *R/V Ferrel* operations, sound speed profile data were acquired with the ODIM MVP30 as deemed necessary by the hydrographer. The typical interval between MVP casts was on the order of 20 to 60 minutes.
  - Casts were acquired to measure sound speed for the deepest depths of the survey in accordance with the HSSD. All casts were reviewed and the profiles extended in Velocwin.
  - Casts were acquired for specific survey areas (e.g. channels, deep water) if necessary.
  - All casts were combined and reviewed in a custom MS Excel worksheet and graph (Figure 3) to monitor cast-to-cast differences and daily variations.

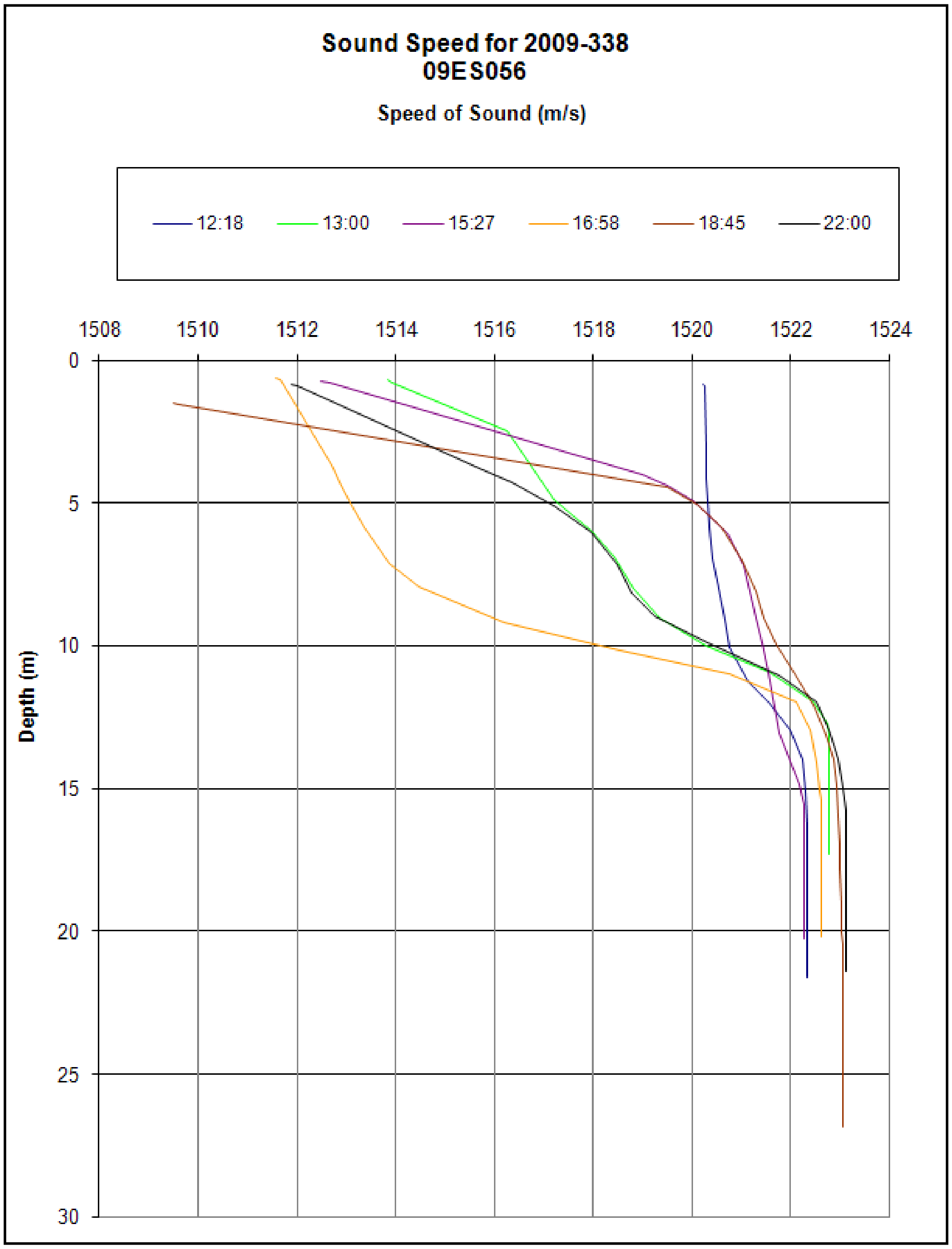

Figure 3. Typical Daily SSP Comparison in Microsoft Excel.

- SWMB
    - Surface sound speed sensor operation and UTC clock synchronization were verified before SWMB acquisition commenced and frequently throughout each survey day.
    - A weekly bar check was performed to verify echo sounder draft offset and system sounding accuracy.
    - Weekly lead line or spot check comparison was performed to verify echo sounder accuracy.
    - The Reson real-time sounding profile “wedge” was monitored in real time.
    - Real-time SWMB waterfall displays and digital terrain model coverage displays were monitored in HYPACK HYSWEEP.

- SSS
    - The pressure sensor was calibrated daily prior to towfish deployment.
    - The cable payout meter was calibrated daily prior to SSS acquisition and throughout the day via index marks on the SSS tow wire.
    - Cable payout meter confidence checks were performed regularly using measured marks on the towfish cable.
    - SSS imagery confidence checks were recorded frequently on recognizable features (e.g. sand waves, bottom texture changes).
    - A slant-range corrected SSS waterfall display was monitored in real time. Contact targets were positioned from the slant-range corrected data and displayed on the helmsman map.
    - An uncorrected SSS waterfall display was monitored in real time to observe water column interference and nadir contacts.

- Digital Acquisition Logs
    - Daily activities
    - Weather and sea state observations
    - Survey trackline ID and time
    - Unusual conditions and events
    - Water column noise
    - Vessel traffic and interference
    - Significant contacts
    - Deviation from planned tracklines
    - Data gaps

B. PROCESSING AND QUALITY CONTROL

B.1 Data Flow and Processing Procedures

B.1.1 Sound Speed Profile Processing

Sound speed profiles (svp format files) were derived from raw CTD and MVP data using Velocwin software. Procedurally, daily sound speed profiles, attributed with position and time of cast information, were concatenated for use in sound speed correction of survey lines in CARIS HIPS. Individual profiles were applied to specific lines as necessary.

B.1.2 SWMB Processing

SWMB processing procedures were designed to meet all requirements described in the SOW and HSSD.

I. Multibeam Sonar Conversion and Batch Processing

Multibeam sonar data conversion and application of sounding correctors were completed using the CARIS HIPS Batch Processor. The Batch Processor runs a user defined script which accomplishes the following standard tasks without user intervention:

1. Convert the pre-process HYPACK HYSWEEP HSX and RAW data to the HDCS data format.
2. Load daily True Heave files.
3. Load zoned, observed preliminary tides or verified tides once available.
4. Load and apply sound speed (SS) profile data. SS profiles were generally loaded with the CARIS *nearest in distance within time* correction method. When location-specific SS data were collected (e.g. deep water cast, channel), SS profiles were applied to individual lines as required.
5. *Merge* data to apply heave, vessel offsets/alignment, position, attitude, tide, and dynamic draft correctors to bathymetry. HIPS/SIPS computes the fully corrected depth and position of each sounding during the *merge* process.

6. Compute TPU (Figure 4). Total Propagated Uncertainty (TPU) is calculated in CARIS HIPS from contributing uncertainties in the echo sounder, positioning and motion sensor measurements as well as uncertainties associated with sound speed and water level correction. The standard CARIS devicemodel.xml was used to create the HIPS Vessel File (HVF). HVF uncertainty values are provided in Section C.1 Vessel Configuration and Offsets. Sound speed TPU values were estimated from manufacturer accuracy of the ODIM MVP-30, Sea-Bird SBE19 and SBE37. Tide TPU values used were in accordance with Section 4.1.6 Error Budget Considerations of the HSSD. (TPU is currently referred to as Total Propagated Error, TPE, in HIPS Version 6.1 and will be modified to TPU in the subsequent version).

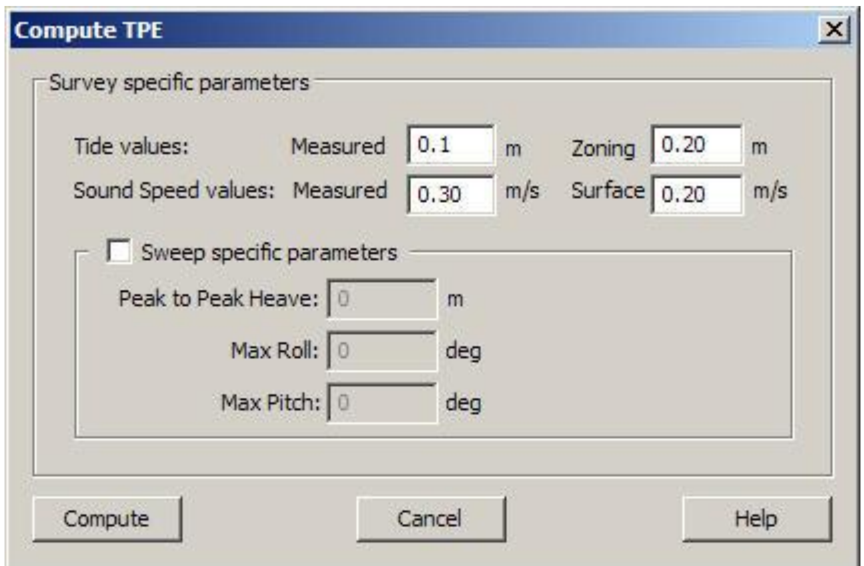

Figure 4. Tide and Sound Speed TPU parameters.

7. Filter data according to the following criteria:
    a. Reject soundings beyond 60^{o} off-nadir to remove outer beam noise and potential refraction errors.
    b. Reject soundings with poor quality flags, (0 and 1 for Reson system).

II. Preliminary BASE Surface Generation

Preliminary BASE surfaces were created using the *CARIS Uncertainty* algorithm for reviewing and cleaning full-density soundings. Daily data review and cleaning were performed using 1–5-meter resolution BASE surfaces as a guide for directed editing. Depth, Standard Deviation and Shoal surface models were viewed with vertical exaggeration and sun illumination to highlight areas that would require immediate investigation. Standard deviation BASE surfaces were reviewed to evaluate data for consistency between overlapping coverage and cross lines; and to detect potential systematic position, motion, tide, or sound velocity errors.

III. Data Cleaning and Editing

1. Line attitude and navigation data were reviewed in their respective CARIS editors to ensure that there were no problems with the correctors, such as gaps in attitude or navigation jumps. Extreme speed jumps were rejected with interpolation and data were re-merged, if needed.
2. The CARIS Swath Editor was used to clean noise, multipath returns, and gross fliers which are most easily reviewed and edited in this time-based (ping) display. Data were filtered on a line-by-line basis to isolate unique environmental conditions, events and features. Soundings were colored by depth and reviewed in multi-directional profile and 3-dimensional displays. Tracklines and swath boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data (RNC, ENC), SSS contacts and field annotations (HYPACK target files).
3. The CARIS Subset Editor was used to clean fully-corrected, geospatially located soundings in 2-D and 3-D displays. Soundings were colored with line, depth and uncertainty attributes. Areas with multiple sounding coverages from adjacent survey lines were evaluated to increase confidence in outer beams and over significant features. Subset boundaries were viewed in the CARIS Map window in reference to BASE surfaces, charted data (RNC, ENC), SSS contacts and, at times, field annotations (HYPACK target files). A complete final sounding review was performed for the entire survey coverage area and tracked with subset tiles.
4. Critical Soundings Management (CARIS convention)
    i. Outstanding - Flag a sounding as requiring further examination.
    ii. Examined - Flag questionable soundings or insignificant features as having been examined and deemed non-critical to navigation.
    iii. Designated – The Designated Sounding flag identifies the shoalest sounding of a feature. The purpose of the Designated Sounding flag is to ensure that the shoalest depths over significant seabed features or shoals are maintained in BASE surfaces (see following section), charts and other standard hydrographic products.

IV. BASE Surface Sounding Selection (*Designated Soundings*)

In areas of significant shoaling, critical soundings were designated on outstanding shoals and features to ensure the representative least depth for the area would be included in the final BASE surfaces. BASE surfaces were reviewed to ensure that shoal soundings were accurately represented by the surface resolution. For water depths ≤20 meters, soundings were designated on any object that had a difference between the gridded surface and reliable shoal depth greater than one half the allowable IHO Order 1 error budget for that depth. For water depths >20 meters, soundings were designated on any object that had a difference between the gridded surface and reliable shoal depth greater than the allowable IHO Order 1 error budget for that depth. Near nadir soundings were designated as least depths on shoal features in lieu of outer beam soundings whenever possible. Full density soundings were reviewed for each SSS contact in the CARIS Subset Editor and a sounding was designated for the representative least depth of each contact (or Primary/Secondary contact pair).

V. AWOIS, Contact and Feature Development BASE Surface Creation

When necessary, in addition to mainscheme data acquisition, development/investigation lines were run over AWOIS items, significant contacts and other features observed in SWMB and SSS records to meet the HSSD Complete Multibeam Coverage specification (Section 5.1.2.2). Once an item was deemed significant, nearly significant, or simply required more data to make a determination, a series of short, high density sounding lines were run over the feature. Fifty-centimeter resolution CUBE BASE surfaces were created over each feature and the immediate surrounding seabed to inspect sounding density. A 50-centimeter BASE surface was created using the CARIS HIPS implementation of the CUBE (Combined Uncertainty and Bathymetry Estimator) algorithm with advanced CUBE parameter settings configured to prove/disprove Object Detection Coverage per HSSD Section 5.1.2.1. The Capture Distance Scale and Capture Distance Minimum parameters were modified such that only the soundings that fell within a fixed radial distance of 0.35 meters of a node were used to calculate sounding density.

VI. Final BASE Surface Creation

Final BASE surfaces were created using the CUBE algorithm. The CUBE algorithm generates surface models from multiple hypotheses that represent the most accurate possible depths at any given position. Hypotheses with lower combined Total Propagated Uncertainty (TPU) are given higher significance for incorporation into the final surfaces.

The following options were selected when final CUBE surfaces were created:

- Surface Type – CUBE
- IHO (International Hydrographic Organization) S-44 Order 1
- Include status – Accepted and Designated
- Disambiguation method - Density & Locale
- Shallow configuration for less than 20 meters depth (Figure 5).

Final BASE surfaces were created to meet minimum requirements specified by the HSSD with exemptions detailed in a September 16, 2009 email. The exemptions are described as follows:

- For mainscheme multibeam bathymetry acquired concurrently with 200% side scan coverage ("skunk stripe"):

- Grid resolutions of 2m for depths less than 20 meters and 4m for depths 20 - 40 meters are acceptable.
- Minimum sounding density shall be 3 soundings per node.
- Small holidays in the multibeam coverage due to mid-water targets or attitude dynamics are acceptable where adjacent soundings show no evidence of significant shoaling, and the 200% side scan coverage does not indicate the presence of a feature.

- For multibeam developments of AWOIS items and significant targets identified in side scan sonar:
  - Coverage as per the "Object Detection Coverage" specification (Section 5.1.2.2) over the feature and the immediate surrounding seabed.

Critical soundings were incorporated into the BASE surfaces when finalized. Final BASE surface resolutions are unique for each survey area and are described specifically in the respective descriptive reports.

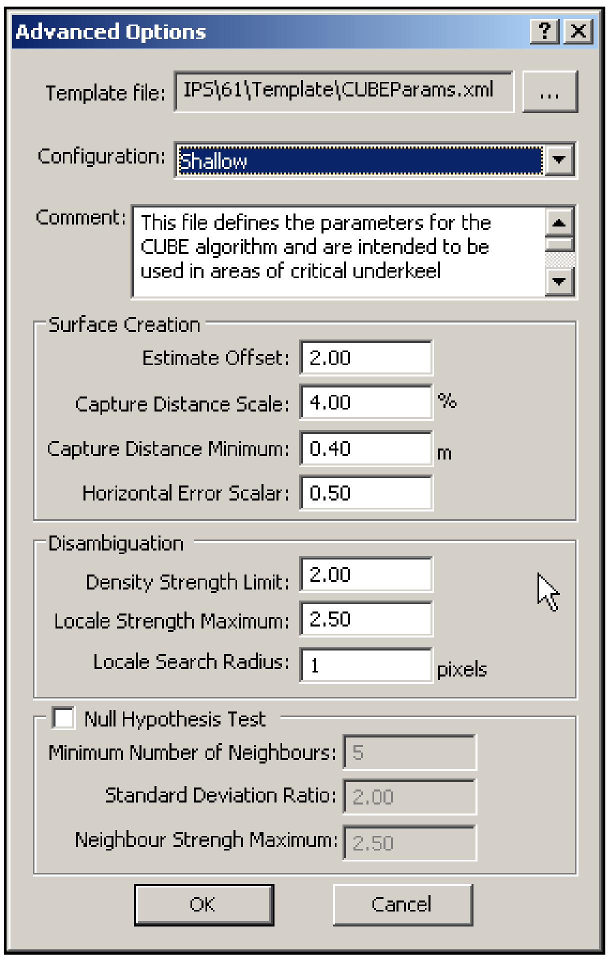

Figure 5. Example of CUBE Parameter selection.

VII. Sounding Density BASE Surface Creation

The Density Attribute Layer for CUBE BASE surfaces was used to evaluate the sounding density for fixed node spacing. Density requirements were evaluated as specified in Section VI.

The Density sounding selection area is based upon two CUBE parameters:

1. The Capture Distance Scale (CDS) defines a radial distance from the node which is based upon a percentage of water depth. The CDS value can range from 1 to 10 percent of the water depth. All soundings within this radius are included in the Density value (and propagated to the node).

2. The Capture Distance Minimum (CDM) defines a fixed radial distance in meters from the node in which all soundings are included in the Density value (and propagated to the node).

The maximum value of the two capture distance parameters is used to set the actual capture distance. These values can be manipulated to ensure that the capture distance minimum is the determining factor for the radius of influence and, therefore, define a fixed radius for calculating the sounding density.

Example for a 2-meter BASE surface in depths less than 20 meters:

CDS = 1
CDM = 2 / root(2) = 1.414 (maximum propagation distance defined in the HSSD 2009)

The CDS radius maximum value (0.01 * 20 = 0.2 meters) will not exceed the CDM value (1.414 meters) for the maximum depth, and therefore the Density Attribute Layer will represent those soundings that lie within a fixed radial distance (1.414 meters) for all nodes.

VIII. Combined Final Surface

All final BASE surfaces were combined at the resolution of the largest grid size of any one contributing surface. The combined final surface was used to generate contours and soundings for chart comparisons and final product review.

IX. Quality Control (QC)

1. Cross Lines
   Cross line data were acquired in accordance with the HSSD. Statistical quality control information is generated by comparing the beams of each cross line to a combined BASE surface. Cross line evaluations are performed with respect to IHO Order 1 uncertainty specifications with the CARIS QC Report Utility, and are presented in Separate IV of the DR.
2. BASE Surface QC Reports
   The TPU values for final BASE surface depths were evaluated with the CARIS BASE surface QC Report Utility with respect to IHO Order 1uncertainty specifications. BASE surface QC reports are presented in Separate IV of the DR.

B.1.3 Side Scan Sonar (SSS) Processing

SSS processing procedures were designed to meet all requirements described in the SOW and HSSD. Side scan sonar data were processed using CARIS SIPS and the following processes/procedures:

1. Convert the pre-process CTI SonarWiz XTF data to the HDCS data format in CARIS' Conversion Wizard. Vessel trackline positions were converted from the XTF bathymetry/ship position field. Towfish positions were converted from the XTF sensor position field and fish heading was computed from course made good (CMG) from vessel navigation. SonarWiz calculated the towfish position from layback and fish depth; therefore, it was not necessary to re-compute the towfish navigation or position in CARIS SIPS. Both 100 kHz and 500 kHz data were converted for review when the Klein 3000 was used.
2. Line attitude and navigation data were reviewed in their respective CARIS editors to ensure that there were no problems with the correctors, such as gaps in attitude or navigation jumps. Extreme speed jumps were rejected with interpolation.
3. After an initial review of the Sheet B 100 kHz and 500 kHz SSS data, the frequency that exhibited the least amount of noise and phase interference was selected to be processed for mainscheme SSS coverage. The Klein 5000, used exclusively on Sheets A, C & D, is a single frequency (455 kHz) instrument. Refraction impacted a small portion of the Klein 5000 imagery which was subsequently reacquired. Overall, refracting effects were much less prevalent in Sheets A, C & D.
4. SSS line imagery was reviewed in CARIS SIPS for water column interference and accurate bottom tracking. Bottom tracking was re-digitized when necessary, automatically by SIPS, or manually to ensure accurate slant range correction.

5. Slant range correct SSS imagery – A flat-bottom model and 1500 meter/second sound velocity was used to slant range correct line imagery at 0.1-meter resolution.
6. Angle varying gain correction (AVG) – Angle varying gain correction was applied to slant-range corrected SSS imagery to normalize angular response from varying sediments.
7. Contact processing:
    a. Slant range corrected line imagery was reviewed in SIPS to identify objects by the presence of sonar shadows.
    b. Shadow lengths were measured and converted to heights.
    c. Contacts with significant heights were positioned and created at the top of the shadow. Significant contacts were identified based upon height above the seafloor bottom in accordance with the SOW and HSSD (Table 4).
    d. Contacts were attributed with the following information:
        i. Height
        ii. Width (if significant)
        iii. Length (if significant)
        iv. Feature type (e.g. rock, obstruction, wreck, unknown)
        v. Processor remarks

Table 4
Significant Contact Selection Criteria

Surrounding Depth or Area (meters)	Significant Contact Height (meters)
0-20	1
>20	10% of surrounding depth

8. Contact correlation and bathymetric feature resolution:
    a. All contacts were visually correlated between 100% and 200% coverages in the CARIS Map window (Figure 6). Once correlated, contacts were evaluated with respect to BASE surfaces (i.e. depth and standard deviation), charted information, trackline swaths, and designated soundings. All significant contacts (or contact pairs) were evaluated in full density sounding subsets to ensure that there was adequate SWMB coverage. Soundings were designated on all significant contacts to obtain an accurate position and least depth.
    b. Significant contacts were visually correlated with designated soundings in the CARIS Map window.

c. Contacts, contact images and designated soundings were exported from CARIS. These data were processed with MS Excel to produce a contact spreadsheet as specified in the SOW and HSSD. A custom macro displayed contact images and remarks, calculated contact and designated sounding relationships (i.e. distances, depths), updated processing flags/remarks and associated contact/sounding pairs (Figure 7). Unique contact ID's were created from line-profile-range data. The contact spreadsheet is attributed with NAD83 positions and can be imported into a GIS.

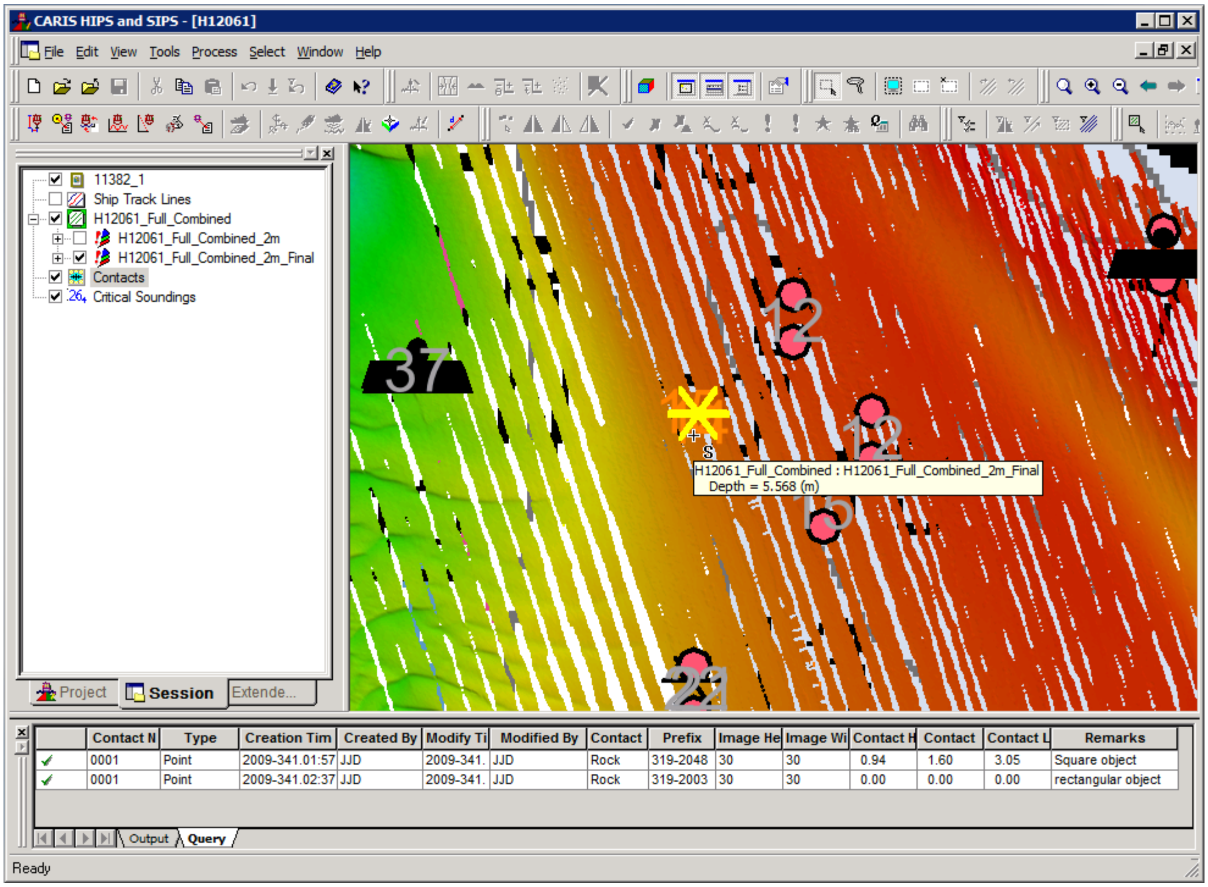

Figure 6. CARIS Map View Correlation Window.

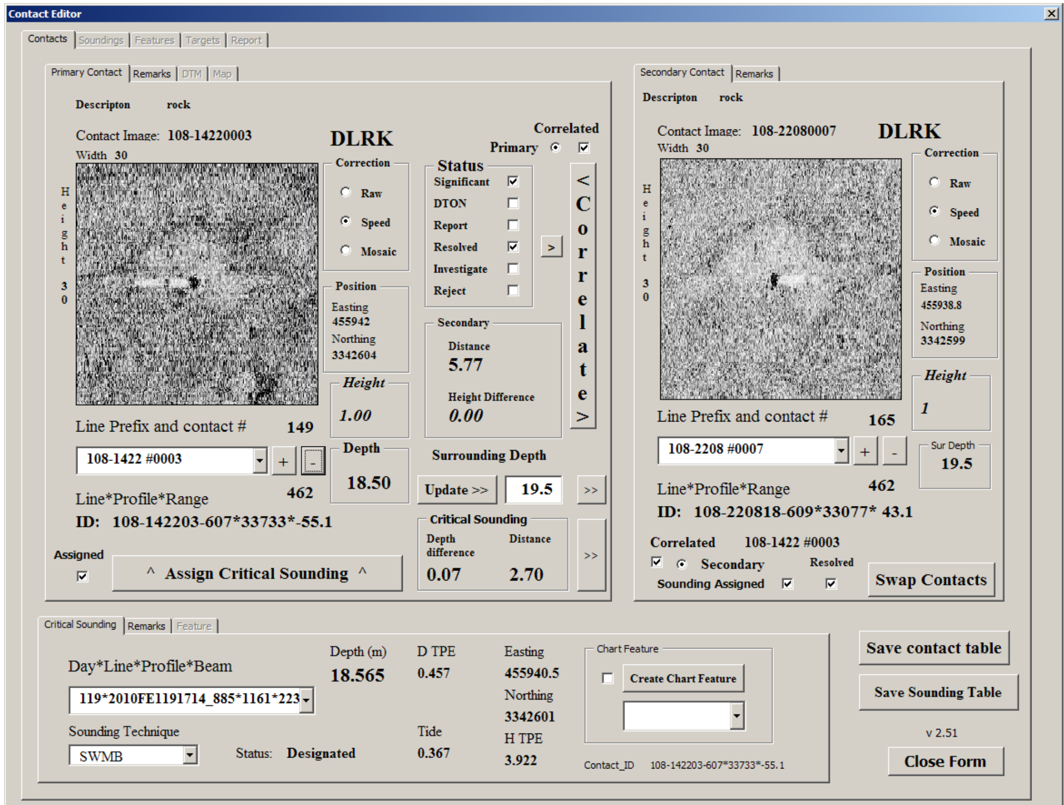

Figure 7. Spreadsheet correlation macro.

B.1.4 S-57 Feature Processing

An S-57 feature file was created in CARIS Notebook to emphasize navigationally significant objects discovered during the survey and to provide information for these objects that could not be portrayed in the BASE surfaces. Features' depths (VALSOU – value of sounding) and positions were extracted from soundings generated from the final combined BASE surface. Bottom samples were included as attributed SBDARE (Seabed Area) point objects. Separate CARIS HOB format files and a combined S-57 format 000 file were created for each survey.

All S-57 features were attributed in accordance with guidance provided in the SOW and HSSD using the following conventions:

- INFORM was used for survey descriptive information to aid in chart application. SBDARE bottom sample object INFORM attributes contain the original field descriptions of the sediment samples.
- SORDAT was attributed with the final date of the survey.
- SORIND was attributed with the country codes and survey registry (e.g. US, US, Surveys, H12060).

C. CORRECTIONS TO ECHO SOUNDINGS

C.1 Vessel Configuration and Offsets

C.1.1 CARIS Vessel Configuration Files and Device Models

SWMB CARIS Vessel Configuration Files (.hvf format with TPU calculation) were created to convert HYPACK RAW and HSX data files. The Reson 7101 device was configured from the default CARIS devicemodel.xml. Multibeam data were converted from RAW/HSX line file pairs. All raw geographic position data were converted from the HYPACK RAW format line files. All raw attitude sensor data were converted from HSX file structure. Vessel offsets, alignments and sensor installation accuracies were entered into the .hvf and used for TPU calculation. General vessel configuration and horizontal offsets are depicted in Figure 8 and Figure 9.

SSS CARIS Vessel Configuration files were created to convert CTI SonarWiz XFT data files. The SSS vessel file is a “zero” configuration because all towpoint offset and layback calculations were performed in SonarWiz. No additional towfish position calculation was necessary in CARIS SIPS.

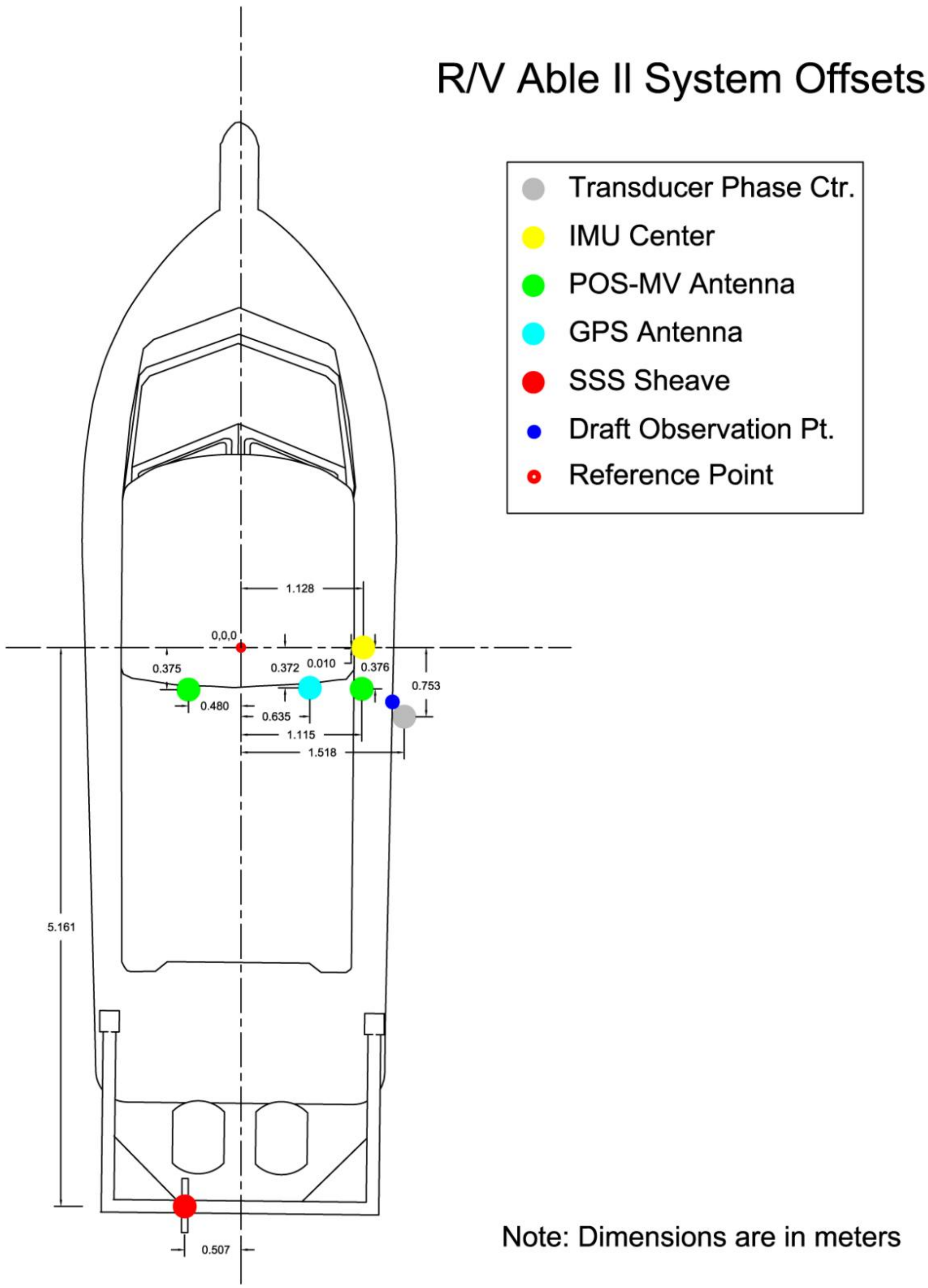

Figure 8. *R/V Able II* equipment offsets and configuration.

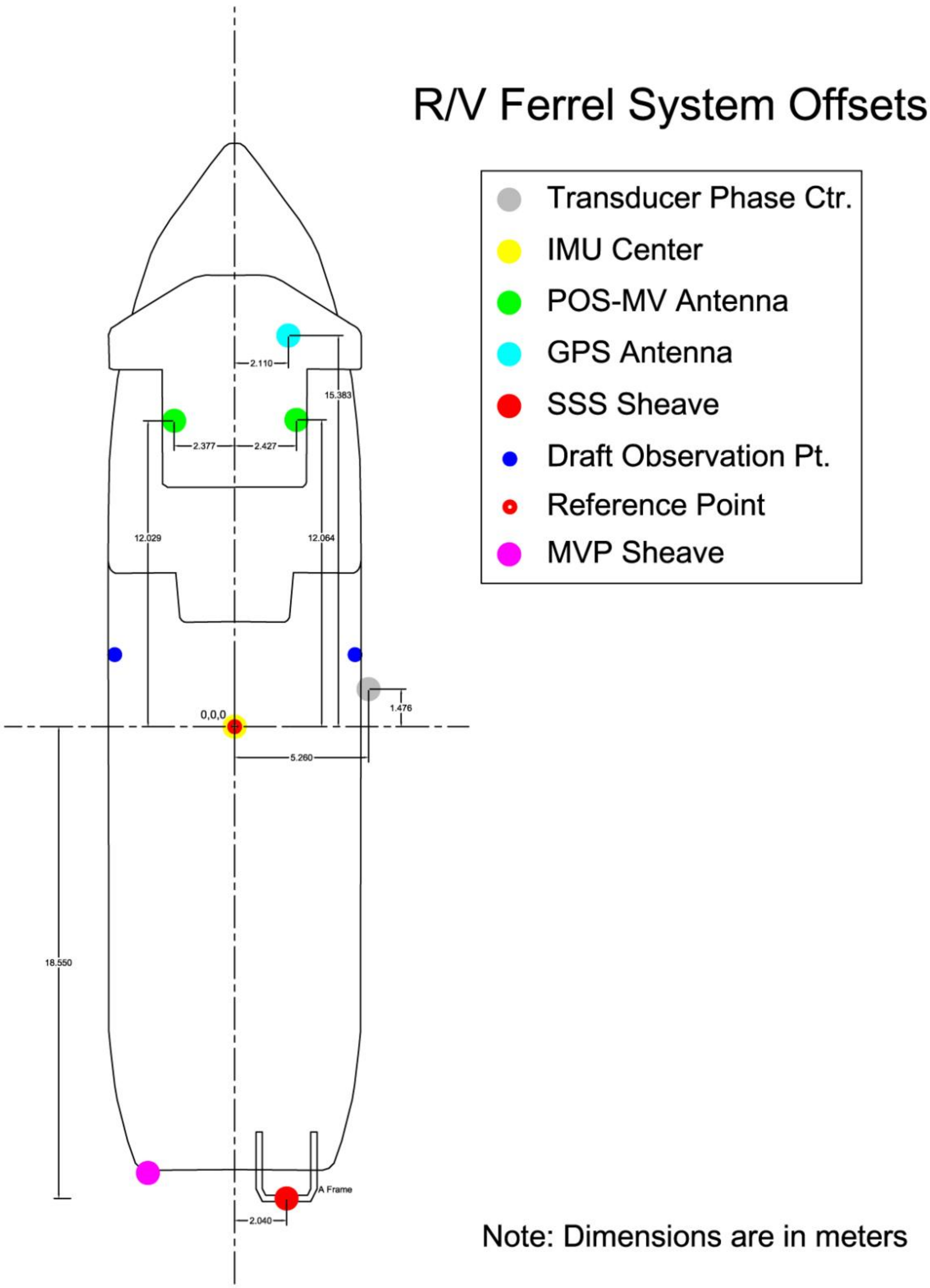

Figure 9. *R/V Ferrel* equipment offsets and configuration.

C.1.2 Offsets and Uncertainty Estimates

Tables of instrument offsets and Total Propagated Uncertainty (TPU) values input to the CARIS vessel configuration file are included in Tables 5-10 below. A bar check was performed prior to survey data acquisition to measure the transducer phase-center vertical offset with respect to the vessel reference point.

Table 5
***R/V Able II* Sensor Offsets (see Figure 8)**

***R/V Able II* Offsets via Topcon Total Station Survey. Offsets are relative to Reference Point (R/P) or Waterline**	**Forward Positive (m)**	**Starboard Positive (m)**	**Up Positive w.r.t R/P (m)**	**Up Positive w.r.t. waterline (m)**
R/P Washer On Deck Vessel 0,0,0	0.000	0.000	0.000	0.015
GPS POS Antenna Phase Center Port	-0.375	-0.480	2.307	2.322
GPS POS Antenna Phase Center Starboard	-0.376	1.115	2.285	2.300
GPS Antenna Phase Center	-0.372	0.635	2.400	2.415
Transducer Phase Center	-0.753	1.518	-0.905	-0.890
Top Of Sheave (Wire at top of sheave)	-5.161	-0.507	2.100	2.115
IMU Center	-0.010	1.128	0.350	0.365

Table 6
***R/V Ferrel* Sensor Offsets (see Figure 9)**

***R/V Ferrel* Offsets via Topcon Total Station Survey. Offsets are relative to Reference Point (R/P) or Waterline**	**Forward Positive (m)**	**Starboard Positive (m)**	**Up Positive w.r.t R/P (m)**	**Up Positive w.r.t. waterline (m)**
R/P IMU Center 0,0,0	0.000	0.000	0.000	-0.840
GPS POS Antenna Phase Center Port	12.029	-2.377	10.962	10.122
GPS POS Antenna Phase Center Starboard	12.064	2.427	10.957	10.117
GPS Antenna Phase Center	15.383	2.110	11.047	10.207
Transducer Phase Center	1.476	5.260	-1.770	-2.610
Top Of Sheave (Wire at top of sheave)	-18.550	2.040	4.080	3.240

Table 7
***R/V Able II* CARIS Vessel File Transducer Offsets (RP to Tx)**

Tx Offsets	**IMU/Navigation to Transducer (m)**
X Phase Center	1.518
Y Phase Center	-0.753
Z Phase Center	0.905

Table 8
***R/V Ferrel* CARIS Vessel File Transducer Offsets (RP to Tx)**

Tx Offsets	IMU/Navigation to Transducer (m)
X Phase Center	5.260
Y Phase Center	1.476
Z Phase Center	1.770

Table 9
***R/V Able II* CARIS Vessel File TPU Estimates**

TPU Values Included in CARIS VCF			
Gyro Measurement Error (deg)	0.02	Pitch Timing Error (sec)	0.01
Heave % Amplitude	5.00	Roll Timing Error (sec)	0.01
Heave Error (m)	0.05	Vessel Speed Error (m/s)	0.03
Roll Measurement Error (deg)	0.02	Loading Error (m)	0.03
Pitch Measurement Error (deg)	0.02	Draft Error (m)	0.03
Navigation Measurement Error (m)	2.00	Delta Draft Error (m)	0.03
Transducer Timing Error (sec)	0.01	Tide Measurement Error (m)	0.10
Navigation Timing Error (sec)	0.01	Tide Zoning Error (m)	0.20
Gyro Timing Error (sec)	0.01	Sound Speed Error (m/s)	0.30
Heave Timing Error (sec)	0.01	Sound Speed Error Surface (m/s)	0.20

Table 10
***R/V Ferrel* CARIS Vessel File TPU Estimates**

TPU Values Included in CARIS VCF			
Gyro Measurement Error (deg)	0.01	Pitch Timing Error (sec)	0.01
Heave % Amplitude	5.00	Roll Timing Error (sec)	0.01
Heave Error (m)	0.05	Vessel Speed Error (m/s)	0.03
Roll Measurement Error (deg)	0.02	Loading Error (m)	0.03
Pitch Measurement Error (deg)	0.02	Draft Error (m)	0.03
Navigation Measurement Error (m)	2.00	Delta Draft Error (m)	0.03
Transducer Timing Error (sec)	0.01	Tide Measurement Error (m)	0.10
Navigation Timing Error (sec)	0.01	Tide Zoning Error (m)	0.20
Gyro Timing Error (sec)	0.01	Sound Speed Error (m/s)	0.30
Heave Timing Error (sec)	0.01	Sound Speed Error Surface (m/s)	0.20

C.2 Static and Dynamic Draft Measurements

C.2.1 Static Draft

On the *R/V Able II*, static draft was measured from a permanent benchmark on the starboard gunwale to the waterline using a steel tape. The vessel attitude was adjusted to level the roll axis during the measurement. The draft measurement was corrected to the vessel reference point and recorded in the acquisition log. Static draft values were time stamped and entered into the CARIS vessel configuration file.

On the *R/V Ferrel*, static draft was measured from a permanent benchmark on both starboard and port sides to the waterline using a fiberglass stadia rod. Vessel attitude was accounted for as the final measured static draft value is an average of the port and starboard measured values.

A Hazen tide gauge was also installed within the transducer mount pole to monitor the draft of the transducer. The static draft measurement was calculated daily using the Hazen tide gauge method and the measure down values were acquired when sea conditions allowed. The draft measurement was corrected to the vessel reference point and recorded in the acquisition log. Static draft values calculated from physical measurement, “measure downs,” or the Hazen gauge data, were time stamped and entered into the CARIS vessel configuration file.

The Hazen tide gauge pressure sensor was installed at a fixed elevation within the transducer pole. The transducer mounting flange at the bottom of the transducer pole was fitted with a small diameter copper orifice making the transducer pole, in effect, a stilling well. Once per day, survey operations were suspended on the *R/V Ferrel* and the vessel was brought to a full stop, enabling a static draft measurement. On calm days, “measure downs” from the port and starboard draft observation locations (Figure 9) were acquired. However, on most days, the water surface was too rough for a reliable physical measurement. In these cases, the Hazen-derived water level (draft measurement) was entered to the HVF.

Prior to data acquisition the *R/V Ferrel* was secured to a pier in very calm conditions. A number of physical measurements were then made from both port and starboard draft observation locations to the water surface. During this period, the Hazen gauge (input to HYPACK) was used to record water levels within the transducer pole. The Hazen data were processed and compared to the physical measurements. The delta between these datasets was determined and subsequently used to convert Hazen water level information to static draft.

C.2.2 Settlement and Squat (Dynamic Draft)

The dynamic draft of both survey vessels was determined using RTK GPS methods. In each case a GPS base station was established onshore near the test area and the POS-MV was configured to operate in RTK "FIX" mode. Position and elevation data were obtained as the vessel transited "up and down" a pre-determined trackline at a set RPM. Tidal variations were accounted for by recording the GPS position and elevation values with the vessel at rest (i.e. dead in the water) at the beginning and end of each RPM-setting reciprocal line pair. Dynamic draft measurements were made at select RPM intervals within the range of possible survey speeds. The final dynamic draft values were then determined by averaging the results of each RPM pair. The data points displayed in Figures 10 and 11 and noted in Tables 11 and 12 were entered in the CARIS vessel file for the respective vessels.

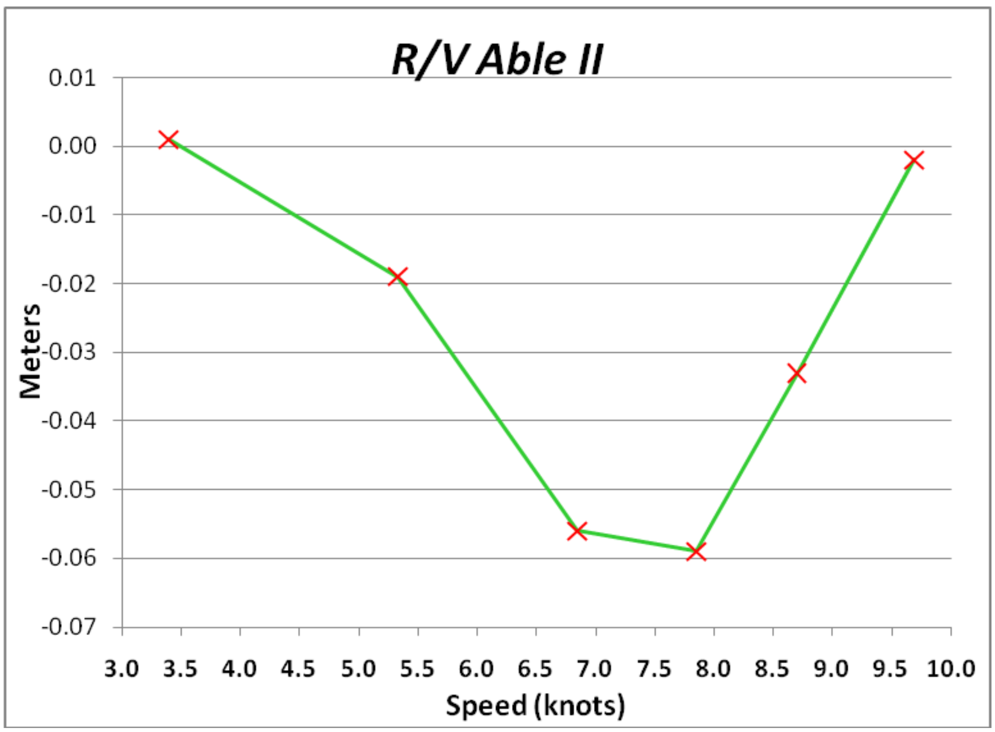

Figure 10. *R/V Able II* Dynamic Draft Curve.

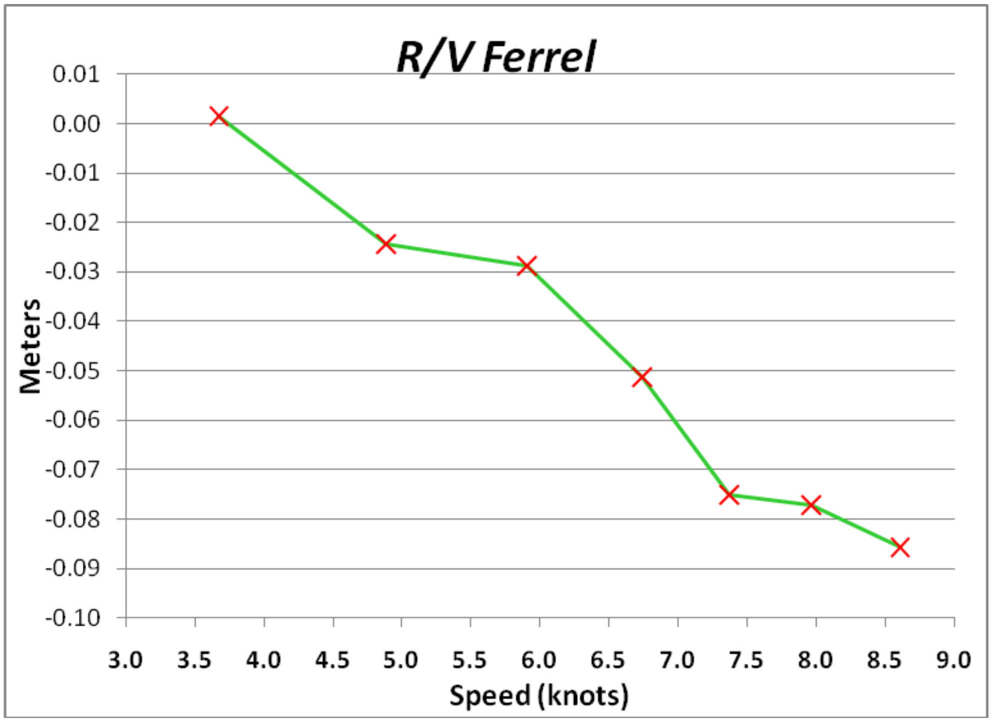

Figure 11. *R/V Ferrel* Dynamic Draft Curve

Table 11
***R/V Able II* Dynamic Draft Correctors**

***R/V Able II* 7101 Multibeam/SSS Dynamic Draft Correctors**			
RPM's	**Speed**		**Dynamic Draft**
Both Engines	**M/S**	**Knots**	**Meters**
1,000	1.74	3.39	-0.001
1,500	2.74	5.33	0.019
2,000	3.52	6.84	0.056
2,500	4.04	7.85	0.059
3,000	4.47	8.70	0.033
3,500	4.98	9.69	0.002

Table 12
***R/V Ferrel* Dynamic Draft Correctors**

***R/V Ferrel* 7101 Multibeam/SSS Dynamic Draft Correctors**			
RPM's	**Speed**		**Dynamic Draft**
Both Engines (unless noted)	**M/S**	**Knots**	**Meters**
680 (1 engine)	1.89	3.67	-0.002
680	2.52	4.89	0.024
800	3.04	5.91	0.029
900	3.47	6.74	0.051
1000	3.79	7.37	0.075
1100	4.10	7.97	0.077
1200	4.43	8.61	0.086

C.3 Motion, Timing Errors and Sensor Alignment

An Applanix POS MV 320 V.4 was employed for motion, heading, and position determination. Manufacturers stated accuracy and resolution values are tabulated below in Table 13.

Table 13
POS MV Specifications

POS MV 320 V.4 Manufacturers Specifications		
Parameter	**Accuracy**	**Resolution**
Roll	0.02°	0.01°
Pitch	0.02°	0.01°
Heave	5cm or 5% of wave height	0.01m
Heading	0.02°	0.01°

Prior to commencement of survey operations, a sensor alignment or patch test was performed. The initial patch test for the *R/V Able II* was performed on October 23, 2009 (DN 296) and the initial patch test for the *R/V Ferrel* was performed on April 5, 2010 (DN 095). The patch tests were conducted in order to determine biases in roll, pitch, heading and navigation timing. Data were acquired in accordance with HSSD April 2009 Section 5.1.4.1. For each vessel, initial patch test calibrations were accomplished employing RTK GPS positioning and water level determination.

Each set of patch test lines were run multiple times to ensure system repeatability. Patch test biases were determined in the following order: navigation timing error (latency), pitch, roll, and heading. The CARIS HIPS Calibration Tool (Figure 12) was primarily used to determine offset values. However, all patch test values were verified with the HYPACK HYSWEEP patch test routine (Figure 13).

For each parameter, multiple processing iterations were performed. The final offset values for each vessel are an average of the CARIS-derived values. The final applied values, entered into the respective CARIS vessel files, are shown in Table 14 and Table 15. The patch tests results were of high quality and repeatability.

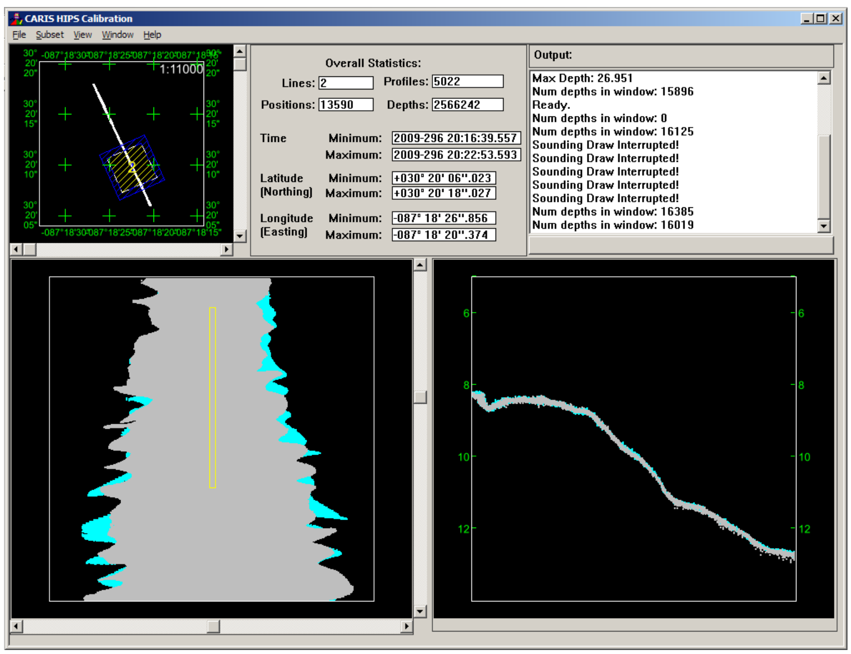

Figure 12. CARIS HIPS Calibration Tool

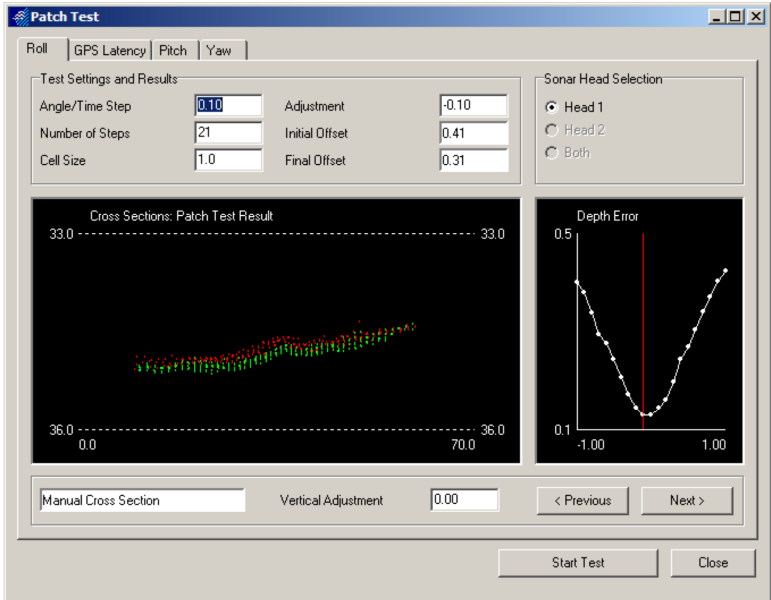

Figure 13. HYPACK HYSWEEP Patch Test Utility.

Table 14
Initial *R/V Able II* Patch Test Alignment Correctors

CARIS Patch Test Results	
Latency	0.0 sec
Pitch	-0.30 deg
Roll	-0.06 deg
Yaw (heading)	-0.10 deg

Table 15
Initial *R/V Ferrel* Patch Test Alignment Correctors

CARIS Patch Test Results	
Latency	0.0 sec
Pitch	-0.25 deg
Roll	0.44 deg
Yaw (heading)	-0.30 deg

C.4 Water Levels

The tidal datum for this project is Mean Lower Low Water (MLLW). All sounding depths are referenced to MLLW. The operating National Water Level Observation Network (NWLON) station at Pensacola, FL (872-9840), served as datum control for this project.

The water level station at Pensacola, FL (872-9840), is the reference station for predicted, preliminary observed and verified tides for all hydrography for this project. The time and range ratio correctors for applicable zones were applied to all tide correctors in CARIS HIPS during the preliminary and final processing phases of this project. Predicted and preliminary observed zoned tides were applied to sounding data for preliminary processing. Verified tide data were downloaded from the NOAA CO-OPS Internet page http://tidesandcurrents.noaa.gov/olddata and applied with final zoning for all final soundings and BASE surfaces. Water levels used for DTON submissions are specified in the reports. Additional information is provided for this survey in the VHCR and DR.

D. APPROVAL SHEET

LETTER OF APPROVAL

REGISTRY NOS. H12060, H12061, H12062, AND H12157

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H12060, H12061, H12062, and H12157 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the Statement of Work.

George G. Reynolds
Ocean Surveys, Inc.
Chief of Party
August 18, 2010