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

DATA ACQUISITION & PROCESSING REPORT

Type of Survey:	Hydrographic Survey
Project Number:	OPR-K339-KR-13
Time Frame:	November 2013-January 2014

LOCALITY

State:	Louisiana
General Locality:	Gulf of Mexico
Sub-locality:	Approaches to Barataria Bay, LA

2014

CHIEF OF PARTY

George G. Reynolds

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Date:

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY NUMBERS:
HYDROGRAPHIC TITLE SHEET	H12550, H12551 H12552, H12553

State:	**Louisiana**
General Locality:	**Gulf of Mexico**
Sub-Locality:	**Approaches to Barataria Bay, LA**
Scale:	**1:40,000**
Date of Survey:	**November 9, 2013 to January 20, 2014**
Instructions Dated:	**April 16, 2013**
Project No.:	**OPR-K339-KR-13**
Vessel:	**R/V Ferrel - Official Number 1182802**
Chief of Party:	**George G. Reynolds**
Surveyed By:	**Ocean Surveys, Inc.**
Soundings by:	**Multibeam Echosounder**
Imagery by:	**Side Scan Sonar**
Verification by:	**Atlantic Hydrographic Branch**
Soundings Acquired in:	**Meters at MLLW**
H-Cell Compilation Units:	

Remarks: The purpose of this survey is to update existing NOS nautical charts in a high commercial traffic area. All times are recorded in UTC. Data recorded and presented relative to UTM Zone 16 North.

Contractor: Ocean Surveys, Inc.
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APPENDICES

A. EQUIPMENT

A.1 Survey Vessel: *R/V Ferrel*

All survey operations were conducted from the *R/V Ferrel* (Figure 1). *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 CAT D 353 diesel engines.

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

The *R/V Ferrel* was modified to support hydrographic survey operations by Oceans Surveys, Inc, hereinafter referred to as OSI. 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, thereby eliminating pole movement. The transducer pole was fitted with fairings on the trailing edge to minimize cavitation. The bottom of the transducer pole was fitted with termination flange configured with a small copper orifice. This configuration allowed the transducer pole to be used as a stilling well.
4. 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.
5. A moving vessel profiler (MVP) was installed on the port quarter of the ship.

A full survey of the *R/V Ferrel* was conducted March 31, 2010 by OSI during which reference points (permanent shipboard benchmarks) were established on the *R/V Ferrel* 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 while the vessel was hauled out and held static at a dry dock facility.

Prior to the start of survey operations for OPR-K339-KR-13, a full offset verification to confirm instrument and shipboard benchmark locations aboard the *R/V Ferrel* was completed by OSI employing a steel tape measure on November 8, 2013. All checks confirmed values derived during the original full static survey.

The multibeam transducer pole is capable of variable draft settings. During the 2013 vessel mobilization the transducer phase center-to-RP value was established relative to shipboard benchmarks employing a steel tape measure. Survey offsets and estimated measurement accuracies were incorporated into the CARIS vessel configuration file.

Major data acquisition system components that were employed during the project are summarized in Table 1 below. A brief description of the equipment follows.

Table 1
Acquisition Equipment

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Side Scan Sonar Towfish	Imagery/Contacts	Klein	5000	N/A	357
Side Scan Sonar Processor	Imagery/Contacts	Klein	5000	Sonar Pro 11.3	191
Side Scan Sonar Towfish	Imagery/Contacts	EdgeTech	4200 MP	N/A	46846 46929
Side Scan Sonar Processor	Imagery/Contacts	EdgeTech	701-DL	Discover 4200 MP V.8.24	39487
Multibeam Echosounder Processor	Soundings	Reson	7125 SV2	SV2 SP4 7K 6,0,0,6	18342213063
Multibeam Echosounder Transducer	Soundings	Reson	7125 SV2	N/A	Proj. 472049 Rec. 212063
Sound Speed Profiler	QC Comparison Sound Speed	Sea-Bird	SeaCAT SBE 19+ CTD	2.3	6513
Surface Sound Speed	Sound Speed	AML	Micro X w/ SV-Exchange.	N/A	10315 MicroX 203524 SV Ex
Moving Vessel Profiler	Sound Speed	ODIM	MVP-30	MVP Controller 2.43	10646
Sound Speed/Depth (2)	Sound Speed	AML	Micro SVPT PT (SV)	N/A	201525 (7777) 201527 (7786)
Navigation, Vessel Attitude & Heading	Position, Attitude, Heading	Applanix/ Trimble	POS MV 320 V.4	HW 1.1-7 SW 05.03	TPU 3352 IMU 861
Navigation	Position	Trimble	MS750	1.58	220332327
U.S.C.G. Differential Beacon Receivers (2)	DGPS correctors	Trimble	ProBeacon	3	0220033958 0220181939
SSS Cable Payout Indicator	SSS Fish Layback	Hydrographic Consultants	SCC16”	2	2027

System	Data	Manufacturer	Model/ Version No.	Firmware/Software Ver.	Serial Number (s)
Land Survey GPS	RTK GPS Base Station	Trimble	5700	V3.01	220332818
Water Level Gauge	Static Draft	Hazen	HTG5000	N/A	363764R
Lead Line	Bar Check	OSI	Lead Disk	N/A	2010A
Stadia Rod	Static Draft	Crain	CR-4.0M	N/A	OSI SR-02
Autopilot	Vessel Steering	Simrad	AP50	V1R4	22083083

A.2 Echo Sounding Equipment

A.2.1 Side Scan Sonar Systems

A.2.1.1 Klein 5000

The primary side scan sonar imaging tool was a Klein 5000 single-frequency sonar operating at 455 kHz. The system was operated at 50, 75, and 100 m ranges. The system consists of a Transceiver Processor Unit (TPU), coaxial double armored steel tow cable, hydraulic powered slip ring winch, digital cable payout meter, and sonar towfish. System components were interfaced to the acquisition system and other ancillary devices, via a local network hub or serial cable connections. The towfish was equipped with a pressure sensor which was used to measure towfish depth. A SSS calibration test was performed on November 9, 2013 (DN 313) for the Klein 5000 system and is documented in the DAPR Appendix II: Echosounder Reports.

Figure 2. Klein 5000

A.2.1.2 EdgeTech 4200 MP

Due to the Klein 5000's sensitivity to wave-generated surface noise an EdgeTech 4200 MP (multi-pulse) side scan sonar system was used to acquire imagery on days when the sea surface was relatively rough, i.e. covered with white caps. The 4200 MP is a dual-frequency sonar capable of operating at 100 kHz and/or 400 kHz. For this survey the system was operated exclusively employing the "high speed" mode using only the 400 kHz frequency. Of the available range scales, only the 50 and 75 meter settings were used. The system consists of a Transceiver Processor Unit (TPU), coaxial double armored steel tow cable, hydraulic powered slip ring winch, digital cable payout meter, and sonar towfish. System components were interfaced to the acquisition system and other ancillary devices, via a local network hub or serial cable connections. The towfish was equipped with a pressure sensor which was used to measure towfish depth. Two separate 4200 MP towfish, having identical specifications, were employed. Calibration tests for both EdgeTech 4200-MP systems were performed; the first on November 30, 2013 (DN 334) for the towfish with SN# 46846 and the second on December 11, 2013 (DN 345) for the towfish with SN# 46929. The SSS calibration test results are documented in the DAPR Appendix II: Echosounder Reports.

Figure 3. EdgeTech 4200 MP

A.2.2 Multibeam Echosounder

A.2.2.1 Reson SeaBat 7125 SV2

The SeaBat 7125 SV2 is a dual-frequency Multibeam Echosounder (MBES) System with operational frequencies of 200 kHz or 400 kHz. For Project OPR-K339-KR-13, the echosounder's 400 kHz capability was employed. At this frequency the 7125 system illuminates a swath of the seafloor that is 140º across track by 1.1º along track with a maximum ping rate of 50 Hz. The system can be configured with numerous beam density and swath angle combinations. The 512-equidistant beam configuration was used for Project OPR-K339-

KR-13. The manufacturer's stated depth resolution is 6 mm. This sonar system, as employed, is designed to comply with International Hydrographic Organization (IHO) standards to measure seafloor depths to a maximum range of 175 meters. Digital data were output through the Ethernet data port and displayed in real time on a high-resolution color monitor.

Figure 4. Reson 7125 transducer as mounted.

The transducer X, Y, Z position and angular offsets (relative to the vessel frame and a vessel reference position (RP)), were referenced to values derived during the original full static survey in 2010 (OPR-J364-KR-09). These values were confirmed during the "partial" survey prior to use of this sonar on Project OPR-K339-KR-13. A patch test and performance test were completed on November 10, 2013 (DN 314) prior to commencement of survey operations. A verification patch test and performance test were run on January 20, 2014 (DN 020) following the completion of survey operations. Patch test and performance test results are presented in DAPR Appendix II.

A Sea-Bird Electronics SBE37 sound speed sensor (shown protruding aft of the MBES transducer in Figure 4) was mounted to the MBES framework as a back-up for the primary surface sound speed measuring tool, an AML Micro X sound speed sensor. The AML Micro X sensor functioned properly throughout the project; therefore, the SBE37 was not employed.

A.3 Manual Sounding Equipment

A.3.1 Lead Line

The lead line was constructed by OSI utilizing a 9 kilogram, 0.3-meter round lead disk attached to a stainless steel cable with permanent index markers established at measured 1-meter intervals (from 1-10 meters) and then 2-meter intervals thereafter.

Prior to survey operations the lead line was calibrated on October 8, 2013 (DN 281) with a steel survey tape to verify index mark accuracy.

A.4 Positioning and Attitude Equipment

A.4.1 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. Per manufacturer's literature there are two navigation algorithms incorporated into the system, namely a tightly coupled and a loosely coupled inertial/GPS integration. Tightly coupled inertial/GPS integration involves the processing of GPS pseudo range, 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 generates attitude data in three axes (roll, pitch and heading). Roll and pitch measurements are made within an accuracy of 0.02°. 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 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 an antenna baseline ≥ 2-meter) when blended with the inertial navigation solution. The system uses this heading information together with the position, velocity and raw observations information supplied by the primary GPS receiver. GAMS heading 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 RP, were measured during the original (2010) full static survey and confirmed prior to commencement of Project OPR-K339-KR-13. An Applanix-specified GAMS calibration procedure was conducted prior to survey data acquisition on November 9, 2013 (DN 313).

A.4.2 DGPS

Individual Trimble Pro Beacon DGPS beacon receivers were manually tuned to one of the two local USCG differential beacon stations and interfaced to the project GPS systems (POS-MV and Trimble MS750). Refer to the Vertical and Horizontal Control Report for additional details of DGPS position correctors.

A.4.3 Other Positioning and Attitude Equipment

A.4.3.1 Secondary Positioning: Trimble MS750

A secondary or "position integrity alarm" GPS system consisted of a Trimble MS750 GPS operating in DGPS mode.

A.4.3.2 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.

A.5 Sound Speed Equipment

The surface sound speed sensor, the sound speed comparison profiler, and the undulating velocimeter (ODIM MVP) sensors were manufacturer calibrated just before survey data acquisition. Copies of the calibration sheets are included in DAPR Appendix IV.

A.5.1 Sound Speed Profiles

A.5.1.1 CTD Profiler: SBE 19+ CTD

"Comparison Cast" water column conductivity, temperature, and pressure (depth) profiles were acquired using a Sea-Bird Electronics (SBE) 19+ SEACAT profiler CTD. The SBE 19+ SEACAT profiler acquires high resolution water column measurements at a continuous rate of 4 Hz.

A.5.1.2 Sound Speed Profiler: ODIM MVP30

The ODIM MVP30 Moving Vessel Profiler allows sound speed profiles to be collected while the vessel is underway. The ODIM MVP consists of towfish-mounted sensors (AML sound speed, temperature, and depth "micro SVPT"), an electro-mechanical 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 MVP 30 was the primary sound speed profiler employed during this survey. Sound speed data from the SBE19+ CTD (comparison cast data) and AML Micro X (surface sound speed at MBES transducer) were frequently referenced to confirm proper operation of the MVP 30 (AML) sensors.

Figure 5. MVP 30 as mounted on the vessel stern.

A.5.2 Surface Sound Speed: AML Micro X

The AML Micro X is a high-accuracy sound speed sensor capable of measuring and transmitting sound speed data directly to the MBES via a manufacturer-supplied data cable. The Micro X, mounted within the bow faring of the MBES transducer, transmitted real-time surface sound speed data to the Reson 7125 multibeam system and the HYPACK acquisition computer via the Reson interface. The Micro X, like the AML SVPT sensor discussed above, uses a sound speed "exchange" sensor.

A.6 Horizontal and Vertical Control Equipment

A.6.1 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 temporary horizontal control/navigation checkpoints located at the vessel's fueling dock. The checkpoints were established in 2012

(OPR-K339-KR-12) using a Trimble 5700 GPS system configured with a Trimble Zephyr Geodetic antenna.

A.6.2 Pressure Gauge: Hazen Water Level Gauge

Data from a Hazen water level gauge were used to calculate vessel static draft values while the vessel was offshore. The Hazen gauge consists of a vented pressure transducer connected to a top-side transmitter. The transmitter communicates with a remote receiver via radio link. The Hazen gauge transducer was installed well below the waterline at a fixed elevation within the multibeam transducer pole. As mentioned earlier, the sealed base of the multibeam pole was configured with a small copper orifice, in effect making the transducer pole a stilling well. The physical offset between the sensor and vessel draft was established dockside during a series of physical draft measurements versus sensor value observations (static dockside calibration).

During offshore operations, sensor data were logged once a day (when practical) when the vessel was at full stop. The sensor was configured to record a water level at a rate of 2Hz. The receiver was interfaced with the acquisition computer through a serial port and the water level reading was logged to a HYPACK .RAW file for at least 10 minutes while the ship was at a full stop. The average sensor value for the term of the observation was used for each offshore static draft calculation. Sensor readings were adjusted based on the derived fixed offset value established during the static dockside calibration procedure. This approach allowed the field team to accurately track vessel static draft despite offshore conditions.

A.6.3 Stadia Rod

A fiberglass stadia rod was employed throughout the survey for various tasks requiring a rigid measuring tool. Due to the relatively high freeboard of the *R/V Ferrel*, manual static draft measurements were accomplished employing the stadia rod. Static draft measurements were made relative to permanent shipboard benchmarks which were related to the vessel RP during the 2010 full ship survey (confirmed during 2013 “partial” survey). Prior to utilization, the rod graduations were compared to a steel tape measure to confirm accuracy.

A.7 Additional Acquisition Equipment

A.7.1 Bottom Sampler

A sediment sampler was employed to obtain seafloor sediment samples within the survey area. A PowerWinch system aboard the *R/V Ferrel* was employed to recover the unit.

A.7.2 Auto Pilot

A Simrad AP50 Marine Autopilot was installed to steer the vessel during concurrent MBES and SSS mainscheme data acquisition. When activated, the Autopilot controlled the rudder adjustments to keep the vessel on line.

A.8 Computer Hardware and Software

A.8.1 Computer Hardware

Table 2
Computer Hardware

Use	Manufacturer	Model	Operating System
MBES Acquisition	Dell	Vostro 420	Windows XP
SSS Acquisition	Dell	Vostro 420	Windows XP
MVP Acquisition	Hewlett Packard	HP 530	Windows XP
Data Processing	CyberPowerPC	GX3000Z	Windows 7
Data Processing	CyberPowerPC	GX3000Z	Windows 7

MBES acquisition was completed using HYPACK software installed on a Windows XP computer which has a 3.16 GHz Intel Core 2 Duo processor, a 320 gigabyte (GB) hard drive, a 2 terabyte (TB) hard drive and 4.0 GB of RAM. This computer was also used to monitor the MV POSView controller and record POSPac data.

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 GB hard drive, a 2 TB hard drive and 4.0 GB of RAM.

Data processing was completed using two Windows 7 computers with 3.50 Ghz Intel Core i7-2700K 64-bit processors (8 core CPU), 120 GB program drives, 1 TB solid state drives in speed configuration, 2 TB hard drives in redundant configuration, and 16 GB of RAM.

A.8.2 Computer Software

Computer software utilized during this survey is itemized in Table 3 below.

Table 3
Computer Software

Manufacturer	Application	Version	Version Date
HYPACK	HYPACK SURVEY	13.0.9.21	April 24, 2013
HYPACK	HYSWEEP SURVEY	13.0.13.0	June 25, 2013
Chesapeake Technology, Inc.	SonarWiz	5.06.0037	Oct. 18, 2013
L3 Klein	SonarPro	11.3	Aug. 13, 2008
EdgeTech	Discover 4200-MP	8.24	June 28, 2012
Universal Systems, Ltd.	CARIS HIPS/SIPS	7.1.2	SP2 2012
Universal Systems, Ltd.	CARIS Notebook	3.1.1	SP1 2011
HYPACK	MBMax	13.0.1.0	Jan.28, 2013
NOAA	NOAA Velocwin	8.92	May 8, 2008
Sea-Bird Electronics	SeaTerm V2	2.2.6	March 5, 2013
Sea-Bird Electronics	Seasave V7	7.22.0.5	March 15, 2013
Microsoft	Office (Word, Excel)	2010	Apr. 15, 2010
ODIM Brooke Ocean	MVP Controller	2.430	Jan. 20, 2010
Applanix	MV POS View	5.1.0.2	Dec. 2, 2009
Applanix	POSPac MMS	6.2	July 30, 2013
Global Mapper Software LLC	Global Mapper	13	March 29, 2012
AutoDesk Inc.	AutoCAD	2004	Feb. 14, 2003
Hydrographic Consultants	CALLOAD	2.0	Dec. 18, 2005
Trimble	MS Controller	1.1.0.0	May 21, 2002
Trimble	Pro Beacon PC Interface	5.0	March 2, 2010

A.8.2.1 HYPACK SURVEY

Survey vessel trackline control and position fixing were accomplished by using the HYPACK SURVEY data-logging and navigation software package. 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, sent to the autopilot, and displayed on a video monitor, enabling the vessel's helmsman (and autopilot) 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 current NOS raster nautical charts (RNCs). Multibeam echosounder 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 MVP or CTD cast positions, bottom sample locations, and side scan targets of interest.

Raw, geographic position data (NAD83 degrees latitude and longitude) were time tagged with UTC time by the POS MV and recorded by HYPACK SURVEY 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 separate instance of HYPACK SURVEY was run on the side scan sonar acquisition computer in order to ensure that the acquisition computers were time-synced. Each acquisition computer’s HYPACK SURVEY program was configured to use the PPS signal from the POS-MV to continuously sync computer time to UTC.

A.8.2.2 HYSWEEP SURVEY

Multibeam data were logged with HYPACK HYSWEEP software which was run simultaneously with HYPACK SURVEY.

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

Multibeam backscatter data were recorded via HYSWEEP SURVEY in HYPACK .7K format.

A.8.2.3 Chesapeake Technologies, Inc. (CTI) SonarWiz 5

A dedicated acquisition computer was used to record and display side scan sonar imagery. Chesapeake Technologies’ SonarWiz 5 was configured to record imagery from either the Klein 5000 or EdgeTech 4200-MP system employed on this project. The sonar image waterfall was monitored continuously for data quality and to identify significant features. SonarWiz compiled side scan sonar data along with vessel position, towfish position, layback and cable out values and recorded raw data in XTF format files.

Significant side scan contacts were targeted in the SonarWiz waterfall window, simultaneously creating a target in HYPACK SURVEY. The HYPACK targets were used by the field team to informally track targets of interest and/or hazards as related to image acquisition on adjacent planned lines.

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 towfish 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. Towfish position parameters (e.g. altitude, depth, cable out, layback and lat/long) were recorded in the raw XTF file.

SonarWiz was configured to operate in "master" mode which allowed this software to control sonar functions (of each system) such as range scale changes and pressure sensor calibration. The SonarWiz image waterfall was configured using the grey scale pallet such that acquisition personnel would be looking at imagery closely mimicking what processing personnel would see in the CARIS SIPS waterfall. The image waterfalls of the "slave" systems discussed below were configured with their native image palate such that the acquisition personnel could simultaneously view the real-time imagery from another perspective, e.g. different contrast.

Use of a single "master" sonar controller software ensured a consistent fish positioning technique and data processing work flow despite the frequent sea state-induced hardware/software switches.

A.8.2.4 L3 Klein SonarPro

L3 Klein SonarPro software was operated in "slave mode" 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.). In general, ancillary sonar data such as fish pitch, roll, and depth were viewed using the SonarPro interface so as to maximize the screen space available for viewing the image waterfall of the recorded data.

A.8.2.5 EdgeTech Discover 4200-MP

The Discover software was run in the background in order for the primary side scan acquisition software, SonarWiz, to utilize the EdgeTech 4200-MP's signal. Discover 4200-MP software was operated in "slave mode" 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.). In general, ancillary sonar data such as fish pitch, roll, and depth were viewed using the Discover interface so as to maximize the screen space available for viewing the image waterfall of the recorded data.

A.8.2.6 CARIS HIPS and SIPS

All multibeam echosounder data were converted from raw HYPACK format data files to HDCS format and processed using CARIS Hydrographic Information Processing System (HIPS) software Version 7.1.2 for 64-bit processors.

All SSS data were converted from raw XTF format line files to HDCS format and processed using the CARIS Sonar Image Processing System (SIPS) software Version 7.1.2 for 64-bit processors.

HIPS/SIPS Version 7.1.2 was also utilized to process MBES and SSS calibration data, including patch test and performance test processing.

A.8.2.7 CARIS Notebook

Notebook was used extensively during shipboard and home office processing. During acquisition Notebook was used to track and organize side scan sonar targets of interest, i.e. significant targets and targets requiring further investigation. Dangers to Navigation (DtoN) submittals that were generated onboard the vessel or at the home office were compiled in Notebook and exported using Notebook in the NOS Hydrographic Specifications and Deliverables (HSD)-specified format, an S-57 .000 file.

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 S-57 feature file for submission with the hydrographic survey data. Notebook was also used to complete chart comparisons.

A.8.2.8 HYPACK MBMax

MBMax was used for various shipboard and home office support functions such as patch test data processing and performance test data processing as well as general data QA/QC review. MBMax patch and performance test data processing were accomplished as a QA/QC measure and to validate the CARIS-derived values.

A.8.2.9 NOAA Velocwin

Velocwin was used to convert the MVP sound speed cast data into CARIS SVP format. Along with the Sea-Bird Electronics data processing software, Seasave, and Microsoft Excel, the Velocwin software was also used for daily/weekly sound speed comparisons. Velocwin uses the "Wilson" equation to calculate sound speed from water column temperature and conductivity. However, the Wilson equation is no longer acceptable per the 2013 HSD. The MVP employed on this survey measures sound speed directly so the prohibition on Wilson's equation does not apply. However, the weekly comparison cast instrument was a CTD. Therefore, in order to accomplish weekly confidence checks using Velocwin the CTD data were converted to sound speed/depth profile data using the Chen-Millero equation via the SBE Seasave program. These data were reformatted into .ZZQ format using MS Excel such that the CTD cast data could be compared to a MVP profile via the comparison utility in Velocwin.

A.8.2.10 Sea-Bird Electronics SeaTerm V2 and Seasave V7

As mentioned above, CTD data were used as the comparison data input for HSD-specified weekly comparison casts. The comparison CTD instrument was downloaded using SeaTerm and processed in to sound speed/depth format using Seasave. During processing Seasave applies manufactures-provided calibration coefficients when converting from raw voltages to conductivity-temperature-depth values. As mentioned above, Seasave used the Chen-Millero equation in calculating sound speed from conductivity and temperature.

A.8.2.11 Microsoft Office Word and Excel

MS Excel was used for log keeping (acquisition and processing), organization and preparation of field and office tasks, report figure production and statistical data analysis. Excel was also used to reformat CTD sound speed/depth data into the .ZZQ format files for use in Velocwin's weekly comparison cast utility.

MS Word was used for report generation.

A.8.2.12 ODIM Brooke Ocean MVP Controller

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 exported 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. 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 near 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 water column, MVP casts.

A.8.2.13 Applanix MV POSView

The MV POSView controller software was used to configure and monitor the POS MV navigation and motion systems. Inertial Measurement Unit (IMU) parameters (heave, pitch, roll), 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.

A.8.2.14 Applanix POSPac MMS Post-Processing Data

POSPac MMS is a post-processing software module, which, given acceptable distance and geometry between the survey vessel and nearby Continuously Operating Reference Stations (CORS) stations, 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.

POSPac data were acquired during survey operations primarily so the True Heave component of the solution was available for application to multibeam data.

Inertially Aided Post Processed Kinematic (IAPPK) position and attitude data resulting from the process described above, was not applied to the multibeam data as the area of operation did not fall within a strong network of shore-based CORS stations. As a result the IAPPK solution is not expected to be considerably better than the Differential GPS (DGPS) position data acquired in real-time. However, POSPac MMS was used to extract high rate, regularly timed position data that was used in recalculating side scan sonar fish position. The practice of recalculating fish position using high rate position data via the CARIS Generic Data Parser utility results in image mosaics that have far less pixel stretching artifacts than realized using the relatively slow update rate positioning recorded in SonarWiz.

A.8.2.15 Global Mapper

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.8.2.16 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.8.2.17 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. This process was completed frequently throughout side scan sonar operations between data acquisition runs.

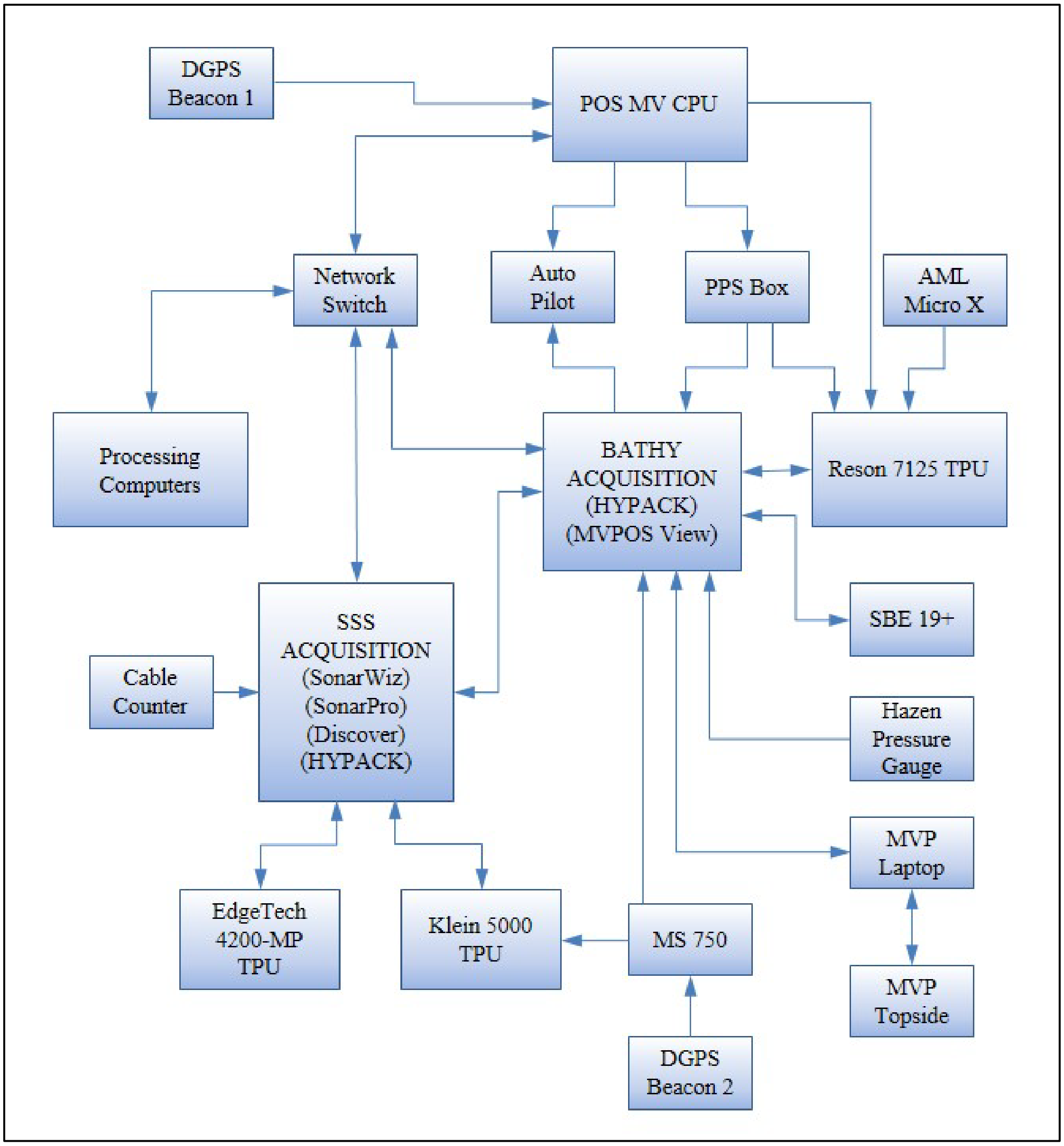
A.8.2.18 Trimble MS Controller

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.8.2.19 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.

A.8.2.20 Acquisition System Block Diagram



B. QUALITY CONTROL

B.1 Data Acquisition

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 well over three years of experience conducting hydrographic surveys.

Prior to the survey, a review of the current charted data was conducted to identify critical features and areas including platforms, obstructions and wrecks. The Composite Source File (CSF) and Project Reference File (PRF) supplied by NOAA were included in this review.

Line plans were created to achieve 200% SSS coverage with concurrent MBES, with lines planned for side scan acquisition at 75-meter (60m spacing) and 100-meter (85m spacing) ranges. In planning cross line coverage the planned 60-meter offset mainscheme line mileage was considered, i.e. planned cross line mileage was ≥ 8% of planned 60-meter offset line miles. The line plans meet the coverage requirement specified in the OPR-K339-KR-13 Project Instructions. Full MBES coverage was not required; however, due to the depth of water, near full bottom coverage was achieved with only a few coverage holidays realized associated with the vessel swerving around platforms. Specific line plans and survey coverage are described in the individual survey descriptive reports.

Data acquisition quality control was established and performed to ensure survey data met requirements specified in the SOW and HSD.

B.1.1 Bathymetry: Multibeam Echosounder (MBES)

Transducer offsets for the Reson 7125 were measured relative to previously established permanent shipboard benchmarks and to the vessel reference position (RP) using a steel tape measure. The benchmarks were established in 2010 (OPR-J364-KR-09) when a full static survey of the *R/V Ferrel* was completed using standard optical survey equipment and techniques. The transducer mounting orientation is based on angles derived during the initial full static survey when the survey vessel was dry-docked. It is possible to repeat the transducer orientation at each installation since the transducer pole and transducer mounting flange are "keyed," indexed, hardware components with mounting angles fixed relative to the vessel frame and RP. The IMU "bullseye" or reference point, located on the top of the IMU served as the vessel RP. The IMU mounting plate, as well as transducer pole mounting apparatus, are permanently installed hardware components of the survey vessel. For detailed information regarding system offsets refer to *Section C* Correction to Echo Soundings.

The Reson 7125 processor was interfaced with the POS MV such that UTC date and time information from the POS MV was used to accurately time stamp the Reson output data string. The Reson 7125 processor received a pulse-per-second (PPS) signal and a serial $ZDA NMEA timing string from the POS MV. The POS MV also supplied a "TSS1" message to the Reson TPU allowing for real-time roll stabilization. Surface sound speed recorded at the transducer head with the AML Micro X was output to the Reson 7125 processor to be used in beam-forming. Raw sounding data were output from the Reson 7125 TPU to the HYPACK acquisition computer via an Ethernet connection.

The POS MV received DGPS correctors from the Trimble ProBeacon. POS MV position, heading and attitude data strings were output to the HYAPCK acquisition computer via an Ethernet connection.

HYPACK SURVEY and HYSWEEP SURVEY were configured to record position, heading, attitude and depth to RAW and HSX data files. For the real-time display, system offsets for the IMU and for the transducer phase center were entered into the HYPACK configuration files. These offsets were subsequently incorporated into the CARIS data processing routine.

Prior to the start of data collection using the Reson 7125, the vessel static draft was measured and the transducer draft was confirmed by means of a “bar check” while alongside a dock. The bar check procedure consists of lowering the lead line disk to various indexed depths (calibration points) directly below the multibeam transducer and recording the nadir depth value output from the Reson 7125 as returned from the acoustic target. A “spot check” was also completed which consisted of sounding the seafloor directly below the multibeam transducer with the lead line while simultaneously observing the multibeam nadir depth. Throughout the course of the survey bar checks were completed at least weekly. The majority of the bar checks were completed dockside. However, when sea and wind conditions allowed, bar checks were completed offshore. All bar checks and spot checks indicate that the multibeam sonar system was performing within expected accuracy limits.

The initial vessel and MBES calibration to establish the dynamic draft correction table (squat test), residual transducer alignment offsets (patch test), and a multibeam system performance test were completed on November 9 and November 10, 2013 respectively (DN 313 and DN 314). These tests were performed with the POS-MV in RTK-GPS mode as a land based RTK GPS reference was established for this purpose.

During the initial dynamic draft test, RTK GPS performance was relatively poor. It was assumed that due to the poor quality of the RTK data, the settlement and squat test did not yield the expected results in reference to the *R/V Ferrel* dynamic draft values derived in previous field seasons. The dynamic draft dataset and associated settlement table collected on November 9, 2013 was discarded and a dynamic draft table established in 2012 for OPR-K339-KR-12 was utilized for preliminary data processing. Calibrations and data acquisition proceeded while waiting for the home office to process the associated POSPac data into an IAPPK dataset which, it was hoped, would yield better settlement test results when used in lieu of the RTK-GPS dataset. As mentioned previously the survey area is not located in a strong CORS network area. As such, the IAPPK dataset did not improve settlement test results when incorporated. For this reason the RTK GPS base station was reinstalled and another settlement test completed on January 7 to January 8, 2014 (DN 007 and DN 008). In this case RTK GPS performance was excellent and the settlement test results were in keeping with the results from previous years’ vessel calibration. The January 7-8 dynamic draft results were entered into the

CARIS HIPS Vessel File (HVF) for the Reson 7125 and served as the only settlement correction file applied to final project data. As a point of interest, experience has shown that the vessel's settlement response is on the order of ≤ 0.1 meters through the entire range of vessel speed.

Post-survey patch and performance tests were completed to ensure that the transducer alignment and system performance remained consistent over the course of the survey. Calibration results are presented in detail in *Section C*. Correction to Echo Soundings.

The SeaBat display and user interface installed on the Reson 7125 TPU were used to configure MBES settings, to monitor sounding acquisition, and to adjust system parameters in real time. The Reson 7125 was operated in equidistant mode using 512 beams. During calibration, the system was operated at a swath of 140°. However, the swath was reduced to 130° at the start of data acquisition due to observed degradation of data quality in the outer beams (beyond 65°) caused primarily by dynamic changes in the sound speed profile. The roll stabilization feature was activated throughout the term of the survey. "Absolute" depth gates were conservatively employed to reject fliers during mainscheme and cross line data acquisition. Depth gate filters were used sparingly or turned off all together during item investigations.

The Reson sounding profile "wedge" was monitored in real time. Power and gain settings were monitored and adjusted to optimize bottom detection. Range settings were monitored and adjusted for observed depths to maximize the ping rate.

Bathymetry, position, motion and heading data were logged in HYPACK SURVEY and HYSWEEP SURVEY. Position information from the primary and secondary DGPS receivers were continuously compared in HYPACK SURVEY and status indicators were monitored in real time. By means of a utility in the HYPACK SURVEY program a position disparity that exceeded three meters (primary v. secondary positioning system) would be reported by means of a visual alarm on the data acquisition screen.

The HYSWEEP SURVEY program allows for real-time monitoring of surface sound speed as transmitted by the transducer-mounted AML Micro X. A utility in HYSWEEP SURVEY allows for real-time comparison of the Micro X-reported surface sound speed to the surface sound speed recorded in the most recently acquired water column sound speed profile (as reported by the ODIM MVP). For this project the system was configured to provide a visual alarm if the difference between these surface sound speed values exceeded 2 meters per second. If the alarm threshold was reached a new water column profile was acquired.

In HYSWEEP, real-time MBES sounding wedge and digital terrain model (DTM) waterfall displays were monitored. The sounding wedge, DTM waterfall, and plan view coverage displays were corrected for draft, motion, preliminary tides and sound speed. Survey coverage was tracked in the HYPACK SURVEY display window with a matrix file updated in real time. MBES survey line names were composed of the year, vessel, Julian day, UTC time and line number, for example: 2013FE3141033_2.HSX/RAW, where "FE" stands for Ferrel.

The POSView software was used to monitor position, heading and motion accuracy status indicators. Applanix "TrueHeave" and POSPac 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. TrueHeave and POSPac data were logged at least 5 minutes prior to and after MBES acquisition. POSPac TrueHeave file names include the project number, device (POS-MV), year, Julian day, and date (ex: 13ES026_POS_2014_020_0120.000). POSPac files were saved in individual day folders. Once the file size reached 64 MB, a new file was created; therefore, each day of survey has multiple TrueHeave files.

The POS MV 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 during the survey.

During the daily "UTC midnight" changeover, the vessel was stopped and a number of mandatory and/or elective QA/QC functions performed: a static draft physical measurement was obtained (conditions permitting), a Hazen gauge pressure series was acquired and processed into a static draft value (conditions permitting), a new Applanix POSPac Trueheave file was begun, a bar check was performed (weekly) to verify echosounder draft offsets and system sounding accuracy, a CTD comparison cast was performed (weekly or more frequently), and side scan sonar depth sensor function/accuracy was confirmed. A surface sound speed comparison (AML Micro x vs. ODIM MVP) was often recorded at this time via the Velocwin "Daily Comparison" utility. However, if conditions were too rough to make the aforementioned static vessel tests impractical the vessel was kept underway and the surface sound speed "Daily Comparison" was performed while underway.

Data were copied, via network connection, onto shipboard processing computers for editing. Raw, processed and supporting data (acquisition logs, sound speed profiles, etc.) were periodically transferred to OSI's home office via courier delivery.

B.1.2 Imagery: Side Scan Sonar

Prior to commencing survey operations, the location of the top of the side scan sonar sheave, at its operational, deployed position was verified with respect to the vessel RP. The vertical offset between the SSS sheave reference point and the water line was also confirmed. The position of the sheave marks the starting point for the cable out measurement used to calculate towfish layback. The survey vessel "steering point" origin was the fore-aft location of the vessel RP and the athwart-ship or starboard offset of the side scan sonar cable sheave.

The Klein 5000 TPU was interfaced with the SSS acquisition computer transmitting the raw SSS profiles over an Ethernet connection. Speed information from the MS 750 was input into the Klein 5000 TPU, which used the VTG data string to adjust the real time waterfall display.

When the Klein 5000 was not in use the SSS acquisition computer IP settings were edited to accommodate the EdgeTech 4200-MP. This relatively easy SSS changeover also entailed switching the Ethernet cable and slip ring winch deck cable and, of course, the SSS towfish.

Chesapeake Technologies, Inc. SonarWiz side scan acquisition software was used to log the side scan imagery and position information to XTF files. SonarWiz was interfaced with the Klein 5000 or EdgeTech 4200-MP, a cable out indicator and the POS MV. Ship position and heading were input from the POS MV into the SSS acquisition computer. The length of cable deployed, ship navigation and heading, along with towfish depth converted from the towfish pressure sensor were used to determine an accurate towfish position. Imagery, layback, cable out, ship position, towfish position, depth and altitude were all logged to the raw XTF file. SSS survey line names included Julian day, UTC time (hhmmss) and line number, for example: 342-164254-2603.xtf.

Cable out readings were verified and/or recalibrated at least once per survey line by observing measured index marks on the towfish cable with respect to the reference position at the top of the sheave. The calculated depth from the pressure sensor within the Klein 5000 or EdgeTech 4200-MP towfish was confirmed regularly throughout the survey day. Neither system's pressure sensor was observed to drift throughout the term of the survey.

During acquisition, SonarWiz was configured to monitor a slant-range corrected SSS waterfall display in real time. Contact targets of interest were positioned from the slant-range corrected data and displayed on the helmsman HYPACK map through a serial connection to the multibeam acquisition computer. As a QC check of the imagery in SonarWiz, the waterfall display within the Klein SonarPro or EdgeTech Discover side scan sonar software was employed in display mode only.

Two hundred percent (200%) SSS coverage was attained in the survey area employing line spacing and side scan sonar range scales tabulated in Table 4 below. As mentioned above the towing sheave starboard offset, i.e. the towing sheave reference point was used as the navigation tracking point when acquiring mainscheme survey lines, ensuring overlapping coverage between SSS lines.

Table 4
SSS Line Spacing and Range Scales

Trackline Offset (meters)	SSS Range Scale (meters)
40	50
65	75
85	100

Vessel speed was maintained such that any 1 m^3 objects would be ensonified more than three times per pass at the operating range scale. Approximate vessel speed for mainscheme SSS acquisition was 7-8 knots. The towfish height was adjusted to fly at 8-20 percent of the range scale, with a visual alarm setup to indicate when the fish was nearing the upper and lower limits of the height threshold. Refraction and surface noise effects were minimized by changing the depth/altitude at which the towfish was flown. On rare occasions, when searching for a clean, refraction-free image, the towfish was unintentionally dipped below the lower height threshold while flying the fish at the lower height limit. In these cases the imagery swath width was trimmed to 12.5 times water depth in keeping with guidance in the HSD Section 6.1.2.3. Due to the conservative SSS line spacing described above, 200% coverage was still easily accomplished.

Confidence checks observed across the full range (e.g. scour marks and bottom type changes) were recorded frequently (often once per line) to verify system operation and object detection capabilities. Confidence checks were recorded with line names, observation times, and comments in the daily acquisition log.

B.1.3 Sound Speed

B.1.3.1 Sound Speed Profiles

Sound speed profile data were acquired with the ODIM MVP30 approximately every 15 minutes, except when this time interval occurred while the vessel was turning. The MVP operator acquired casts more frequently if high variability was noted in the surface sound speed or if the surface sound speed alarm threshold was exceeded (> 2 meters/second change). Profiles were acquired to a depth approximately 2 meters off the bottom when operating in freewheel mode. At all times the MVP fish reached a depth greater than 80% of water depth and at least once per day the MVP fish reached a depth of at least 95% of water depth. All casts were acquired within the area surveyed. The moving vessel profiler was operated in accordance with the ODIM Brooke Ocean's MVP30 Operation and Maintenance Manual.

The ODIM MVP Controller software was configured to receive navigation data from HYPACK via the MVP.dll. HYSWEEP SURVEY was configured to receive MVP casts in real time to correct the real time waterfall and profile displays with the most recent sound speed profile. MVP cast position, sound speed and depth data were logged to CALC files saved to the designated MVP laptop computer. Profiles were named for Julian day and cast number, for example: MVP_JD012_0002.calc.

Frequently during the daily "UTC midnight" changeover, while the *R/V Ferrel* was at a full-stop offshore, the MVP was manually deployed to near full seafloor depth while an SBE 19+ CTD was simultaneously deployed for a comparison cast. This satisfied the HSD-specified "independent sound speed measurement system confidence check" requirement. SBE 19+ CTD comparison casts were used for quality assurance only and were not utilized in sound speed correction of soundings. Raw CTD data were uploaded via a serial port to a designated PC following each cast before the "Weekly DQA" comparison was made. The Sea-Bird CTD was 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.

B.1.3.2 Surface Sound Speed

The AML Micro X sound speed sensor was installed within the bow fairing of the multibeam transducer essentially at the draft of the transducer phase center. Real-time surface sound speed values were transmitted to the Reson 7125 topside unit and subsequently recorded with multibeam echosounder data in the raw HYPACK .HSX data files. Sound speed data were also utilized by HYSWEEP SURVEY which was configured to display a visual alarm if the surface sound speed changed +/- 2 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 speed quality assurance (DQA) checks were performed using NOAA's Velocwin software by comparing the AML Micro X surface sound speed to the surface sound speed of a MVP manual cast (stopped offshore) or an automated cast (underway).

B.1.4 Horizontal and Vertical Control

The U.S. Coast Guard (USCG) Differential GPS (DGPS) station in English Turn, LA served as the primary horizontal position control and USCG station in Eglin, FL served as the secondary horizontal position control. The POS MV received pseudo range corrections from the English Turn station and the MS 750 received pseudo range corrections from the Eglin station.

Prior to the start of survey operations, navigation checkpoints were established at the vessel fueling dock located in Port Fourchon, LA employing a Trimble 5700 with a Zephyr geodetic antenna (May 2012, OPR-K339-KR-12). Dual-frequency GPS observations were recorded at three locations along the length of the fuel dock to help ensure vessel access during the course of the survey. The dual-frequency GPS observables were submitted to the National Geodetic Survey's (NGS) On-line Positioning User Service (OPUS) and processed to determine the positions of the temporary control points. 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 Horizontal and Vertical Control Report (HVCR).

Position confidence checks of the POS MV and the MS 750 were accomplished at the start of survey and, when practical, during fueling or weather delay stops in Port Fourchon. 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 as measured with a steel tape. In all cases, dockside navigation system accuracy testing demonstrated that the POS-MV, employing USCG correctors, had an accuracy of better than 1.0 meter. A tabulation of navigation system performance checks is included in DAPR Appendix III.

A HYPACK SURVEY "position integrity alarm" was utilized throughout the term of the survey. In practice the utility continuously compared the position reported by the POS-MV to the position reported by the MS750. For the purposes of the comparison the physical, shipboard position of the MS750 antenna was related to the RP (POS-MV IMU) via forward and starboard offsets in HYPACK SURVEY. The position solution difference, expressed in meters and viewed on a window on the HYPACK SURVEY display, was monitored by the acquisition team. An on-screen visual alarm notified the system operator if the difference in positions exceeded 3-meters. The alarm threshold was exceeded infrequently when the DGPS beacon receiver configured to use the Eglin, FL station lost signal. The ship lost signal from the English Turn, LA DGPS beacon only three times. Project data acquired during this period were not retained and new data were not acquired during the outages.

During data acquisition, the MV-POSView controller software was used to monitor real-time position accuracy, with the accuracy alarm set at 2.0 meters.

Per the Project Instructions, water level data from NOS-NOAA tide station 876-2075 in Port Fourchon, LA was used for vertical control. Predicted tide files were downloaded from the Center for Operational Oceanographic Products and Services (CO-OPS) website, http://opendap.co-ops.nos.noaa.gov/axis/text.html, prior to survey operations. Predicted tide files were used during preliminary processing. Preliminary tides from the Port Fourchon station were downloaded and reviewed for data gaps. Verified tides were downloaded and reviewed when available.

Final project data are delivered with verified tides applied using the zoning file "K339KR2013CORP.zdf" provided by CO-OPS and verified by OSI.

B.1.5 Feature Verification

When necessary, development/investigation MBES only lines were run over AWOIS items, significant contacts and other features observed in MBES and SSS records to determine a least depth and to meet the Object Detection Coverage specification in the HSD (Section 5.2.2.1). Once an item was deemed significant, nearly significant, or simply required more data to make a determination, the contact or outstanding sounding position was exported to an ASCII file, import into a Notebook HOB file and exported as a .000 file or simply edited into a HYPACK "target file" that could be opened in HYPACK SURVEY to display the investigation position.

A series of short MBES lines were run over the feature from multiple directions to obtain soundings on the object at various angles with high sounding density. During feature development lines, vessel speed was slowed to approximately 4-6 knots.

B.1.6 Bottom Sampling

Bottom samples were acquired in close proximity to the recommended positions included in the Project Reference File (PRF), provided with the OPR-K339-KR-13 Project Instructions. A sediment sampler was deployed from the A-frame located on the stern of the vessel to acquire seafloor sediment samples. Bottom sample locations were logged in a target file in HYPACK SURVEY. Once the sample was on deck it was photographed and classified based on the criteria outlined in Appendix 10 Bottom Classification in the HSD.

B.1.7 Other

B.1.7.1 Autopilot

The Simrad AP50 Marine Autopilot was configured to receive heading from the POS MV, and speed, position and the Autopilot (APB) message from HYPACK. Once in control, the Autopilot maintained the vessel steering point within approximately 2 meters of the selected trackline.

B.1.7.2 Digital Acquisition Logs

An acquisition log was maintained in Microsoft Excel to record all pertinent information related to acquisition, such as:

- Daily operations and locations
- Weather and sea state observations
- MBES and SSS survey line ID and start time
- Date and Time of MVP and TrueHeave (POSPac) files
- Navigation System Performance Checks, Bar Check Table, Vessel Water Level Tabulation and Sound Speed Comparison Table
- Systematic changes (i.e. range scale change, equipment repairs or replacements)
- SSS Confidence Checks
- Significant SSS contacts or Bathy features
- Excessive Noise in the SSS/MBES records due to fish, vessel traffic, or surface noise
- Deviations from planned tracklines or Data Gaps
- System “crashes” or Position Outages
- Line Miles and Survey Statistics

B.2 Data Processing

B.2.1 Bathymetry

I. Data Conversion and Preliminary Sounding Correction

Preliminary data processing occurred simultaneously with data acquisition. Therefore, at regular intervals throughout a survey day, raw MBES data, MVP casts, and TrueHeave files were copied across the network to a preprocess folder located on the processing computer as they became available. The acquisition computer's directory and log were reviewed to verify line names and file size and to remove any aborted lines from the preprocess folder prior to converting the data in CARIS HIPS. All lines and MVP casts successfully copied from the acquisition computer were entered into the survey processing log, which was used to track the processing progress of each line and to enter all notes pertinent to individual lines or days.

Vessel configuration files (.HVFs) were created in CARIS HIPS Vessel Editor prior to data conversion. The HVF files contained transducer offsets relative to the RP, alignment offsets derived from the calibration testing, as well as the waterline height and standard deviation values for all surveyed parameters (used to model sounding uncertainty). Duplicate HVFs were created for the MBES system to convert lines into HDCS folders according to classification, i.e. mainscheme lines and cross lines. Waterline correctors were updated in the HVF files as new values became available. See *Section C* Corrections to Echo Soundings for additional information regarding vessel configuration files.

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 accomplished the following standard tasks in succession:

1. Convert the HSX and RAW data to the HDCS data format.
2. Load zoned, predicted tides or preliminary tides, if available.
3. Load daily True Heave files.
4. Load and apply concatenated sound speed (SS) profile data. SS profiles were loaded with the CARIS *nearest in distance within time* correction method. During CARIS SV Correction, the following correctors were applied: sound speed, heave, pitch, roll and waterline.
5. Merge data to apply vessel offsets/alignment, position, gyro, 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 6). Total Propagated Uncertainty (TPU) is calculated in CARIS HIPS from contributing uncertainties in the echosounder, 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 HVF. Tide uncertainty values for measured and zoned tides were provided in the OPR-K339-KR-13 Tides Statement of Work as 0.15 meters. Sound speed TPU values were

estimated from manufacturer accuracy of the ODIM MVP-30 and SBE37 and from guidance in the OCS Field Procedures Manual (FPM) Appendix 4 under CARIS HVF Uncertainty Values. Given that the MVP was cast approximately every 15 minutes an uncertainty value of 1 m/s was chosen for the measured sound speed.

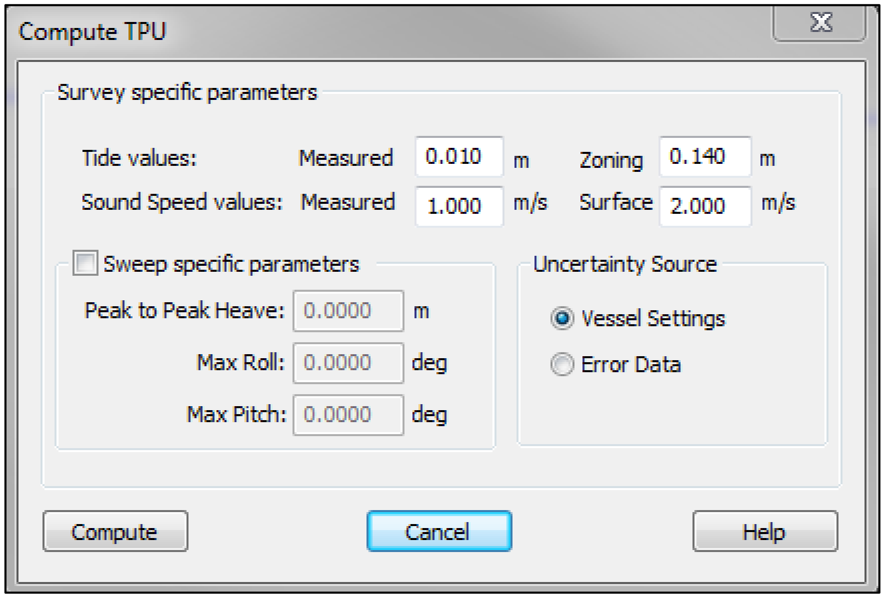


Figure 6. Uncertainty values entered into the Compute TPU process in CARIS HIPS & SIPS.

II. Preliminary BASE Surfaces

Preliminary field sheets and CUBE surfaces were created for reviewing and cleaning full-density soundings. Daily data review and cleaning were performed using 2-meter resolution CUBE surfaces as a guide for directed editing. CUBE surfaces with a 4-meter resolution were created to evaluate coverage. While in the field, 0.5-meter resolution CUBE surfaces were used to evaluate coverage for item investigations. However, for final deliverables, item investigation surface resolutions were depth dependent (resolution = 2.5% water depth).

After the lines were run through the batch process, they were added to the 2-m Cleaning surfaces and the 4-m Coverage surfaces. Depth, Standard Deviation and Shoal surface models were viewed with sun illumination and/or vertical exaggeration to highlight areas that would require immediate investigation. Standard deviation 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. Highest standard deviation values were observed over obstruction features, seafloor depressions and in the vicinity of offshore platforms.

The 4-m coverage surface was reviewed for any data gaps in excess of 3 nodes while the Object Detection coverage surfaces were reviewed with respect to the holiday definition described in Section 5.2.2.4 of the HSD. All surfaces were reviewed to ensure that Object Detection Coverage was obtained over significant shoals and features. Density layers were reviewed to verify that 95% of all nodes in the Set Line Spacing coverage surfaces were populated with at least 3 soundings and that 95% of all nodes in the Object Detection Coverage surfaces were populated with at least 5 soundings.

III. Data Cleaning and Processing

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 data or navigation jumps. Extreme speed jumps were rejected with interpolation and data were re-merged, if needed.

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. Soundings were colored by depth and reviewed in multi-directional profile and plan view 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).

The CARIS Subset Editor was used to clean fully-corrected, geospatially located soundings in 2-D and 3-D displays. Soundings were primarily colored by line to verify the validity of bathy features or SSS contacts recorded by multiple MBES passes and to reject fish or water column noise recorded in one MBES pass and disproved by overlapping coverage from a different MBES line. 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), and SSS contacts. A complete final sounding review was performed for the entire survey coverage area using Subset Editor and tracked with subset tiles.

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 significant contacts (or Primary/Secondary contact pair).

Beam filters were used to reject soundings in specific lines that exhibited excessive sound speed uncertainty in the outer beams.

An Outstanding flag was given to soundings on features or possible features that required further investigation or development. Outstanding sounding positions were exported from CARIS to an ASCII file that was converted into a Feature Investigation S-57 .000 file in CARIS Notebook that could be opened as a background file in HYPACK SURVEY.

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, charts and other standard hydrographic products. When a designated sounding was selected on a feature, it indicated that no further investigation was required.

In Section 5.2.1.2 of the HSD, the guidance for selection of designated soundings in depths greater than 20 meters is “a designated sounding may be selected when the difference between the gridded surface and reliable shoaler sounding(s) is more than the maximum allowable TVU at that depth.” All depths surveyed within Project OPR-K339-KR-13 were deeper than 20 meters; therefore, with the HSD criteria in mind, a designated sounding flag was applied to features taller than 0.5 meters. Designating a sounding ensured that the least depth of all features insignificant or significant in height resolved with the MBES would be adequately represented in the final surfaces. Near nadir soundings were designated as least depths on features in lieu of outer beam soundings whenever possible. In the instance that soundings from multiple MBES lines suggested different least depths, the contact heights measured in side scan editor were reviewed to assist with least depth designation.

Once the surface deliverables were finalized, chart comparisons were completed with the surveyed depths and charted depths located on all affected Raster Nautical Charts (RNCs) and Electronic Nautical Charts (ENCs). The final chart comparison was completed using charts downloaded from the OCS website, nauticalcharts.noaa.gov, on March 6, 2014. CARIS Notebook and CARIS HIPS & SIPS were utilized to complete chart comparisons with the RNCS and ENCS. This was accomplished by overlaying surveyed depths in the form of finalized surface layers, sounding layers and S-57 features over the RNCs and ENCs. Surveyed data were compared to all charted depths, contours and features, with agreements, discrepancies and disprovals addressed in each survey’s descriptive report.

B.2.1.1 Methods Used to Maintain Data Integrity

Preprocessed data were copied onto processing computers located on the ship for editing. The hard drives on the processing computers retained both the raw and processed data. The processing computers, DP2 and DP3, were backed up to external, 2-terabyte hard drives each day, with a rotating cadre of 5 hard drives for each processing computer. Backups of the raw, processed and supporting data (acquisition logs) were periodically transferred to OSI’s home office via courier delivery during vessel in-ports. Upon completion of field work, DP2 and DP3 were used to complete survey processing at OSI’s home office.

B.2.1.2 Methods Used to Generate Bathymetric Grids

After MBES sounding editing was complete, final BASE surfaces were created using the CUBE algorithm as incorporated in CARIS HIPS and SIPS. 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. Also, soundings closest to a grid node have a greater weight on the node depth value than soundings that are further away.

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

- Surface Type – CUBE
- IHO (International Hydrographic Organization) S-44 Order 1a
- Include Status – Accepted, Examined, Outstanding
- Additional Attributes – Shoal and Deep
- Disambiguation Method – Density & Locale

CUBE parameter configuration varied with surface resolution. The CUBE parameters Capture Distance Scale and Capture Distance Minimum were modified according to grid resolution to meet the requirement that the maximum propagation distance for a node shall be no more than the grid resolution divided by the √2.

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

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).

During CUBE surface creation, the maximum value of the two capture distance parameters is used to set the actual capture distance. To ensure that the CDM was the determining factor for the radius of influence for each node, a CDS value of 0.50 % was used for the creation of all surfaces.

Example for a 4-meter BASE surface in depths less than 40 meters:

CDS = 0.005
CDM = 4 / (√2) = 2.83

The CDS radius maximum value (0.005 * 40 = 0.2 meters) will not exceed the CDM value (2.83 meters) for the maximum depth, and therefore the Density Attribute Layer will represent those soundings that lie within a fixed radial distance (2.83 meters) for all nodes.

Table 5 displays the CDS and CDM values entered for the various grid resolutions used.

Table 5
CUBE Parameters Applied in Surface Generation

Grid Resolution (m)	Capture Distance Scale (%)	Capture Distance Minimum (m)
0.65	0.5	0.46
0.70	0.5	0.49
0.75	0.5	0.53
0.85	0.5	0.60
0.875	0.5	0.62
0.90	0.5	0.64
0.95	0.5	0.67
1.0	0.5	0.71
4.0	0.5	2.83

Per the Set Line Spacing Coverage requirements in Section 5.2.2.3 of the HSD, a grid resolution of 4-meters was used to establish MBES coverage for the entire project area. Sounding density and coverage achieved is based on requirements specified in the Project Instructions: 200% SSS with concurrent Set Line Spacing SBES or MBES with Backscatter, or Object Detection MBES with Backscatter.

All significant features were developed with MBES to meet Object Detection coverage standards. Water depth throughout the assigned survey area was greater than 20 meters. As such, the field sheet grids utilized to prove Object Detection Coverage were depth dependent. Specifically, significant feature development grid size is nominally 2.5% of the surrounding water depth. The object detection surfaces were centered over the significant features and covered a minimum area of 400 m^2.

The attributes associated with each grid node are as follows:

- Depth Value
- Uncertainty
- Standard Deviation
- Mean, Deep and Shoal Depths
- Sounding Density
- CUBE Surfaces: Hypothesis Count, Hypothesis Strength & User Nominated

B.2.1.3 Methods Used to Derive Final Depths

The Set Line Spacing Coverage grids were "finalized" in CARIS according to depth. Per the CARIS HIPS & SIPS 7.1 Users Guide, a finalized BASE surface "is a finished version of the surface that is ready for export." Designated soundings were incorporated into the BASE surfaces when finalized; making certain the least depth is honored in the grid. When finalizing the set line spacing coverage and object detection coverage surfaces, the final uncertainty was chosen from the greater of either the uncertainty value from the source surface or the standard deviation value from the source 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.

Final BASE surface resolutions are unique for each survey area and are described specifically in the respective descriptive reports.

B.2.2 Imagery

Preliminary data processing occurred simultaneously with data acquisition. Therefore, at regular intervals throughout a survey day, raw XTF files were copied across the network to a preprocess folder located on the processing computer as they became available. The acquisition computer's directory and log were reviewed to verify line names and file size and to remove any aborted lines from the preprocess folder prior to converting the data in CARIS HIPS. All lines successfully copied from the acquisition computer were entered into the survey processing log, which was used to track the processing progress of each line and to enter all notes pertinent to individual lines or days.

CARIS HVFs were created to convert CTI SonarWiz XTF data files. The SSS vessel file is a "zero" configuration because all tow point offset and layback calculations were performed in SonarWiz. No additional towfish position calculation was necessary in CARIS HIPS/SIPS. Duplicate HVFs were created for each 100% side scan coverage (100 and 200) and for side scan development lines.

The preprocess SonarWiz XTF data were converted to the HDCS data format in CARIS' Conversion Wizard. Vessel trackline positions were converted from the XTF 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. Survey lines with odd numbers were converted under the 100% coverage HVF and survey lines with even numbers were converted under the 200% coverage HVF.

Navigation time stamp irregularities were edited and navigation data were reviewed in the CARIS Navigation Editor. Each side scan line was reviewed in CARIS Attitude Editor to ensure that the towfish attitude, depth, height, and cable out were converted from the XTF file and that there were not gaps or problems with these parameters.

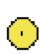
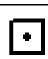
CARIS Side Scan Editor was used to review and edit bottom tracking, slant range correct the data, and to apply image processing correction. Processing was completed as follows:

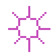
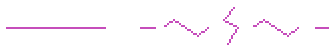
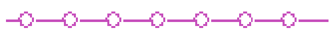
1. Review the raw side scan data in Side Scan Editor and correct any bottom tracking errors by re-digitizing the bottom trace.

2. Slant range correct the side scan lines with a resolution of 0.03 meters to convert the across track axis from time to distance and remove the water column from the imagery. Calculate an average speed of sound value from MVP casts acquired that same day of side scan acquisition. Sound speed values used for slant range correction varied between 1508 m/s and 1532 m/s. The slant range correction sound speed used for each day of side scan acquisition is noted in the processing log.
3. Lines were AVG corrected to normalize angular response across the swath.
4. Lines were TVG corrected to balance the beam signature of the port and starboard channels.

During pre-survey planning, the CARIS HIPS and SIPS ContactFeatures.hcf file, located in the CARIS\HIPS(x64)\System directory, was modified by OSI to include additional Contact Feature types with which to classify contacts in Side Scan Editor. The additional contact types are included in Table 6 below, along with their graphical display in CARIS HIPS and common remarks that would accompany the contact type. The OSI-modified ContactFeatures.hcf file is provided within the project deliverables Processed directory.

Table 6
Modified OSI Contact Types Selected in Side Scan Editor

Contact Type		Typical Remarks
	Rock	• Rk • Group of rks
	Unknown Contact	• Unknown Contact • Unknown Contact; Possible Rk/Fish • Unknown Contact; Possible Gas Leak
	Fish Contact	• Fish • Fish; detached shadow • Dolphins in water column
	Contact with Insignificant Height	• Ftr with insig ht
	Obstruction	• Obstruction • Obstruction/Debris
	Wreck	• Wk • Wk; Dispersed Debris
	Platform	• Platform; west extent

Contact Type		Typical Remarks
	Confidence Check	• Conf ck; ftr with insig ht; stbd side; outer rng
	Underwater Cable	• Chd Cable • New Cable
	Pipeline	• Chd Pipeline, insig ht • New Pipeline, at base of platform

Once image processing was completed contacts were selected in the Side Scan Editor waterfall. Objects were identified by the presence of sonar shadows. Shadow lengths were measured and converted to heights. Contacts with significant heights or horizontal dimension were positioned and created at the top (closest to nadir) of the shadow, and attributed with the following information: feature type (obstruction, platform, unknown, wreck), height, width & length (if significant), and processor remarks. Heights were measured with the shadow tool and lengths and widths were measured with the distance tool. An example of an attributed contact selected in Side Scan Editor is displayed in Figure 7.

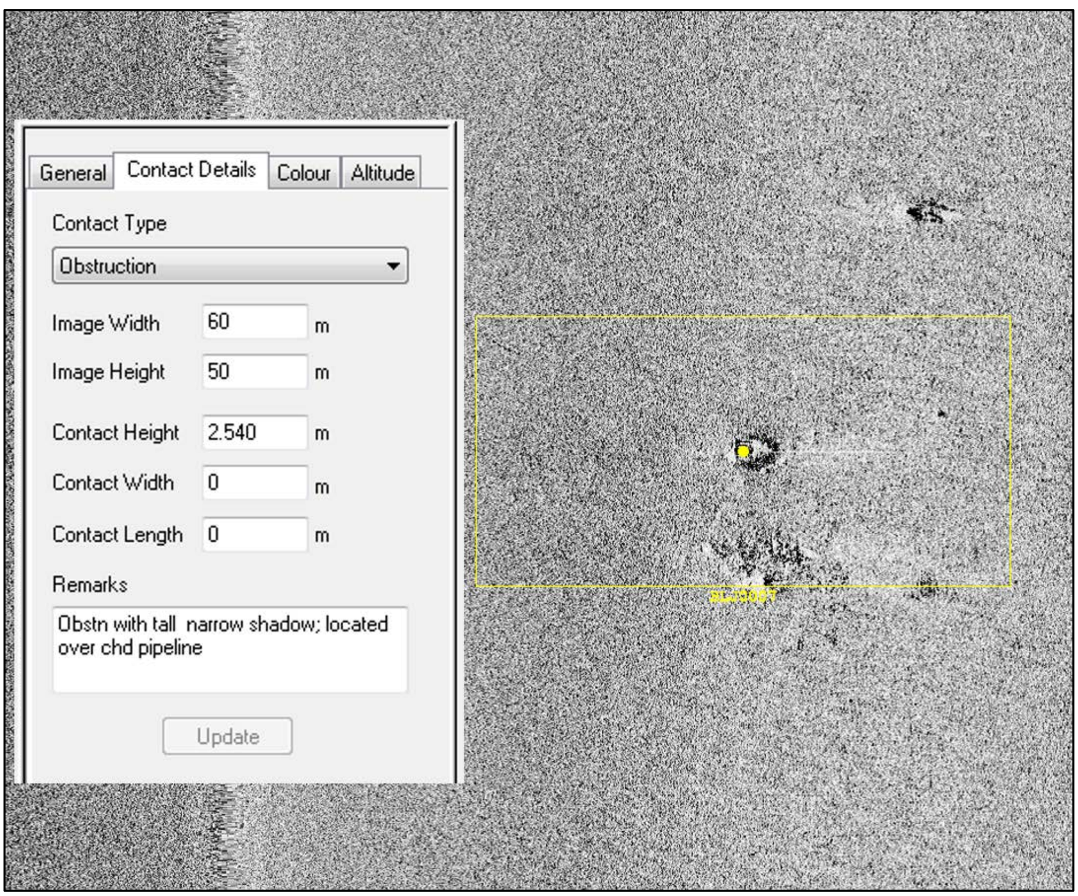


Figure 7. Attributed side scan contact selected in Side Scan Editor waterfall display.

SSS lines were reviewed a minimum of two times by more than one hydrographer while in the field to make certain that all significant contacts were selected that may require investigation. The contacts selected in Side Scan Editor were positioned in the Display window. The accuracy of the side scan towfish navigation and contact positioning was regularly confirmed in the display window when the same contact was selected from overlapping side scan coverages. All contacts were reviewed in CARIS Subset Editor with full sounding density with the rejected soundings visible, as well.

To improve SSS navigation, the real-time navigation data logged in SonarWiz was replaced with higher frequency navigation recorded in the POSPac data. The navigation replacement was accomplished with The CARIS Generic Data Parser, and towfish and contact positions were updated with the "Recompute Towfish" tool.

The 100 and 200 percent coverage mosaics were generated frequently in CARIS HIPS and SIPS using the Mosaic Editor. First, all lines from the 100 percent coverage HVF were selected and GeoBars (Georeferenced Backscatter Rasters) were created for each line. The GeoBars were generated with a resolution of 1 meter and were saved in the HDCS line folder for each side scan line. With all the GeoBars loaded for the 100 percent side scan coverage, mosaics were generated in the survey coverage fieldsheets with a 1 m resolution. The same steps were followed to generate the 200 percent coverage mosaic.

The 100 and 200 percent coverage mosaics were reviewed in HIPS and SIPS for coverage gaps and poor quality imagery that would necessitate SSS fill-in lines. Fill-in lines were collected as deemed necessary. At the completion of survey operations, final 100 and 200 percent coverage mosaics were export from CARIS HIPS and SIPS to individual GeoTiffs.

B.2.2.1 Methods Used to Maintain Data Integrity

Preprocess data were copied onto processing computers located on the ship for editing. The hard drives on the processing computers retained the raw and processed data. The processing computers, DP2 and DP3, were backed up to external, 2-terabyte hard drives each day, with a rotating cadre of 5 hard drives for each processing computer. Backups of the raw, processed and supporting data (acquisition logs) were periodically transferred to Ocean Surveys' home office via courier delivery during vessel imports.

Upon completion of field work, DP2 and DP3 were used to complete survey processing at OSI's home office.

B.2.2.2 Methods Used to Achieve Object Detection and Accuracy Requirements

By means of "multibeam" technology, the Klein 5000 side scan sonar generates 5 beams per ping improving greatly upon the resolution capability of traditional "single beam" side scan units allowing for "high speed" operations while ensuring sufficient bottom coverage and object detection to meet requirements in the HSD Section 6.1.2. The EdgeTech 4200-MP's high speed capability is accomplished as the system allows two pulses in the water during each ping cycle. This system is also capable of meeting or exceeding coverage and resolution requirements described in the HSD. Specifically, each system is capable of survey speeds of ≥ 9.6 knots while meeting HSD requirements of three pings on a 1-meter target even at the maximum sonar range employed on this project, 100 meters.

The *R/V Ferrel* survey speed never exceeded 9 knots during side scan acquisition. Careful review of side scan sonar imagery throughout the course of data acquisition and processing phases regularly confirmed that the vessel speed and side scan sonar ping rate allowed for ensonification of a seafloor feature at a density in excess of that required in the HSD.

B.2.2.3 Methods Used to Verify Swath Coverage

Line spacing was planned such that there was ample overlap between adjacent lines from each single 100 % coverage. Side scan lines run at a range scale of 50 meters had a coverage overlap of 20 meters, and side scan lines run at range scales of 75 meters and 100 meters had a coverage overlap of 30 meters. Given that the Autopilot maintained line steering within 2 meters of the planned line and the towfish was flown at a height as not to diminish the scanning range, full swath coverage was achieved on the majority of mainscheme lines. Gaps in side scan coverage that occurred when the vessel steered off line to avoid oil platforms were subsequently filled with side scan development lines to the extent that safety of the ship and platforms allowed. In two cases a mosaic gap in both SSS coverages exists due to the layout and size of certain sprawling, multi-segmented platform structures (Figure 8). The gaps exist on “inside corners” within the footprint of the sprawling platforms and could not be safely ensonified even during clam weather with the Klein 5000 operating at 100 meter range.

The 100 and 200 percent side scan coverage mosaics were updated daily and reviewed for gaps or poor quality data that would require fill-in lines or re-runs of the mainscheme line.

Figure 8. A sprawling, multi-segmented platform within Survey H12551.

B.2.2.4 Criteria Used for Contact Selection

The criteria used to select contacts was based on the guidance provided in the HSD Section 6.1.3.2 Significant Contacts, which defines a contact as significant based on its shadow height in different depth ranges. The HSD significant contact specifications are summarized in Table 7.

Table 7
Significant Contact Selection Criteria

Surrounding Depth or Area	Significant Contact Height
≤ 20 meters	1 meter
> 20 meters	10% of surrounding depth

During field operations OSI used a more conservative approach when selecting contacts, to make certain that significant features would not be overlooked for further investigation or correlation in the MBES record. All contacts with a minimum height, based on shadow length, of 0.5 meters were selected; however, contacts that had an estimated height below ~1.5 meters were classified as a "contact with insignificant ht." Contacts with estimated heights above ~1.5 meters, irrespective of survey depth, were considered potentially significant and possibly requiring further investigation. All assigned survey areas had water depths greater than 20 meters. OSI's conservative side scan contact selection and classification criteria are summarized in Table 8.

Table 8
OSI Side Scan Contact Selection and Classification

Contact Height		Action	Contact Type
≥ 1.5 m	Potentially Significant	Create Contact	Obstruction/Rock/Wreck/Unknown
0.5 m to 1.5 m	Insignificant	Create Contact	Contact with Insignificant Height
< 0.5	Insignificant	Disregard	N/A

There was an abundance of fish encountered within the survey area, represented in the side scan record as individual fish and as schools. Fish contacts were created when the fish schools, singular swimmers or an occasional dolphin created detectable shadows in the side scan record. Singular fish presented themselves in the record most often as hard returns with long detached shadows. Sometimes the fish reflections were evident in the water column, which also created shadows in the SSS record. Fish contacts had the potential to be actual features; therefore, all fish contacts were correlated with the second 100% side scan coverage and with the MBES record. The presence of fish contacts in the HIPS display window was also helpful during editing of bathymetry as an indicator to the hydrographer to anticipate noisy data. Fish contacts were not assigned heights.

Most side scan contacts were symbolized as point features; however, sections of exposed pipelines were digitized as linear contacts, as well. At times, contacts without a shadow were selected if there was a noteworthy shape or size to the item, despite its insubstantial relief.

B.2.2.5 Compression Methods Used for Reviewing Imagery

The CARIS Side Scan Editor "Skip" option for compression was used while reviewing imagery. The Skip option selects pixels for display at regular intervals across track. The computer monitors used for data processing were high resolution (1920 x 1080), and the full width of the screen was utilized while reviewing the side scan waterfall. Therefore, the data compression effects were minimized.

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

Preliminary data processing occurred simultaneously with data acquisition. Therefore at regular intervals throughout a survey day, raw MVP sound speed profile files were copied across the network to a preprocess folder located on the processing computer as they became available. The acquisition computer's directory and log were reviewed to verify file names and size and to remove any aborted casts from the preprocess folder prior to converting the data to SVP files. All casts successfully copied from the acquisition computer were entered into the survey processing log, which was used to track the addition of each cast to the concatenated "Master" SVP file.

The ASCII CALC files logged with each MVP cast were converted using NOAA's Velocwin software. The BROOKE-OCEAN MVP Automatic mode was used to convert one or more CALC files and append them to a CARIS HIPS SVP file, referred to as the "CARIS HIPS Accumulating SVP File" in Velocwin. All individual MVP casts, attributed with position, date and time of cast, were concatenated to a survey level SVP file (ex: H12552_Master.svp) for use in sound speed correction of survey lines in CARIS HIPS.

During the Load SVP step in the HIPS Batch Editor, the Master.SVP file was chosen and the Edit option was selected to open the CARIS SVP Editor. All new casts that had been appended to the SVP file were reviewed and the Extended Depth modified as needed.

The CARIS Profile selection method used to apply sound speed correction was the "Nearest in distance within time" option. For the majority of lines, 1 hour was chosen as the time increment. However, as discussed in the DR for H12552, for several lines, 2 hours was used. Prior to the final application of sound speed correctors, the Master.SVP file for each survey was opened as a Background File in CARIS HIPS to verify that the cast positions all fell within the area surveyed.

The frequent CTD and MVP comparison casts (at least weekly) acquired during the "UTC midnight" changeover were converted in Velocwin to generate ZZQ files used to compare the sound speed profiles with the "Weekly DQA" tool. The CTD comparison casts were not appended to the CARIS SVP file used for sounding correction. A listing of DQA results is included in DR Separate II.

B.2.3.2 Surface Sound Speed

Frequent comparisons were also made between the surface sound speed of the stationary MVP (and CTD cast) and the surface sound speed recorded by the AML Micro X at the time of the cast. The surface DQA comparisons were accomplished using Velocwin's "Daily DQA" tool.

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

RTK GPS positioning and water level determination were employed during pre- and post-survey MBES patch test and performance testing, pre-survey side scan sonar positioning verification, and settlement and squat testing.

This approach was chosen in order to achieve higher accuracy positioning of the discrete objects used to determine the angular biases of the MBES transducer and to accurately account for the vessel's vertical response to changes in speed, i.e. settlement.

B.2.4.2 Vertical Control

Predicted, Preliminary and Verified tides were downloaded from the CO-OPS SOAP web services website and were re-formatted as TID files to be used in CARIS HIPS tide correction.

The preliminary tidal zoning file (ZDF) that was provided by CO-OPS with the OPR-K339-KR-13 Tides Statement of Work was used when applying the tide correctors from the Port Fourchon, PORTS station (876-2075) in CARIS HIPS. The time and height corrections in the zoning file were used to extrapolate the water level measured at the tide gauge to each discrete tide zone. The zoned tide correctors were then applied to the soundings.

B.2.5 Feature Verification

Contacts were exported daily from HIPS and SIPS to an ASCII text file, which was reformatted and imported into a CARIS Notebook edit layer (.HOB file). The lead hydrographer would identify the contacts that required additional investigation from the contact HOB file. An item investigation HOB layer was created which included the positions of all side scan contacts and outstanding soundings to be developed with additional MBES coverage. The Investigation HOB layer was exported to an S-57 (.000) file which could be opened as a background layer in HYPACK SURVEY during acquisition of development lines.

The item investigation and development lines were converted and processed in CARIS HIPS following the bathymetry processing procedures outlined above. The development lines were processed immediately following their acquisition while the vessel was still in the vicinity of the investigation item, such that if additional near nadir coverage was required to obtain a least depth the vessel would be at the ready.

While in the field, CUBE surfaces with a grid resolution of 0.5 meters were created over the investigated features. The density layers were reviewed to verify that the Object Detection Coverage requirement of 5 soundings per node was met. Least depths were designated on all verified features and significant contacts.

All contacts were visually correlated between 100% and 200% coverages in the CARIS Map window and in CARIS Notebook. Version 7.1.2 of CARIS HIPS and SIPS does not allow the user to query contact attribution entered in Side Scan Editor in the Display Window. Therefore, a temporary hob file was generated in CARIS Notebook that included all contact positions and attribution (e.g. contact id, height, hydrographer remarks) with contacts classified as Cartographic Symbols. When opened in CARIS HIPS, the intermediary contact HOB file allowed the hydrographer to query the attributes associated with the side scan contacts to assist in data processing.

Correlated contacts were evaluated with respect to BASE surfaces, charted information, and designated soundings. All significant contacts (or contact pairs) were evaluated in full density sounding subsets to ensure that there was adequate SWMB coverage.

Contacts, contact images and designated soundings were exported from CARIS HIPS and SIPS. These data were processed with a custom, OSI correlation macro in MS Excel. The 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 9). Unique contact ID's were created from line-profile-range data. Correlating contacts were assigned the same Group ID number and their respective designated sounding, if present.

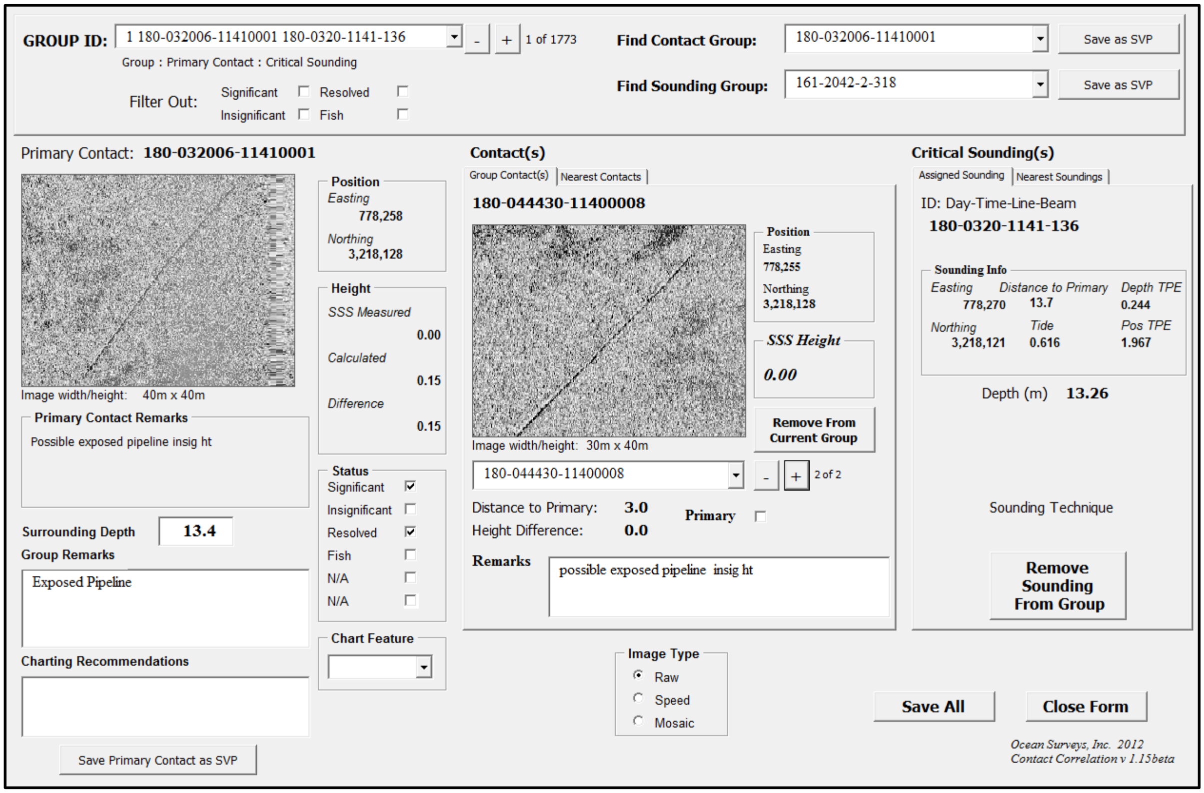


Figure 9. MS Excel contact correlation macro.

After contact correlation was completed, the Excel macro output a contact XML file that was imported into CARIS Notebook to generate the Side Scan Contact File deliverable. Using the Pydro Data Import tool, the contacts were imported as Cartographic Symbol Objects ($CSYMB) and the attributes were mapped to their respective NOAA Customized Attributes as specified in the "Side Scan Sonar Contact Points" table from Section 8.2 of the HSD. To indicate correlating contacts, the Group ID assigned with the Excel macro is included as a prefix in the Remarks attribute field. Individual contacts without a correlating feature (i.e. fish or insignificant contacts) do not have a Group ID. The contact number entered in the "userid" attribute field is composed of the SSS line name and ends in a 4 digit number (e.g. 0001, 0002, etc.) that restarts at 0001 for every individual SSS line (Example: 333-024618-16210002). A screen grab of the S-57 attribution for a typical SSS contact in the Side Scan Sonar Contact File is shown in Figure 10. Note the correlation Group ID number for this contact is 00036, the prefix in the Remarks field.

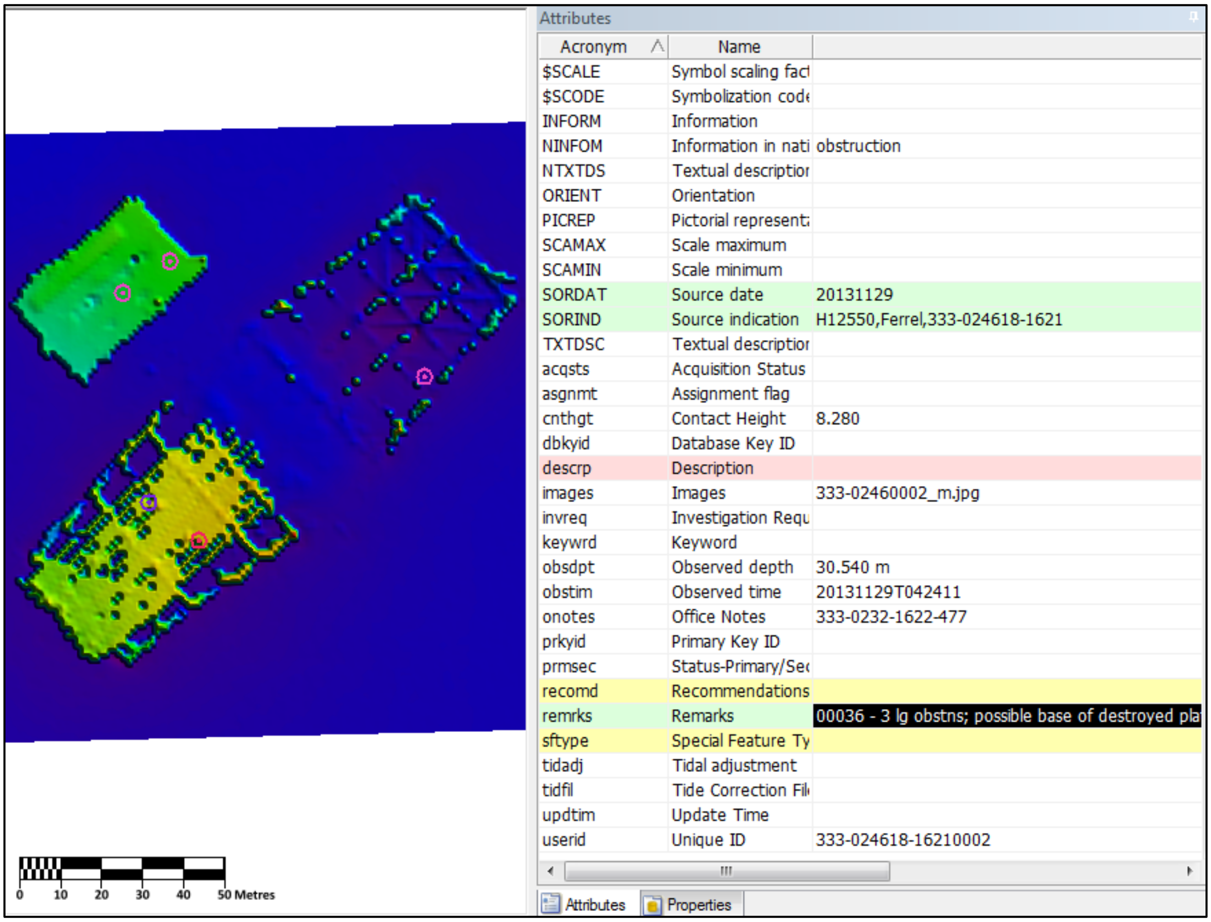


Figure 10. An example of the required attribution for the Side Scan Sonar Contact File.

A Final Feature File (FFF) in S-57 .000 format was created in CARIS Notebook beginning with the "Assigned" features from the OCS provided Composite Source File (CSF) as its base. The FFF includes new survey features, updated and disproved charted features provided in the composite source file, and Meta-Objects and is in the WGS84 datum.

New or Updated features' depths (VALSOU – value of sounding) and positions were imported into Notebook from designated least depth soundings selected in CARIS HIPS and SIPS. Bottom samples were included as attributed SBDARE (Seabed Area) point objects.

Descriptive information pertinent to each feature was entered in the IHO S-57 attribute fields and the NOAA extended attribute fields as specified in Section 8.2 and Appendix 8: Feature Attribution of the HSD. The following attributes were updated for each item in the FFF:

- SORDAT (Source Date) – Final day of survey. New or verified features only.
- SORIND (Source Indicator) – Survey registry number, ex: US,US,graph,H12551. New, updated or verified features only.
- descrp (Description) – New, Update, Delete, Retain

- remrks (Remarks) – Processing remarks including survey techniques, feature classification (i.e. obstruction, rock, platform).
- recomd (Recommendations) – Hydrographer's charting recommendations.
- sftype (Special Feature Type) – Only updated for ATON, AWOIS and/or DTON items.
- dbkyid (Database Key ID) – AWOIS Record number, when applicable.
- images (Images) – Contact images, CARIS screen grabs or chartlets included in the media folder.
- userid (Unique ID) – Unique Designated Sounding ID for new obstructions.

The mandatory S-57 attribution for each S-57 object class was updated as specified in Section 8.2 of the HSD. The required attributes vary with S-57 object class (i.e. OBSTRN, OFSPLF, SBDARE), but may include:

- WATLEV (Water Level Effect) – updated for OBSTRN features
- VALSOU (Value of Sounding) – updated for OBSTRN features
- CATOBS (Category of Obstruction) – updated for OBSTRN features (when applicable)
- TECSOU (Technique of Sounding Measurement)
- QUASOU (Quality of Sounding Measurement)
- NATSUR (Nature of Surface) – updated for SBDARE features
- NATQUA (Nature of Surface, Qualifying terms) – updated for SBDARE features
- COLOUR (Color) – updated for SBDARE features

The required S-57 Meta-Object, M_COVR(Coverage) is also included in each survey's FFF.000 file, with the required attributes updated as specified in Section 8.2 of the HSD.

B.2.6 Bottom Samples

Bottom sample positions were imported into CARIS Notebook from the HYPACK target file into the Final Feature File. The bottom samples were classified as SBDARE (Seabed area) objects and attributed as instructed in Sections 7.1 and 8.2 of the HSD. The full bottom sample description was entered into the Remarks attribute field. The photo names of each bottom sample were entered into the Images attribute field.

B.3 Quality Management

A full cross line sounding data set was acquired at the start of acquisition, prior to collection of mainscheme coverage. The initial cross line dataset compared well, in a statistical sense, to the mainscheme lines. However, due to the relatively rough conditions in which some of the cross lines were collected, comparison surfaces appeared to show moderate cross line-induced motion artifacts. In an attempt to acquire the best dataset possible (statistically and visually) a number of the initial cross lines were discarded and additional cross lines acquired during a period of fair weather. The planned cross line mileage was > 8% of mainscheme mileage required in the HSD for Set Line Spacing coverage. As mentioned previously, the 60m offset mainscheme line plan was the basis for calculating cross line mileage requirements. Cross lines were run nominally perpendicular to mainscheme lines. Soundings from mainscheme lines and from the cross lines were compared daily throughout survey operations in the preliminary CUBE surfaces and in CARIS HIPS Subset Editor. The cross line comparison served as a check that the system offsets and biases were entered correctly and to verify the accuracy of the sounding correctors (i.e. tide, sound speed, trueheave).

Statistical quality control information was generated by comparing the beams of each cross line to each finalized CUBE Surface. Cross line evaluations are performed with respect to IHO Order 1a uncertainty specifications with the CARIS QC Report Utility, and are presented in Separate II of the Survey DRs. For each survey, difference surfaces were also generated between a surface compiled only from mainscheme MBES data and a surface compiled only from cross line MBES data. The results from the difference surface creation are discussed in the descriptive reports for each survey.

Detailed line queries were utilized periodically throughout data processing to be certain all necessary processes were completed and the right corrector files were applied to all the lines. The line queries were also used to calculate line mileage and were compared to processing logs to verify line names and be certain that no aborted lines were included in the final data products.

The standard deviation, depth and uncertainty layers were reviewed to identify possible systematic errors related to sound speed, tide, trueheave correction or to errors in system alignment.

Sound speed profiles were plotted by day to visualize the variation over time and space (Figure 11). Rapid increases or decreases in sound speed in the top 5 meters of the water column generally correlated with higher error in the sounding position, as evidenced by a “frown” effect across the MBES swath. Surface sound speed logged in the raw HYPACK files was extracted and plotted for every line. High deviation and rapid changes in the surface sound speed over a line, were also an indicator of increased sound speed error in sounding correction, which was most severe in the outer beams (Figure 12). Lines that exhibited high variability in the surface sound speed were reviewed in the CUBE surface layers and in Subset Editor for excessive sound speed error. CARIS beam filters were used on lines that exhibited larger than acceptable uncertainty in the outer beams due to increased error in sound speed data. The beam filters applied on a daily or line-by-line basis were recorded in the survey processing logs.

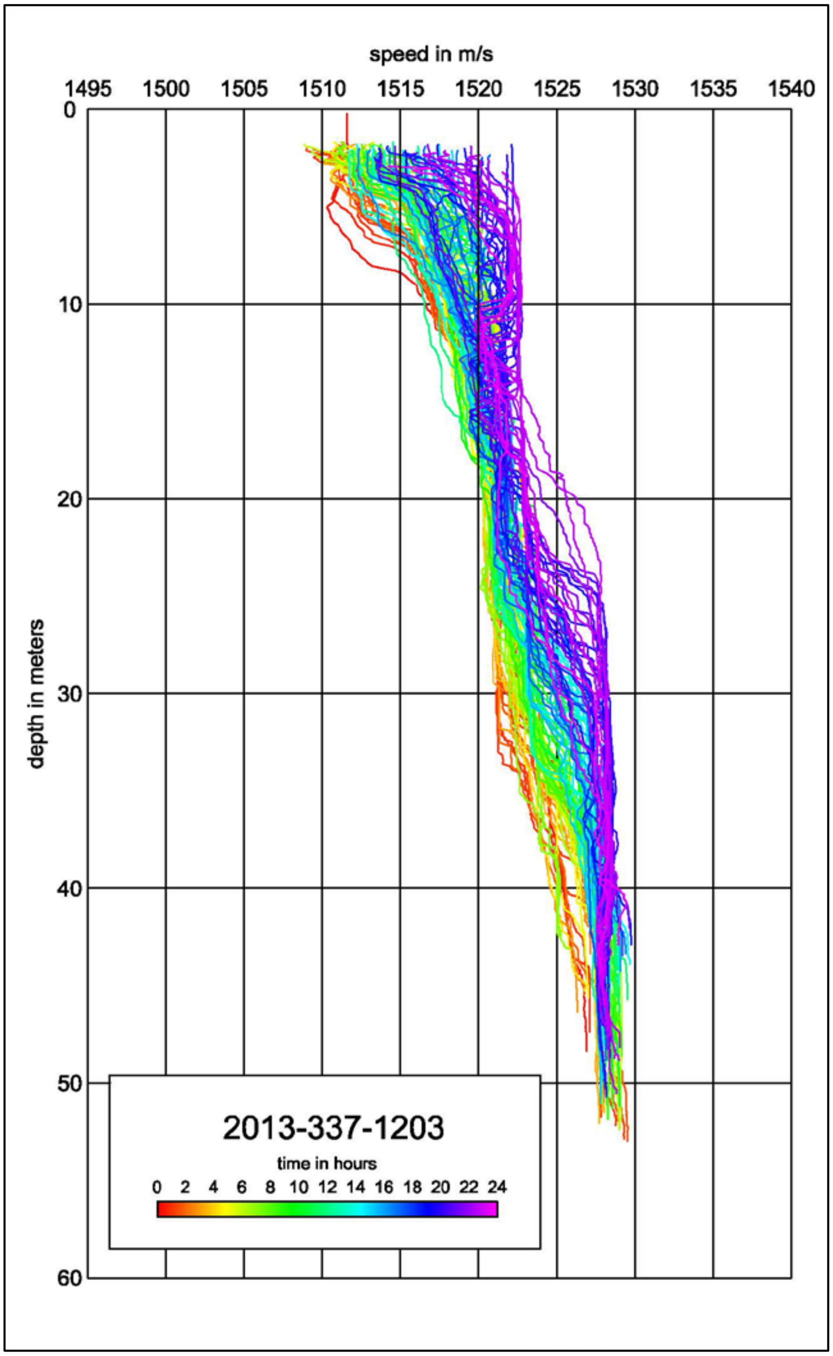


Figure 11. Plot of sound speed casts for December 3, 2013 (DN 337).

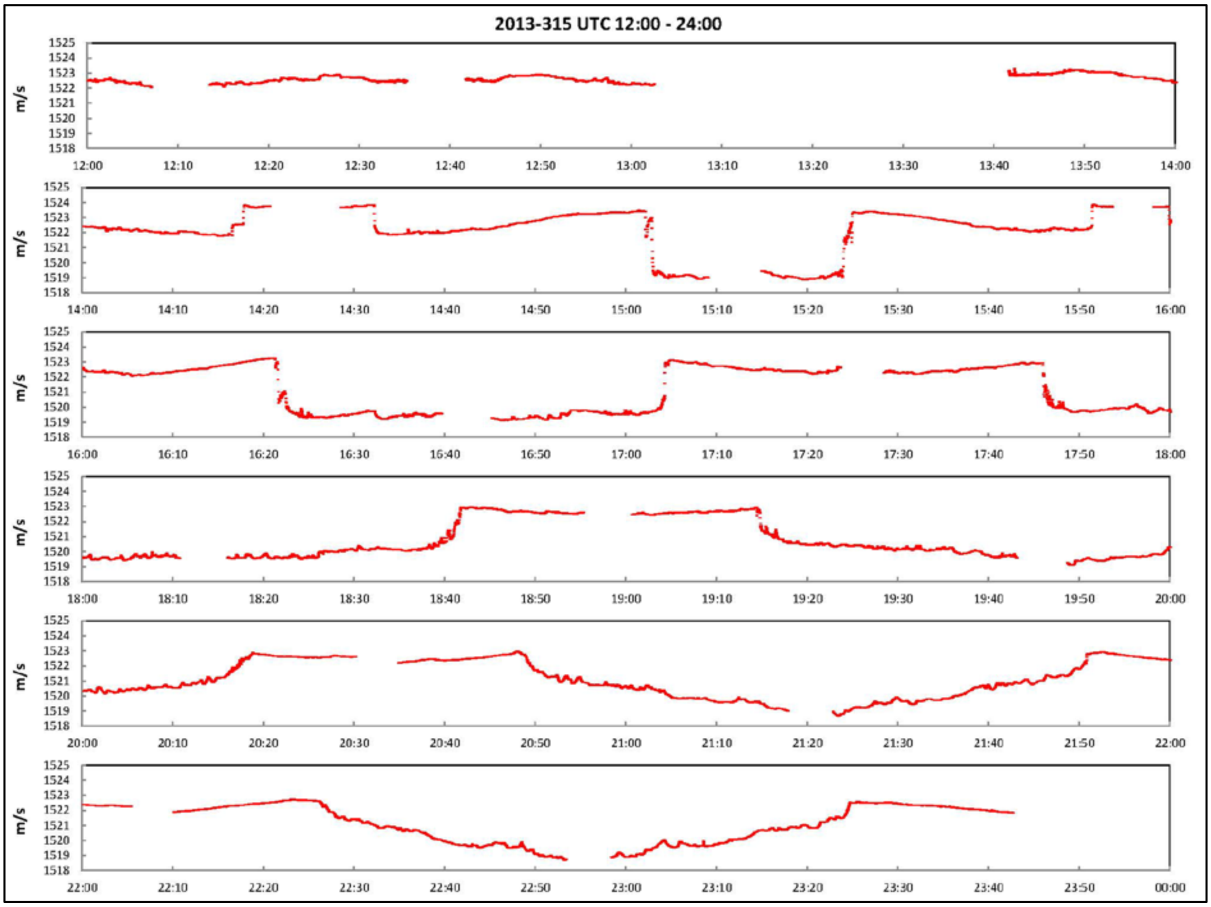


Figure 12. Surface sound speed plot by survey line for Nov 11, 2013 (DN 315) 12:00 to 24:00 UTC.

The TPU values for final BASE surface depths were evaluated with the CARIS BASE surface QC Report Utility with respect to IHO Order 1a uncertainty specifications.

Junction comparisons between current and prior hydrographic surveys were accomplished using the CARIS HIPS difference surface function.

B.4 Uncertainty and Error Management

Estimates for the uncertainty of all measurements associated with sounding collection, were gathered from either reported manufacturer system accuracy or from statistics calculated from multiple measurements of the value in question.

Error is defined as the difference between a measured value and the true, or accepted, value. Since the true sounding value is not known ahead of time, an accurate error value cannot be reported with confidence. Uncertainty, not error, is the chosen parameter to quantify sounding accuracy such that it can be reported in terms of an interval of confidence around the measured value. The uncertainty associated with a measurement is reported as the standard deviation (σ), or the root mean square deviation, of the value from the mean.

The combined uncertainty value per sounding, or the Total Propagated Uncertainty (TPU), was calculated using CARIS HIPS. Standard deviation values for vessel offsets, motion, draft and alignment measurements were entered into the vessel HVF "TPE values" section at the 1-sigma level. The HVF uncertainty values along with uncertainties associated with tide and sound speed were used in combination with the sonar model in the DeviceModels.xml file to assign a total horizontal uncertainty (THU) and total vertical uncertainty (TVU) for every sounding.

B.4.1 Total Propagated Uncertainty (TPU)

Tables 9 lists the standard deviation and uncertainty estimates used for all measurements incorporated into the TPU estimates for the Reson 7125 echo soundings.

Table 9
Reson 7125 Uncertainty Estimates

Uncertainty Values Included in CARIS HVF Files & Compute TPU Fields			
Heading Measurement σ (deg)	0.02	XYZ Offset Measurement σ (m)	0.015
Heave % Amplitude	5.00	Vessel Speed Measurement σ (m/s)	0.03
Heave Measurement σ (m)	0.05	Loading Measurement σ (m)	0.038
Roll Measurement σ (deg)	0.02	Draft Measurement σ (m)	0.015
Pitch Measurement σ (deg)	0.02	Delta Draft Measurement σ (m)	0.012
Navigation Measurement σ (m)	1.00	MRU Align StdDev Gyro (deg)	0.10
Transducer Timing σ (sec)	0.01	MRU Align StdDev Roll/Pitch (deg)	0.10
Navigation Timing σ (sec)	0.01		
Gyro Timing σ (sec)	0.01	Tide Measurement σ (m)	0.01
Heave Timing σ (sec)	0.01	Tide Zoning Vertical Uncertainty (m)	0.14
Pitch Timing σ (sec)	0.01	Sound Speed Error Measured (m/s)	1.00
Roll Timing σ (sec)	0.01	Sound Speed Error Surface (m/s)	2.00

The POS MV 320 manufacturer recommended uncertainty values for the heading, heave, roll, pitch and timing measurements were entered in the HVFs.

The standard deviation value for the XYZ Offset and static draft measurements was calculated from distances acquired with the coarsest tool used to verify vessel offsets, the steel tape.

Standard deviation for the loading measurement was calculated from the measure down values acquired on the port and starboard sides as well as Hazen pressure gauge-derived static draft values measured during the daily changeover.

The uncertainty for the delta draft was established by calculating the standard deviation of the differences between settlement values of reciprocal runs per each vessel speed tested. The settlement curve is included in DAPR Appendix I.

The MRU Alignment standard deviation values were calculated from the bias values estimated by multiple hydrographers who had individually processed the patch test data.

The combined tide measurement and zoning uncertainty was provided by CO-OPS in the Tides SOW.

A sound speed measurement uncertainty of 1 m/s was used in the TPU model since casts were taken every 15 minutes or less, the value recommended in Table 4-9 "Uncertainty values for use in CARIS with vessels equipped with an attitude sensor" from Appendix 4 of the FPM. The surface sound speed uncertainty, 2 m/s, a conservative number per the FPM, was estimated from the surface speed of sound variability measured with the AML Micro X.

C. CORRECTIONS TO ECHO SOUNDINGS

C.1 Vessel Configuration and Offsets

C.1.1 Description of Correctors

Vessel configuration parameters and offsets are measures of the location of the integrated survey systems in respect to an established vessel Reference Point (RP) that serves as XYZ point 0, 0, 0 within the vessel's reference frame. The RP on the *R/V Ferrel* was the phase center or "bullseye" of the POS MV IMU. The measured offsets included the distance between the transducer phase center to the RP, the distances between the GPS antenna phase centers and the RP, and the distance from the top of the side scan sheave and the RP.

C.1.2 Methods and Procedures

As mentioned in prior sections, a total station was used to complete a full survey of the *R/V Ferrel* in 2010 (OPR-J364-KR-09). The POS MV IMU was mounted on a permanent plate close to the vessel's center of rotation. Two permanent benchmarks located on the mid-deck of the *R/V Ferrel* were established in reference to IMU phase center, the RP. The total station was then used to measure the offsets from these benchmarks to the POS MV GPS port and starboard antenna mounts, the Trimble 750 GPS antenna mount, the top of the side scan sheave and the port/starboard draft measurement points. When the multibeam pole mount was fully deployed (vessel in dry dock), the total station was used to establish another survey bench mark on the top side of the transducer pole clamp.

For the 2013-2014 project (OPR-K339-KR-13), the offsets established in 2010 were verified with a steel tape measure on November 8, 2013 (DN 312). The vertical offsets measured from the antenna mounts to the phase center of the GPS antennas were added to the Z-values established with the total station. The vertical offset between the bench mark on the top of the transducer pole clamp and the transducer phase center (TX) was measured with a steel tape.

The 7125 transducer is located directly below the transducer pole clamp bench mark allowing for an unobstructed measurement path.

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 in 2010. The IMU and transducer mounting hardware were co-aligned in 2010 employing a gyrocompass while the survey vessel was in dry dock. The primary GPS antenna position, with respect to the IMU and RP, was established in 2010, as mentioned above, using precise optical survey methods. All critical, custom mounting areas including the IMU receiver plate, the transducer pole mounting plate, and the antenna pole mounting areas (located on the roof of the vessel) remain structurally unchanged since 2010.

C.1.3 Vessel Offset Correctors

Instrument offsets input to the CARIS vessel configuration files are included in Tables 10-11 below.

Table 10
***R/V Ferrel* Sensor Offsets (see Figure 13)**

***R/V Ferrel* Offsets via Topcon Total Station Survey or Measured Relative to Permanent Shipboard Benchmarks. Offsets are relative to Reference Point (RP) or Waterline**	**Forward Positive (m)**	**Starboard Positive (m)**	**Up Positive w.r.t RP (m)**	**Up Positive w.r.t. waterline (m)**
RP IMU Center 0,0,0	0.000	0.000	0.000	-0.840
GPS POS Antenna Phase Center Port	12.029	-2.377	11.267	10.427
GPS POS Antenna Phase Center Starboard	12.064	2.427	11.262	10.422
Comparison GPS Antenna Phase Center	15.383	2.110	11.047	10.207
7125 Transducer Phase Center	1.680	5.250	-1.785	-2.625
Top Of Sheave (Cable at top of sheave)	-18.550	2.040	4.080	3.240
Starboard Side Draft Measurement Point	2.858	4.710	2.065	1.225
Port Side Draft Measurement Point	2.832	-4.708	2.083	1.243

Table 11
Reson 7125 CARIS Vessel File's Transducer Offsets (RP to Tx)

Tx Offsets	**IMU/Navigation to Transducer (m)**
X Phase Center	5.250
Y Phase Center	1.680
Z Phase Center	1.785

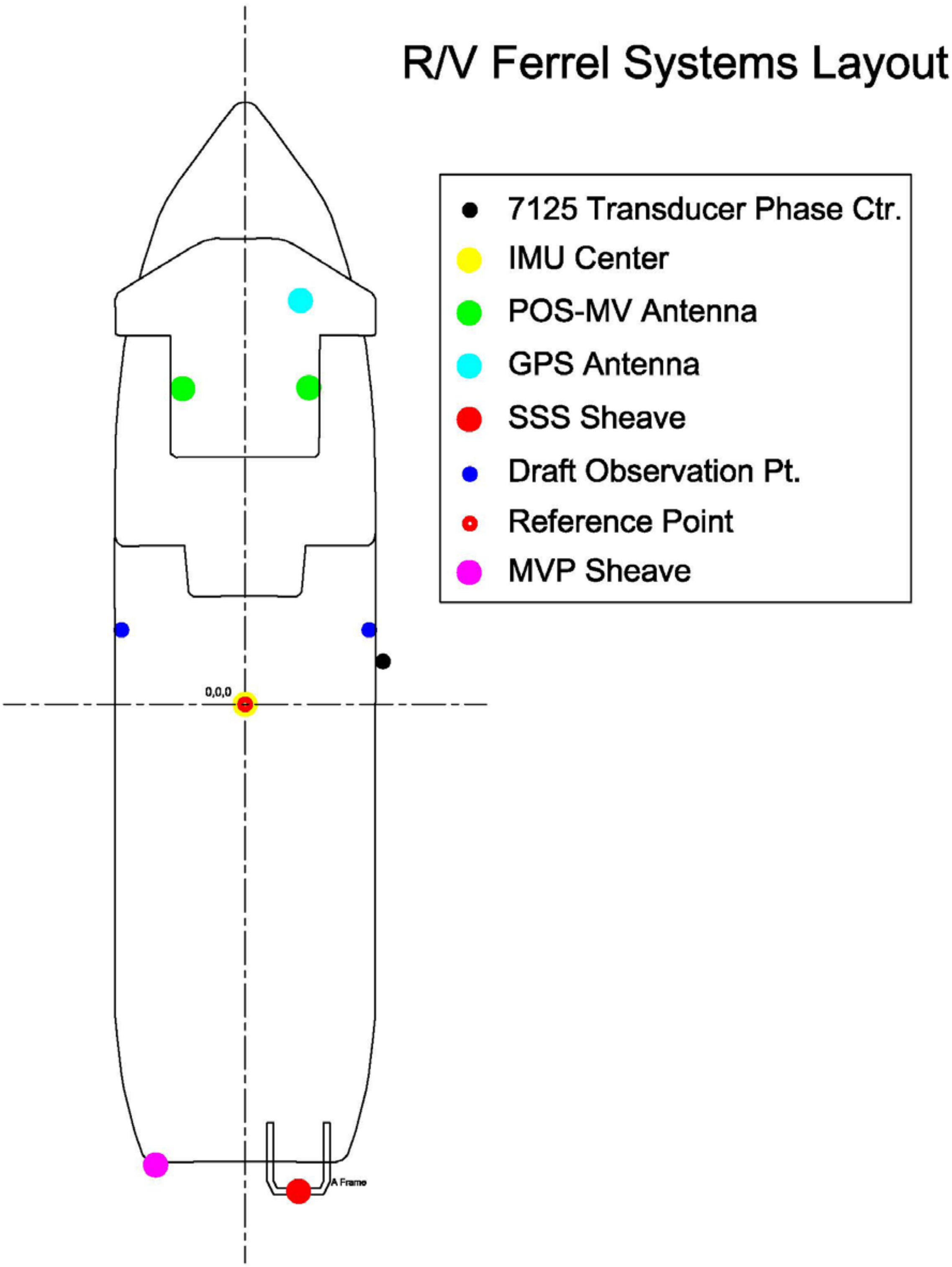


Figure 13. *R/V Ferrel* systems layout.

C.1.4 Layback

Side scan sonar fish positioning was accomplished in real time employing Chesapeake Technology's SonarWiz 5. The software was configured to calculate fish position using Pythagoras Theorem (refined via towfish depth input). The origin for fish position calculations was the top of the cable counter sheave which is related to the vessel RP (within the SonarWiz 5 software) via X, Y, Z offsets. Field testing prior to mobilization of this and other OSI projects employing the SonarWiz software for towfish positioning indicated that a catenary scalar value of 1.0 was appropriate. As mentioned above, cable-out values were derived from a calibrated cable counter sheave whose accuracy was confirmed frequently throughout the course of each survey day.

Side scan sonar target positioning accuracy was verified prior to commencement of survey operations by comparing the position of an oil rig leg located with MBES data to the contact positions of the same platform leg as selected in multiple SSS passes that were run at varying ranges and distances from the target. Accuracy testing results are presented in DAPR Appendix II.

C.2 Static and Dynamic Draft

C.2.1 Static Draft

C.2.1.1 Description of Correctors

Static draft is the vertical distance of the echosounder transducer below the water line and is added to the observed soundings during data processing in CARIS HIPS. The vertical offset between the transducer phase center and the RP was entered into the HVF Swath 1, Z-value field. A vertical offset to account for the distance from the RP to the water surface was updated nearly once a day into the Waterline Height field in the HVF. The Z-value and the waterline corrector added together equaled the static draft of the echosounder transducer phase center.

C.2.1.2 Methods and Procedures

Direct measurements of the water surface, employing a fiberglass stadia rod, were taken at the start of survey (Nov. 8, 2013, DN 312), and periodically throughout the term of the survey. These "measure downs" were made relative to port side and starboard side benchmarks. The waterline height above the RP was determined by averaging the differences obtained from subtracting the measured distances from the water surface to the benchmarks from the known vertical offsets between the RP and the benchmarks. Vessel attitude was accounted for as the final measured waterline height value is an average of the port and starboard measured values.

A Hazen water level gauge was installed within the transducer pole providing an alternate method to monitor the change in static draft due to changes in vessel loading. 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. The Hazen gauge depth below the water surface was calibrated prior to the start of survey to determine its vertical offset in reference to the RP. When the vessel was at a full stop for the daily “UTC midnight” changeover, the Hazen gauge water level data were logged for at least 10 minutes using HYPACK SURVEY. The water level values were extracted from the raw HYPACK file and averaged to obtain the depth of the Hazen gauge sensor below the water line. The waterline height was calculated by subtracting the vertical offset between the Hazen gauge sensor and the RP from the Hazen gauge average depth. Once the measure down-to-Hazen gauge corrector constant was established (and subsequently confirmed with later measurements) the Hazen gauge water level determination method was used exclusively for static draft measurements offshore as the sea state made measure downs impractical when the vessel was offshore.

The waterline height measurement was calculated nearly daily using the Hazen water level gauge method and the measure down values were acquired when the vessel was moored dockside. The waterline height measurement was corrected to the vessel reference point and recorded in the acquisition log. Waterline height values calculated from physical measurement, “measure downs,” or the Hazen gauge data, were time stamped and entered into the CARIS vessel configuration file.

In CARIS HIPS, the time stamped waterline height correctors were added to the Z-value vertical offset between the RP and the transducer phase center to obtain the echosounder static draft.

C.2.2 Dynamic Draft

C.2.2.1 Description of Correctors

Dynamic draft correctors account for the vertical displacement of the transducer when a vessel is underway in relation to its position at rest.

C.2.2.2 Methods and Procedures

Dynamic draft was measured on November 10, 2013 (DN 313) and January 7-8, 2014 (DN 007-008), with the *R/V Ferrel* configured for data acquisition with an average loading weight and vessel trim. As mentioned in a prior section of the DAPR, due to poor quality RTK GPS coverage during the November 10, 2013 dynamic draft calibration, these data were discarded in favor of the data collected on January 7-8, 2014 (excellent RTK GPS coverage).

The dynamic draft calibration test lines were acquired in water with a nominal depth of 13 meters, with wave height of approximately 0.6 meters. Data were acquired along tracklines approximately 2500 meters long at regular intervals of speed, beginning with the engines in “clutch” and increasing by 100 RPMs until the maximum vessel survey speed was reached. A reciprocal line pair was acquired at each speed. Tidal variations were accounted for by recording a “drift line” with the vessel at rest at the beginning and end of each line run at speed.

Lines, at speed or at rest, were only logged after the vessel speed leveled out or stabilized to a static state. POSPac data were acquired for the duration of the dynamic draft calibration testing, with the file logged at least 5 minutes before and after data acquisition. Due to the high quality RTK GPS positioning during the January 7-8, 2014 test sequence and the relatively poor IAPPK solution potential for this area, the POSPac data were not used in processing the settlement test.

C.2.2.3 Dynamic Draft Correctors

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

RPM Both Engines (unless noted)	Speed		Dynamic Draft Meters
	M/S	Knots	
Static	0	0	0
680 (one engine)	1.78	3.47	0.015
680	2.38	4.63	0.015
800	2.76	5.37	0.033
900	3.24	6.29	0.056
1000	3.49	6.78	0.066
1100	3.82	7.43	0.065
1150	4.02	7.82	0.078

C.3 System Alignment

C.3.1 Description of Correctors

A multibeam sonar calibration was completed to determine residual navigation timing error and angle biases in roll, pitch, and heading in the echosounder transducer alignment.

C.3.2 Methods and Procedures

Prior to commencement of survey operations, a sensor alignment or patch test was performed. The initial patch test for the Reson 7125 MBES system was performed on November 10, 2013 (DN 314). The patch test was conducted in order to determine biases in roll, pitch, heading and navigation timing. Data were acquired in accordance with HSD April 2013 Section 5.2.4.1, using a discrete feature rather than a slope to calculate the bias values due to the flat nature of the survey site.

Each set of patch test lines was 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 14) was primarily used to determine offset values. However, all patch test values were verified with the HYPACK HYSWEEP patch test routine (Figure 15).

For each parameter, multiple processing iterations were performed by multiple hydrographers. The final offset values for each vessel file (HVF) are an average of the CARIS-derived values. The final applied values, entered into the respective CARIS vessel files, are shown in Table 13. The patch tests results were of high quality and repeatability.

Throughout the course of the survey the multibeam pole was occasionally recovered (pivoted out of the water for docking). Upon returning the pole to its deployed position an abbreviated patch test was performed. Specifically, a set of reciprocal lines were collected such that the patch test roll offset could be confirmed. Often the reciprocal lines consisted of mainscheme lines that were acquired during the course of the day that the multibeam pole was redeployed. As expected, due to the design of the substantial, indexed, multibeam mounting apparatus, the roll values were very repeatable. The variability in roll values was on the order of 0.02°. Repeated testing indicated that the multibeam pole and MBES were stable as deployed. However, a minute change was detected after the vessel was on prolonged standby (Christmas break). The roll bias trended toward a change from 0.07° (pre-break) to 0.09° (post-break). This change is reflected in the Reson 7125 HVFs.

A post-survey patch test was also performed. This test was completed on January 20, 2014 (DN 020). The bias values calculated from the post-survey patch test verified the values determined with the initial (and interim) patch tests. Pre- and post-survey patch test calibrations were accomplished employing RTK GPS positioning. Interim roll check lines were acquired with the POS-MV in DGPS mode.

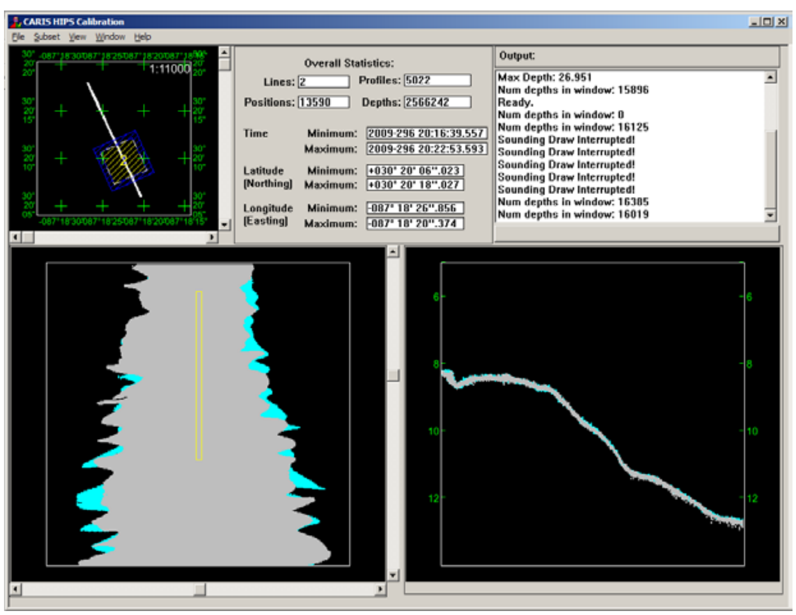


Figure 14. CARIS HIPS Calibration Tool.

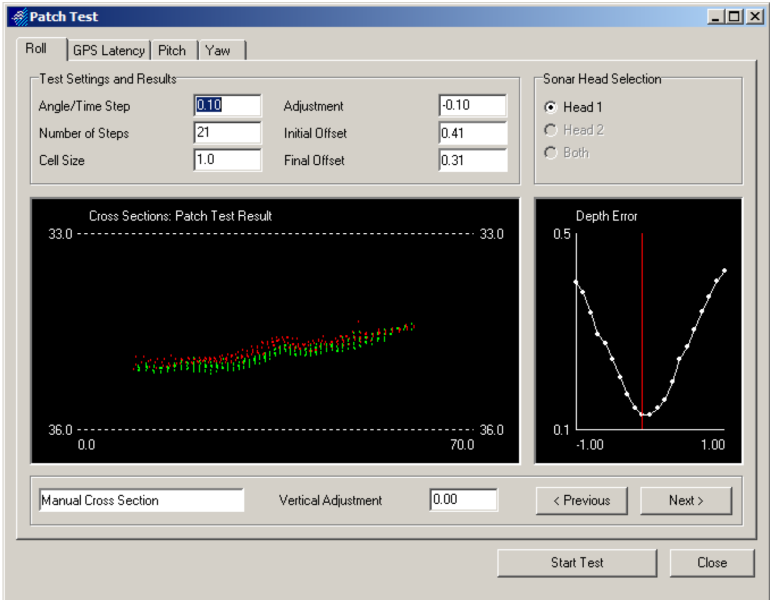


Figure 15. HYPACK HYSWEEP Patch Test Utility.

A performance surface was created on November 10, 2013 (DN 314) from a high density, near nadir sounding set collected with the Reson 7125. Ten MBES lines were acquired over a flat section of seafloor and processed in CARIS HIPS with the patch test bias values for timing, pitch, roll and yaw entered into the HVF. A port and starboard beam filter of 45 degrees was applied to the performance surface lines and a 1 m x 1 m Uncertainty Surface was generated from the processed soundings. Two performance check lines that were run perpendicular across the center of the surface were processed in CARIS HIPS as well; however, no beam filter was applied. The CARIS HIPS QC Report Utility was used to compare the beams of each performance check line to the performance surface to verify system accuracy. This process was completed again at the conclusion of the survey on January 20, 2014 (DN 020)

Performance test results are summarized in DAPR Appendix II.

C.3.3 System Alignment Correctors

Table 13
MBES Patch Test Alignment Correctors

CARIS Patch Test Results	
Latency	0.00 sec
Pitch	+0.28°
Roll (DN 312 to DN 354)	-0.07°
Roll (DN 004 to DN 020)	-0.09°
Yaw (heading)	+1.03°

C.4 Positioning and Attitude

C.4.1 Description of Correctors

DGPS correctors received from the USCG are used to improve positioning accuracy over operation in stand-alone GPS mode. Attitude corrections measured at the vessel RP are applied to soundings to correct for vessel motion.

C.4.2 Methods and Procedures

An Applanix POS MV 320 V.4 was employed for motion, heading, and position determination. Manufacturer's stated accuracy and resolution values are tabulated below.

Table 14
POS MV Specifications

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

Prior to calibration of the POS MV, lever arm distances, mounting angles and the separation distance between the port and starboard GPS antennas were entered in the controller software. The heading accuracy threshold was set to 0.5 degrees. A GAMS calibration was run after the heading accuracy had dropped below the 0.5 degrees threshold, keeping a straight course until the calibration was completed. See DAPR Appendix III, Positioning and Attitude System Reports for additional information on the POS MV configuration and calibration.

C.5 Tides and Water Levels

C.5.1 Description of Correctors

Tide correctors are applied to reduce the soundings to the Mean Lower Low Water (MLLW) datum.

C.5.2 Methods and Procedures

The water level station at Port Fourchon, LA (876-2075), 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 and applied with final zoning for all final soundings and BASE surfaces. Water levels used for DTON submissions (where applicable) are specified in the reports.

C.6 Sound Speed

Observed depth is a function of the speed of sound in the water column, such that depth is equivalent to the sound speed multiplied by the travel time of the sound pulse from transmit to receive divided by 2. Sound speed is not a constant and varies temporally and spatially, affected by changes in temperature, salinity and depth. Sound speed profiles are acquired to model the speed of sound versus depth within a survey site. Improper sound speed correction can result in inaccurate depth values and sounding positions. The sound speed correctors from the profiles are applied to soundings to override the assumed sound speed value used during acquisition and to calculate the depth using the actual sound speed measured in the survey site for a defined space and time.

C.6.1 Sound Speed Profiles

The sound speed profiles used to correct the echo soundings were acquired with an ODIM MVP-30 equipped with two sensors; a sensor that measured sound speed directly at 10 Hz during its descent through the water column and a pressure sensor for profile depth measurement. Due to a communications failure in the primary MVP sensor package, two sensor packages were employed during the course of the project (primary and spare). The MVP sensors (sound speed and depth) were calibrated October 8-11, 2013. The calibration reports are included in DAPR Appendix IV.

Sound speed profile correctors were applied in CARIS HIPS using the Sound Velocity Correction process, which employs a ray tracing algorithm to simulate refraction. With few exceptions (discussed in the survey DRs) the Nearest in Distance Within Time (1-hour) profile selection method was used to determine which cast was applied to the soundings. This method was selected to limit the effects of spatial and temporal variation in sound speed.

C.6.2 Surface Sound Speed

Surface sound speed correctors were sent directly from the AML Micro X sensor to the Reson 7125 TPU in real time to facilitate beam steering in equidistant mode and roll stabilization, a feature used throughout the survey. The AML Micro X sensor was calibrated by the manufacturer September 4-6, 2013.

D. APPROVAL SHEET

LETTER OF APPROVAL

REGISTRY NOS.
H12550, H12551, H12552, AND H12553

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of Surveys H12550, H12551, H12552, and H12553 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.

Digitally signed by George G. Reynolds
Date: 2014.05.14 10:04:07 -04'00'

George G. Reynolds
Ocean Surveys, Inc.
Chief of Party
May 14, 2014