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

Data Acquisition & Processing Report

Type of Survey *Multibeam and Side Scan Sonar*

Project No. *OPR-K380-TJ-10, OPR-H355-TJ-10*
OPR-E350-TJ-10, OPR-D304-TJ-10

Time Frame: *24Apr, 2010 – 26 Oct, 2010*

LOCALITY

State *Texas, Florida, Virgina,Virginia*

General Locality *Approaches to Galveston, TX; Approaches to Key West, FL; Southern Chesapeake Bay, VA; and Approaches to Chesapeake Bay, VA*

2010

CHIEF OF PARTY

CDR Shepard M. Smith
National Oceanic and Atmospheric Administration

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A. Equipment

The methods and systems described in this report are used to meet Complete and Object detection coverage requirements and are in accordance with the Hydrographic Surveys Specifications and Deliverables Manual (2010), Hydrographic Survey Directives, and the Field Procedures Manual for Hydrographic Surveying (2010).

The Survey Vessels

The platforms used for data collection were the *NOAA Ship Thomas Jefferson,* (Figure A-1) *Hydrographic Survey Launches 3101 and 3102* (Figure A-12) and *Utility boat 1701* (no drawing available). *Thomas Jefferson* acquired multibeam echosounder (MBES) data, Side Scan Sonar (SSS) imagery and sound velocity profile (SVP) data. The vessel is equipped with a DT Marine Products tow winch (Model 307EHLWR) for side scan deployment, and a DT Marine Oceanographic winch for CTD and bottom sample deployment, and a Brooke Ocean Technology MVP 100 Moving Vessel Profiler (MVP). Launches *3101* and *3102* acquired multibeam echosounder (MBES) data, vertical beam echosounder (VBES) data, Side Scan Sonar (SSS) imagery and sound velocity profile (SVP) data. Utility boat *1701* acquired VBES data only. Table A-1 presents the vessel characteristics for all platforms.

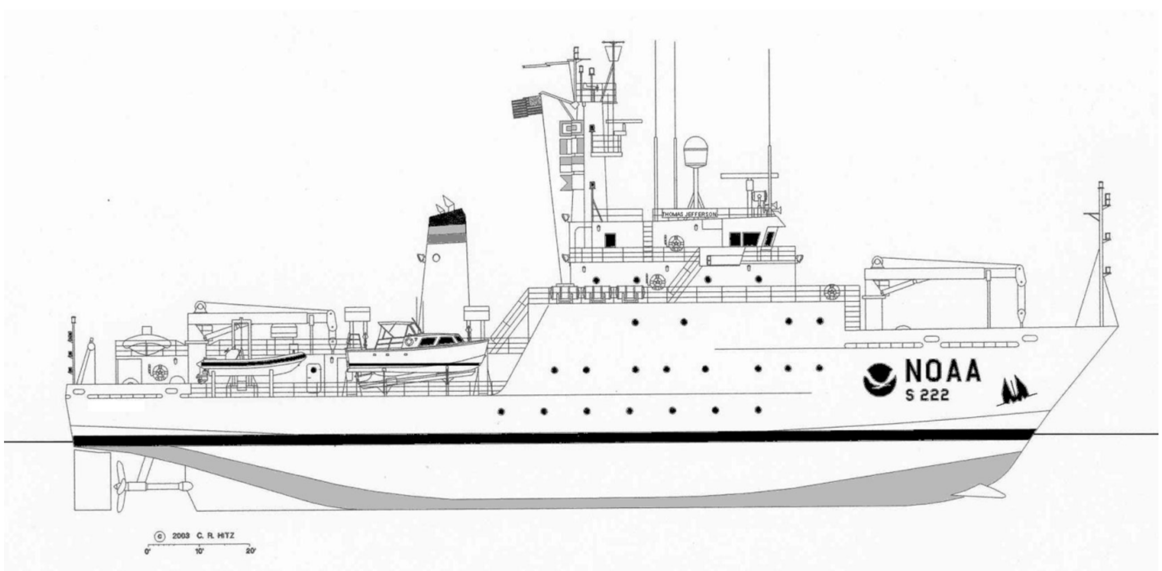

Figure A-1. The NOAA Ship *Thomas Jefferson*

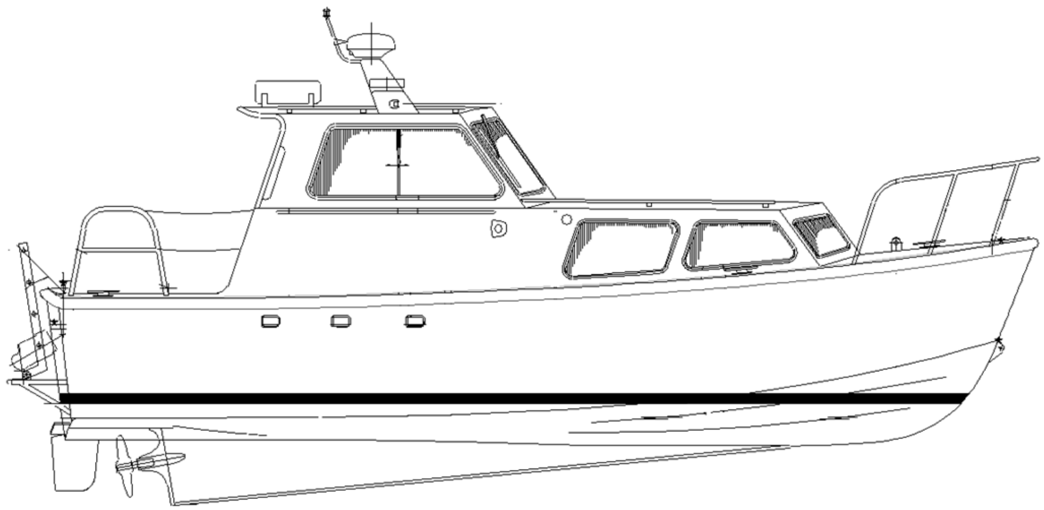

Figure A-2. Hydrographic Survey Launch *3101/3102*

Vessel Name	LOA (Ft)	Beam (Ft)	Draft (Ft)	Survey Speed	Date of last Vessel Survey	Date of last Dynamic Draft Measurement
NOAA Ship Thomas Jefferson	208’	45’	14.0’	5-10 kts	3/10/2005	3/11/2010
HSL 3101	31’	10’8”	5’2”	4-12 kts	1/20/2010	3/12/2010
HSL 3102	31’	10’8”	5’2”	4-12 kts	1/20/2010	3/13/2010
UtilityBoat 1701	17’6”	7”	13”	4-10 kts	10/8/10	9/23/10

Table A-1. Survey Vessel Characteristics

Data Acquisition Systems

A complete listing of the data acquisition systems used for OPR-K380-TJ-10, OPR-H355-TJ-10, OPR-E350-TJ-10, and OPR-D304-TJ-10 are listed in the tables below:

Hydrographic Hardware Inventory
Field Unit: Thomas Jefferson (S-222)

SONAR AND SOUNDING EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD # / ACM #**
Reson	7P Processor	50357	CD0001044551
	Lower Control Unit	61206	None
	Projector	1908203	None
	Reciever, EM7200-1	808042	CD0000825373
Kongsberg	EM 1002	Processor: 227	CD0001474854
		Transducer: 222	AMC-A010656
Klein	5500 high speed high resolution side scan sonar towfish	280	CD0001776003
	Top Side Processor Unit	135	CD0000825295
	5500 SSS Spare	319	
	Spare Top Side Procesing Unit	138	CD0000825294
Odom	Echotrac MKII	9656	CD0000656528
POSITIONING & ATTITUDE EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Trimble	DSM212L	0220227516	CD0000658032
Trimble	DSM212L	0220159716	CD0000832703
Applanix	POS/ MV	PCS - 2321	CD0001472952
Applanix	POS M/V	IMU - 146	CD0001284522
SOUND SPEED MEASUREMENT EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Seabird	SBE 19 SVP	192472-285	CD0001776086
Applied Micro Stystems	Smart SV+T SSVS	4823	A011827
Brooke Ocean Technology LTD	Sensor 1	5340	None
	MVP PU	10332	CD0200825374
	"Fish 1"	10535	None
	"Fish 2"	10333	None
	MVP Computer	0127560	None
	Sensor 2	4988	None
	Deck Unit	10332	None
TIDES & LEVELING EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Lietz / Sokkisha	B1 Automatic Level	7423	None
Carl Zeiss	Ni 2 Level	20606	None

Table A-2 - *Thomas Jefferson* S222 Acquisition Systems

Hydrographic Hardware Inventory			
Field Unit: Launch 3101			
Effective Date: March 01, 2010			
Updated Through:April 26, 2010			
SONAR AND SOUNDING EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Reson	SeaBat 7125-SV TPU	1812018	CD0001527832
	SeaBat 7125-SV X-Ducer	2008044	CD0001776100
Klein	5500 LW ss towfish	292	N/A
	Top Side Processor Unit	137	CD0000825292
Odom	Echotrac CV-200	3260	
POSITIONING & ATTITUDE EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Trimble	DSM212L	0220243252	CD0001606186
Applanix	POS M/V	2320	CD0000825559
		IMU - 352	none
SOUND SPEED MEASUREMENT EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Seabird	SBE 19 Plus SVP	19P33589-4486	CD0001776087

Table A-3- *HSL 3101* Acquisition Systems

Effective Date: March 01, 2010

Updated Through:April 26, 2010

SONAR AND SOUNDING EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Reson	SeaBat 7125-SV TPU	1812031	CD0001529723
	SeaBat 7125-SV X-Ducer	2008027	CD000152972x
Klein	5500 LW ss towfish	322	N/A
	TPU	136	CD0000825297
	Hydrochart 5000	364	N/A
	TPU	184	CD0000508851
Odom	Echotrac CV-200	2917	
POSITIONING & ATTITUDE EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Trimble	DSM212L	0220168291	CD0000819685
Applanix	POS/MV	2562	CD0000156714
		IMU - 356	CD0001474855
SOUND SPEED MEASUREMENT EQUIPMENT			
Manufacturer	**Model**	**Serial Number**	**CD Number**
Seabird	SBE 19 Plus SVP	19P33589-4487	CD0001776088

Table A-4- *HSL 3102* Acquisition Systems

Utility Boat *1701* is outfitted with a Raven Invicta 210 and an Odom CVM200. Serial numbers are not available for these units because they are hidden from view, sealed inside the splash proof pelican case assembly. Documents accompanying this integrated unit do not list the serial numbers.

A.1 ODOM Echotrac CV200

The Echotrac CV-200 is a dual-frequency digital recording echosounder system with a digital recorder. The systems high frequency setting is 200 kHz, low frequency is 24 kHz. It is hull-mounted on HSL *3101*and *3102*.

On Launches *3101* and *3102*, the transducer is mounted on the port side forward of the retractable arm that accommodates the RESON 7125-SV (Figure A-3). The installation of the Odom on Launch *3101, 3102* allows simultaneous acquisition of KLEIN 5000 side scan with general survey-grade bathymetry when the ODOM is operated in either low or high frequency mode.

Figure A-3 - Odom Vertical Beam on *3101 / 3102*

For the purposes of calculating total propagated error (TPU), the ODOM Echotrac CV-200 is assumed to be a single-frequency multibeam transducer with one beam. The maximum across-track and along-track beam angles are assumed to be identical at a value of 7.5°. The sonar is assumed to have a pulse length of 0.1 ms at 100 kHz and a ping rate of 20 Hz.

The ODOM Echotrac is used with side scan sonar to meet NOAA requirements for object detection.

Owing to its wide beamwidth, patch tests are not conducted to solve for mounting angle biases for ODOM Echotrac data. During typical acquisition conditions, the high-frequency beamwidth is wide enough to receive a primary-lobe hit at nadir regardless of vessel attitude. This breaks down, however, when the vessel pitches more than 3° or rolls more than 5°. Care is taken to avoid using the ODOM as the primary source of bathymetry in situations where the pitch or roll would cause attitude artifacts or side-lobe hits.

Notable Odom Echotrac equipment changes:

On DN 103, the transducer for the Odom CV200 on 3102 was lowered away from the hull to reduce bubble sweep across the face of the transducers. On DN 180, the same procedure was done for 3101. The CARIS .HVF files were updated to account for this offset adjustment (see figures A-4 and A-5 below). On DN 281, the Odom CVM200 was put into service on utility boat 1701. Transducer offsets for 1701 are listed in figure A-6 below.

Swath 1
Navigation
Gyro
Heave

	Date	Time	Time Correction (s)	X (m)	Y (m)	Z (m)
1	2010-067	00:00	0.00	-1.03	0.947	0.122
2	2010-180	00:00	0.00	-1.03	0.947	0.198
3		00:00	0.00	0.00	0.00	0.00

Figure A-4. HSL 3101 – Odom CV200 tranducer Z-offset adjustment

Swath 1
Navigation
Gyro
Heave

	Date	Time	Time Correction (s)	X (m)	Y (m)	Z (m)
1	2010-067	00:00	0.00	-1.004	0.867	0.081
2	2010-074	00:00	0.00	-1.004	0.867	0.151
3	2010-103	00:00	0.00	-1.004	0.867	0.14

Figure A-5. HSL 3102 – Odom CV200 tranducer Z-offset adjustment

Swath 1
Navigation
Draft

	Date	Time	Time Correction (s)	X (m)	Y (m)	Z (m)
1	2010-281	00:00	0.00	0.05	-2.00	2.12
2		00:00	0.00	0.00	0.00	0.00

Figure A-6. Utility Boat 1701 – Odom CVM200 tranducer offsets

A.2 RESON SeaBat 7125 Multibeam Echosounder

The RESON SeaBat 7125 system is a single-frequency, digital recording multibeam echosounder with a central frequency of 400 kHz. The RESON 7125 system aboard *Thomas Jefferson* is installed in a steel housing assembly with hydrodynamic shape mounted to a pylon extending from the starboard hull of the ship (Figure A-7).

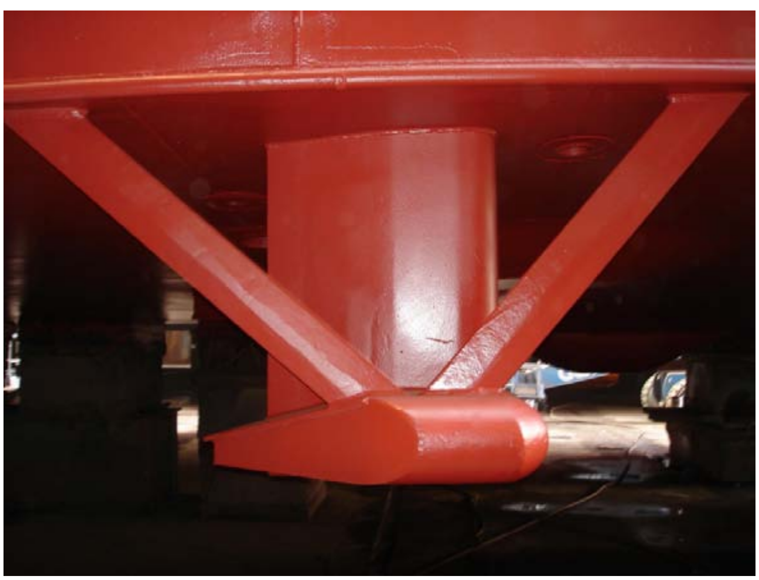

Figure A-7. 7125 Housing on *Thomas Jefferson*

The RESON 7125 forms 256 beams and can be set to interpolate to 512 beams. The RESON 7125 can also be set to acquire equi-distant or equi-angular beam spacing. Each beam in the receive array has a 0.5° across-track resolution and 1° along-track resolution. The RESON 7125 has a maximum ping rate of 48 Hz and can achieve a full swath width to a depth of 75m. Standard operating procedure on *Thomas Jefferson* is to acquire 512 beam, equi-distant bathymetry.

The sonar contribution to the total propagated error is computed using parameters provided by the manufacturer and distributed with Caris HIPS.

The RESON 7125 performs active beam steering to correct for sound velocity at the transducer head using an Applied Microsystems LTD Sound Velocity and Temperature Smart Sensor. This sensor will be discussed in more detail in the Sound Velocity Equipment Section.

The user selectable range scale on the RESON 7125 was adjusted using the "autopilot" settings, or by hand. In some cases during skunk striped surveys or complete coverage surveys, the range scale was set one setting higher than optimal to reduce noise in the data.

A.3 RESON SeaBat 7125_SV Multibeam Echosounder

The RESON 7125-SV system aboard Launches *3101, 3102* are installed on a RESON Seabat 7125 mounting bracket deployed on a retractable arm from the hull. (Figure A-8).

Figure A-8. 7125-SV Housing on Launch *3101/3102*

The RESON 7125-SV forms 256 beams and can be set to interpolate to 512 beams in the receive array and can be set to acquire equi-distant or equi-angular beam spacing. Standard operating procedure on *Thomas Jefferson* is to acquire 512 equi-distant bathymetry. The 400 kHz frequency has a 0.54° across-track resolution and 1° along-track resolution. The 200 kHz frequency has a 1.1° across-track resolution and 2.2°

along-track resolution. The RESON 7125-SV has a maximum ping rate of 50 pings/s and can maintain a full swath width in depths of 1-75 m for the 400 kHz, and 1-150 m for the 200 kHz systems.

The sonar contribution to the total propagated error is computed using parameters provided by the manufacturer and distributed with Caris HIPS.

The RESON 7125-SV performs active beam steering to correct for sound velocity at the transducer head using a RESON Sound Velocity Probe (SVP) 70. This sensor will be discussed in more detail in the Sound Velocity Equipment Section.

The RESON 7125-SV can be configured for roll stabilization. In roll stabilized mode, the sonar can operate in environments with up to +/- 10 degrees of roll without degrading system performance. Standard operating procedure on *Thomas Jefferson* is to acquire data in the roll stabilized mode.

The user selectable range scale on the RESON 7125-SV was adjusted using the "autopilot" settings, or by hand. In some cases during skunk striped surveys or complete coverage surveys, the range scale was set one setting higher than optimal to reduce noise in the data.

Notable RESON7125-SV equipment changes:

The Reson 7125-SV units on 3101 and 3102 were new equipment installation for 2010 field season, new .hvf files were created. Over the course of the season, receiver cables for the new Reson 7125-SV units have failed on four separate occasions due to micro-fractures in the wires. These receiver cables have been replaced by Reson due to design flaws. While some intermittent data dropouts occurred, the accuracy of the data was unaffected. Upon replacement of the cables, patch tests were performed. No changes to the HVFs were deemed necessary as a result of these new patch tests.

A.4 Kongsberg EM 1002 Multibeam Echosounder

The Kongsberg EM1002 system is a single-frequency, digital recording multibeam echosounder with an operating frequency of about 95 kHz. The EM1002 aboard *THOMAS JEFFERSON* was installed in August 2001 in Jacksonville, FL, while the ship was still under the purview of the U.S. Navy.

The Kongsberg EM1002 transducer consists of a curved transmitter array and flat receiver array encased in an acoustically transparent fiberglass blister that is rigidly fixed to the hull of *THOMAS JEFFERSON* at the keel near frame 20. The KONGSBERG EM1002 forms 111 beams each of which has a 2° across-track beam footprint for a maximum total swath width of 150°. Each beam has an along-track beam resolution of 1.5°. The ping rate is nominally 10 Hz, but may vary depending on water depth, swath width, or user specification. For any given survey area optimal line spacing is determined for the system. A maximum width is set in the acquisition software (using the equidistant setting). The resulting swath is usually less than the maximum of 75 degrees. This compressed swath increases the ping frequency and therefore the data density. The KONGSBERG EM1002 is capable of bottom detection in depths from 5-1000m. Aboard the *THOMAS JEFFERSON* the KONGSBERG EM1002 is used in depths from 15m-1000m. The Windows-based Kongsberg Seafloor Information System (SIS) software package is used to acquire EM1002 data.

Active beam steering is performed to correct for sound velocity at the transducer head using an Applied Microsystems Smart SV&T sea surface sound velocity sensor. This sensor will be discussed in more detail in the Sound Velocity Equipment section. In addition, the curved face of the transducer array is designed to mechanically steer acoustic energy. An outer beam roll calibration coefficient is determined before starting acquisition for a project. This value is entered into the acquisition software and cannot be post processed.

The Kongsberg EM1002 does not meet NOAA specifications for object detection in shallow water (<20m). Data must be acquired with side-scan sonar.

For the purposes of calculating total propagated error, the KONGSBERG EM1002 is assumed to have an operational frequency of 95 kHz, pulse length of 0.2ms and a typical ping rate of between 1-8 Hz.

The best expected performance of the KONGSBERG EM1002, as installed on *THOMAS JEFFERSON* in 15m of water with an isopycnal water column and sound velocity of 1500 ms-1, is to the IHO Order 1 standard. Actual performance will vary according to sea state, water depth, swell, tide zoning error, and sound velocity spatial and temporal distribution.

The KONGSBERG EM1002 was not utilized by the field unit during the 2010 fieldseason.

A.5 Variants of the Klein 5000 Side Scan Sonar Sonars

Klein System 5000

The KLEIN 5000 high-speed high-resolution side-scan sonar (SSS) system is a beam-forming acoustic imagery device with an operating frequency of 455 kHz and vertical beam angle of 40°. The KLEIN 5000 system consists of a KLEIN 5500 towfish, a Transceiver/Processing Unit (TPU), and a computer for user interface. Stern-towed units also include a tow cable telemetry assembly. There are two configurations for data acquisition using the KLEIN 5000 system: stern-towed and hull-mounted. S-222 uses exclusively towed SSS, HSL 3101 is hull mount configuration, HSL 3102 can be converted from hull-mounted to towed as required.

The KLEIN 5000 system is distinct from other commercially-available side scan sonars in that it forms 5 simultaneous, dynamically-focused receiver beams per transducer face. This improves along-track resolution to approximately 20cm at the 100m range scale, even when acquiring data at up to 10 knots. Across-track resolution is typically 7.5cm at the 100m range scale. The achievable 20cm resolution meets the NOAA Hydrographic Surveys Specifications and Deliverables Manual (HSSDM) for object detection. Digital data from the KLEIN 5000 TPU is sent directly to the acquisition computer for display and logging by KLEIN SonarPro software. Raw digital side scan data from the KLEIN 5000 is collected in (SDF) and maintained full resolution, with no conversion or down sampling techniques applied. These files are archived to the raw data storage drives at the end of each line for initial processing and quality control review

Towfish positioning is provided by CARIS HIPS using cable out values recorded in the Sonar Pro SDF files. This program uses Payout and Towfish Depth, Figure A-9, to compute towfish positions. The tow fish position is calculated from the position of the tow point using the cable out value received by SonarPro from the cable payout meter, the towfish pressure depth (sent via a serial interface from the KLEIN 5000 TPU to the SonarPro software), and the Course Made Good (CMG) of the vessel. This method assumes that the cable is in a straight line therefore no catenary algorithm is applied at the time of acquisition, but in processing, CARIS SIPS applies a 0.9 coefficient to account for the catenary.

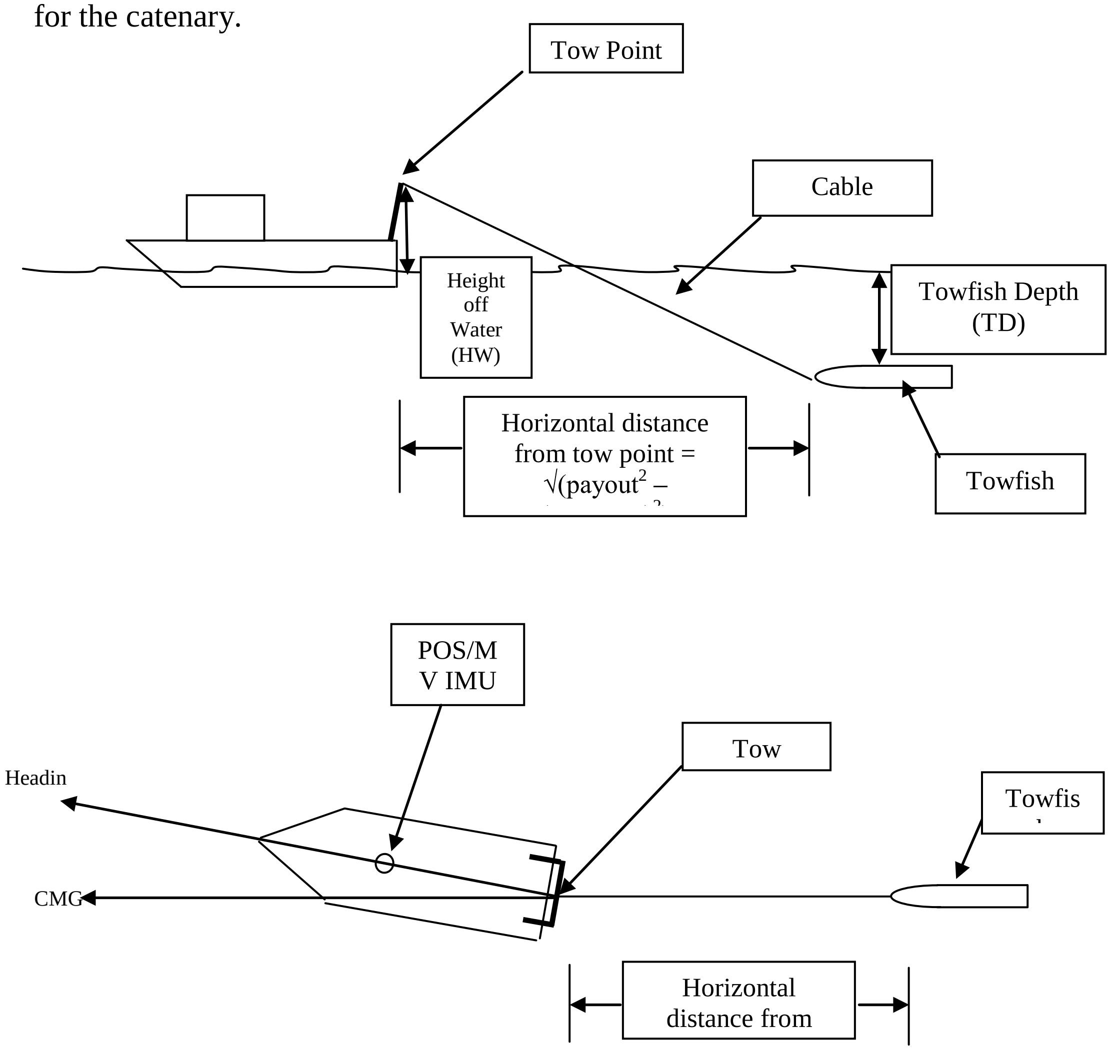

Figure A-9. Side Scan Towfish Position Calculations

When in the towed configuration, the north and east velocity vectors are filtered to calculate the ship's CMG. The CMG is used to determine the azimuth from the tow block to the side scan towfish. The position for the side scan towfish is computed based on the vessel's heading, the reference position (POS/MV IMU), the measured offsets (X, Y, and Z) to the tow point, height of the tow point above the water, Course Made Good and cable out. This calculated towfish position is sent to the sonar data collection system in the form of a GGA (NMEA-183, National Marine Electronics Association, Global Positioning System Fix Data String) message where it is merged with the sonar data file. Cable adjustments are made using a remote winch controller in acquisition in order to maintain acceptable towfish altitudes and sonar record quality. Changes to the amount of cable out are automatically saved to the SonarPro SDF.

Towfish altitude is maintained between 8% and 20% of the range scale in use (e.g. 4m-10m @ 50m range scale), when conditions permit. For equipment and personnel safety as well as safe vessel maneuverability, data may have been collected at towfish altitudes outside the 8% to 20% of the range over shoal areas and in the vicinity of charted obstructions or wrecks. In some regions of the survey areas, the presence of a significant density layer required that the altitude of the towfish be maintained outside the 8% to 20 % of the range to avoid refraction in the sonar data that would mask small targets in the outer sonar swath range. When the towfish altitude was either greater than 20% or less than 8%, periodic confidence checks on linear features (e.g. trawl scars) or geological features (e.g. sand waves or sediment boundaries) were made to verify the quality of the sonar data. Confidence checks ensured the ability to detect one-meter high objects across the full sonar record range.

Another feature that affects the towfish altitude is the use of a K-wing depressor. The K-wing depressor is attached directly to the towfish and serves to keep it below the vessel wake, even in shallower near shore waters at slower survey speeds. The use of the K-wing reduces the amount of cable payout, which in turn reduces the positioning error of the towfish. Another benefit to less cable out is increased maneuverability of the ship in shallow water. Less cable out reduces the need to recover cable prior to turning for the next survey line, permitting tighter turns and increased survey efficiency.

Side scan data file names are changed automatically every 15 minutes and manually at the completion of a survey line.

Notable SSS equipment changes:
On DN220, the Klein 5000 on 3102 was replaced with an experimental phase measuring bathymetric sonar, the Klein HydroChart 5000 Swath Bathymetry Sonar System. This sonar is discussed in greater detail below.

Hull-Mounted Configuration
Aboard both survey launches, the lightweight or heavyweight Klein 5500 towfish can be mounted to an aluminum sled using omega brackets (Figure A-10). Positioning of the hull mounted towfish is determined by entering the X,Y, Z position of the towfish as the

towpoint and a layback value of zero. Otherwise, the system is processed the same as the towed configuration.

Figure A-10. Side Scan Hull Mounted on *3101 / 3102 (lightweight model shown)*

The hull-mounted configuration is normally used in depths of twenty meters or less, per the HSSDM. Aboard Launch *3101* and *3102*, sidescan may be collected concurrently with ODOM Echotrac CV-200 vertical beam bathymetry.

Klein HydroChart 5000 Swath Sonar System

The Klein HydroChart 5000 Swath Sonar System, referred to simply as HydroChart from this point forward, is a phase measuring bathymetric sonar (PMBS).

The HydroChart differs from beam forming sonars like the RESON 7125 in that it uses the phase of the acoustic returns to determine the angle of arrival. The depth is then determined by the two-way travel time of the sound at each calculated angle of return. Position, attitude, and timing information is provided serially from the Applanix POS/MV and timing is achieved via precise timing. It is necessary to input, in real time, the sound velocity measured at the sonar in order to account for the refraction that occurs as the sound crosses the transducer – water interface. Sound velocity necessary to calculate the refraction angles at the sonar is supplied by an AML Micro SV, which is a Time-of-Flight sound velocimeter with an accuracy of +/- 0.05 m/s. Position, attitude, and surface sound velocity are written to the header of the SDF file.

Data from the HydroChart can be logged in raw format, or logged in a preliminary converted format. Standard operating procedure on *THOMAS JEFFERSON* is to log the data in the raw format. This raw data must be processed with the Klein Batch processor, which is a software program provided by the manufacturer which designates the data as either Beam Form data (imagery) or bathymetry data. The intermediate files created by the batch processor are then processed in CARIS Hips using the Convert_SDF.dll converter. The imagery files are processed in the same manner as traditional Klein 5000 imagery. The bathymetry is also processed in CARIS Hips using a modified Convert_SDF.dll, which was renamed aboard *THOMAS JEFERSON* as Convert_SDF_HC5K.dll. The need for different Convert_SDF.dll files was eliminated with the release of CARIS Hips and Sips SP2, HF5. Once CARIS Hips conversion is completed, the intermediate files are discarded. Only the raw sonar data and the final HDCS data from Hips are submitted with surveys.

The HydroChart, was installed on 3102 on DN220 for field testing on Project OPR-H355-TJ-10. After the completion of OPR-H355-TJ-10, it was determined that further field testing was warranted. Testing continued on OPR-E350_TJ-10, H12180. The field unit determined that the bathymetry for the HydroChart during H12192 was suitable for charting purposes, the data from H12180 was not as reliable as the concurrent VBES bathymetry, and therefore, only the side scan imagery from the HydroChart has been submitted with H12180. The HydroChart remained on HSL 3102 for the remainder of the field season. However, no data were acquired with this system for OPR-D304-TJ-10.

A.6 Manual Sounding Equipment

No manual sounding equipment was used for this project.

A.7 Positioning and Orientation Equipment

Positioning for data acquired by the launches and the ship are achieved by writing differentially corrected GPS positions output from the POS/MV to the raw sonar data in real time. Upon conversion in CARIS, the positional information in the raw sonar data is used to create vessel track lines for the processed data. During normal survey operations, no further processing of positional information is required. However, beginning in 2010, OCS has begun adding additional positioning requirements to certain projects in an effort to build the internal capabilities necessary to conduct Ellipsoid Referenced Surveys (ERS).

When assigned, the additional positioning requirements involve logging full POSPac data from the POS/MV and utilizing POSPac MMS to derive Smoothed Best Estimate Trajectory (SBET) files. POSPac MMS requires ephemeris and clock data for the GPS constellation and data downloaded from Continually Operating Reference Stations (CORS) or other base stations to correct for atmospheric effects in the GPS data. SBET files are extremely accurate measurements of the 3-D position, speed, and motion of a vessel and can be used to apply higher quality navigation information to the processed data. Inertially Aided Post Processed Kinematic (IAPPK) navigation may be applied in CARIS during the SVP step in the processing workflow. For OPR-E350-TJ-10, H12180, vertical and horizontal positioning was derived from IAPPK methods. IAPPK methods were not utilized for OPR-K380-TJ-10, OPR -H355-TJ-10 or OPR-D304-TJ-10.

IAPPK methods are discussed in greater detail in Section C of this DAPR.

Applanix POS/MV

A basic requirement of multibeam hydrography is accurate ship's position and attitude data during data acquisition. *THOMAS JEFFERSON* uses inertial positioning and orientation sensors and U.S. Coast Guard Differential GPS (DGPS) for a highly accurate blended position and orientation solution. The 2010 Field Procedures Manual recommends a horizontal positional uncertainty value in the range of 0.5m – 2.0m based on the quality of differential correctors. Surveys covered by this DAPR were acquired within approximately 50nm of USCG differential beacons. Because of this relatively short distance to the differential beacons, horizontal positioning errors of 0.5m were used in Caris HVFs for all platforms during the surveys covered by this DAPR. Processing of SBET data during the ERS component of H12180 indicated that a value of 0.7m would have been more appropriate. No changes to the HVF were made after this discovery was made due to the additional time that would have been required to reprocess surveys. Since the areas surveyed are relatively flat with gentle slopes, the underestimation of horizontal position uncertainty has little effect on the overall uncertainty that would be reported at any given node and does not negate the validity of survey soundings.

THOMAS JEFFERSON, Survey Launch 3101, and Survey Launch 3102 are each equipped with Trimble DSM212L DGPS receivers. The DSM212L includes a 12-channel GPS receiver capable of receiving external RTCM correctors from a shore-based reference station. The DSM212L receivers are used for differential correctors to position only and not for actual positioning. Utility Boat 1701 is equipped with an integrated Odom CVM200 with Raven Invicta 210 DGPS system. The Raven Invicta 210 receives both RTCM differential correctors as well GPS positioning.

Inertial position calculations on *THOMAS JEFFERSON*, *Survey Launch 3101, and Survey Launch 3102* are provided by an Applanix POS/MV Model 320 v.4. The POS/MV 320 system includes dual GPS antennas, an inertial measurement unit (IMU), and data processor (PCS). The IMU measures linear and angular accelerations corresponding to the major motions of the vessel (heave, pitch, roll, yaw) and inputs this data to the PCS, where it is combined with a GPS position determined by carrier-phase differential measurements to give the final position solution. The POS/MV position solution is not sensitive to short period noise, but its accuracy may decay rapidly over time.

According to the manufacturer's specifications, the inertial position/orientation solution has typical values of 0.02° true roll and pitch accuracy, 0.02° heading accuracy, 2m position accuracy, and 0.03 m/s velocity accuracy. These parameters are monitored in real time during acquisition using the POS/MV user interface software. These values were entered into the HVF and were used to compute the TPU of each sounding – except that a value of 0.05° was used for roll and pitch. It is suspected that this was initially entered as a typo and then propagated with each new entry without re-evaluating the validity of the entry. Once the discrepancy was noticed, it was not corrected due to the amount of reprocessing that would be required. The value of 0.05° is a more conservative uncertainty estimate and has been retained for the entire 2010 season.

All acquisition platforms (with the exception of Utility Boat *1701*) are equipped with Precise Timing, a multibeam sonar acquisition configuration which synchronizes all data to the same time. The timing message is generated by the POS/MV which is received by both the acquisition computer and the RESON TPU. Precise Timing reduces the variable effects of time latency and creates a single, measurable latency (usually zero seconds +/- 0.005 seconds). This is verified during patch tests.

All platforms (except for 1701) utilize True Heave (a long-period recording of vessel heave used to detect longer period sea swells that may not be detected during short-period heave calculations) for a post processed heave solution.

IMU's for *Thomas Jefferson, 3101,* and *3102* were all sent to the manufacturer during the winter inport 2009-2010 for tumble testing and calibration. All IMUs passed tumble testing and calibration. See the Applanix report at the end of Section A.

Notable Positioning and Orientation Equipment changes:

On DN137, the port POS/MV antenna on HSL 3101 failed and was replaced on DN 138. A new GAMS calibration was conducted which resulted in the same baseline vector values for the new GAMS solution. Since the GAMS values remained the same, efforts were not made to generate new detailed documentation. The original values and documentation from the 2010 HSRR were retained.

A.8 Sound Velocity Profilers

A Brooke Ocean Technology Moving Vessel Profiler (MVP) with an Applied Microsystems Smart Sound Velocity and Pressure (SV&P) sensor or a Seabird Electronics SBE-19 CTD were used to collect sound speed profile (SSP) data from *Thomas Jefferson*. Seabird Electronics SBE-19 CTD+ units were used to collect sound speed profile (SSP) data from Launches 3101 and 3102. SSP data were obtained at intervals frequent enough to reduce sound speed errors. The frequency of casts is based on observed sound speed changes from previously collected profiles and time elapsed since the previous cast. The ship acquired casts at 15 – 30 intervals while acquiring cross-lines at the beginning of each project to determine the variability in sound speed in the survey area. Subsequent casts were made based on the observed trend of sound speed changes. As the sound speed profiles change, cast frequency and location are modified accordingly. Confidence checks of the sound speed profile casts are conducted weekly by comparing simultaneous casts taken with all sound speed determining devices on the ship and each launch.

Sound speed data and calibration records are included with the survey data in Section II of the Separates for each survey's Descriptive Report. Uncertainty values for sound speed are input into Caris by survey day for each platform during the TPU process. When CTDs are used, uncertainty values of 1m/s for each hour between successive casts is recommended to determine an appropriate uncertainty value. However, to be conservative, all CTD derived sound speeds are assigned an uncertainty of 4m/s even when acquired more frequently than every 4 hrs. An uncertainty value of 1m/s is used for all MVP casts even though MVP casts rarely exceed 30 – 45 minutes between successive casts. Additionally, a surface sound speed uncertainty value of 0.2m is used for launches 3101 and 3102,as recommended in the 2010 FPM.

Sea-Bird SBE19/19+ CTD Profilers

THOMAS JEFFERSON and Survey Launches 3101 and 3102 acquire water column sound velocity data using Sea-Bird Electronics SeaCat SBE19 and SBE19+ Conductivity-Temperature-Depth (CTD) profilers. Temperature is measured directly. Salinity is calculated from measured electrical conductivity. Depth is calculated from strain gauge pressure.

THOMAS JEFFERSON is equipped with a SeaCat SBE19 CTD profiler with strain gauge pressure sensor. The SBE19 is capable of CTD profiling at depths from 0-3400m. Post calibration drift is expected to be 0.02 °C yr^{-1}, 0.012S m^{-1} yr^{-1}, and 4.5 psia yr^{-1} for temperature, conductivity, and pressure, respectively. The SBE19 is deployed by hand or using the DT Marine Oceanographic winch for ship based acquisition.

Survey Launch 3101 and Survey Launch 3102 are each equipped with a SeaCat SBE19+ CTD profiler with strain gauge pressure sensor. The SBE19+ has a specified post-calibration temperature accuracy of 0.0005S m^{-1}, and strain-gauge pressure accuracy of 0.35 psia. Post calibration drift is expected to be 0.002 °C yr^{-1}, 0.004S m^{-1} yr^{-1}, and 0.168 psia yr^{-1} for temperature, conductivity, and pressure, respectively. The SBE19+ is capable of CTD profiling at depths from 0-350m. The SBE19+ is deployed by hand from Survey Launch 3101 and 3102.

All CTD instruments were returned to the manufacturer for calibration during the 2009-2010 winter in port period. See the Seabird Calibration Reports at the end of Section A.

Sea Surface Sound Velocimeters

Unlike CTD profilers, surface sound velocimeter sensors (SSVS) calculate sound velocity in water using two-way travel time. The typical SSVS consists of a transducer and a reflector at a known distance from the transducer. A pulse of known frequency is emitted, reflects at the reflector surface a known distance from the transducer, and returns. The two-way travel time is measured, and sound velocity is derived. SSVS are required for multibeam systems that perform active beam steering at the transducer head. The RESON 7125 and RESON 7125-SV systems both require SSVS data, as does the Klein HydroChart 5000.

The AML Smart SV&T Probe is a real-time time-of-flight sound velocimeter and thermistor sensor. The manufacturer specified sound velocity accuracy is 0.02 m/s and temperature accuracy is 0.03 °C. Empirical observations of drift show a sound velocity drift of approximately 0.5 m/s/yr and temperature drift of approximately 0.05 °C/yr. Aboard *THOMAS JEFFERSON*, the AML Smart SV&T probe is mounted in an insulated sea chest in the sonar void. Sea surface temperature and sound velocity values are output in real time to the SIMRAD EM1002 and RESON 7125 systems at a rate of 10 Hz and are recorded in the raw Hypack .hsx files

The surface sound speed uncertainty for the ship is calculated on a project by project basis after acquisition has completed. This value is calculated due to the physical configuration of the sound speed sensor on the ship. This will be discussed in greater detail in Section C of this DAPR.

The AML Smart SV&T Probe was returned to the manufacturer and calibrated during the 2009-2010 winter in-port period.

RESON Sound Velocity Probe 71 (SVP)

The RESON SVP 71 is a real-time surface sound velocimeter. The manufacturer specified sound velocity accuracy is ±0.15 m/s at 0 – 50m. Surface sound velocity values are output to the RESON 7125-SV system at a rate of 20 Hz and lower. Data can be sent in real time to the RESON 7125-SV processor unit and are recorded in the raw Hypack .hsx files

RESON SVP 71 was installed new this season on Launches *3101* and *3102*.

Notable RESON SVP 70 equipment changes: None

ODOM Hydrographic Systems Digibar Pro

The Digibar Pro is a real-time time-of-flight sea surface sound velocimeter. The manufacturer specified sound velocity accuracy is 0.3 m/s. Sea surface temperature and sound velocity values are output to the RESON 7125-SV system at a rate of 10 Hz. Data can be sent in real time to the RESON 7125-SV processor unit.

The units were returned to the manufacturer and calibrated during the 2009-2010 inport period. See the Odom Digibar Pro report at the end of Section A.

Notable digibar equipment changes:

The Odom Digibar Pro is kept onboard Thomas Jefferson as a ready spare and was not utilized for any surveys covered by this DAPR.

Brooke Ocean Technology Moving Vessel Profiler 100

The Moving Vessel Profiler (MVP) (figure A-11) is a self-contained profiling system capable of sampling water column profiles to 100m depth. MVP-100 was mounted to the port quarter. The MVP consists of a computer-controlled high speed hydraulic winch, a cable metering, over-boarding and docking system, a conductor cable and a streamlined free fall fish (FFF) housing an Applied Microsystems "time of flight" SV&P Smart Sensor (see SV&P below) . The system as configured aboard the *THOMAS JEFFERSON* collects vertical profiles of sound velocity data while the ship is underway at survey speed. The unit is located on the fantail and controlled remotely from the ship's acquisition room. The MVP is capable of importing its data directly into the Kongsberg SIMRAD EM 1002 multi-beam echosounder (MBES) at the time of acquisition. When using MVP casts in conjunction with the RESON 7125 MBES, sound velocity data is processed using Velocwin software, then applied in CARIS HIPS during post processing.

Figure A-11. MVP 100 on S-222

Notable equipment changes: None

AML – Sound Velocity & Pressure Smart Sensor (SV&P)

The SV&P Smart Sensor is the main instrument housed on the MVP free fall fish; it is designed to directly measure sound velocity and pressure in water. Its small size, extremely fast response time and high sampling rate make the sensor ideal for fast profiles or tow speeds. The sensor has internal calibration coefficients and outputs real-time data to allow a "plug and play" environment.

The Applied Microsystems Smart SV&P Sensor was calibrated by the manufacturer during the 2009-2010 winter import. See the AML Smart Probe Calibration report at the end of Section A.

A.9 Bottom Samplers

Two types of bottom samplers are used aboard *THOMAS JEFFERSON* for analyzing bottom sediments.

The Khalisco Mud Snapper model 214WA100 (figure A-6) may be deployed by one person by hand and is best used for shallow-water bottom samples acquired on the survey launches. (Figure A-12)

The Ponar Wildco model # 1728 sampler may be deployed by one person by hand and is sometimes used with the DT Marine Oceanographic winch for Ship based bottom sample acquisition. (Figure A-13)

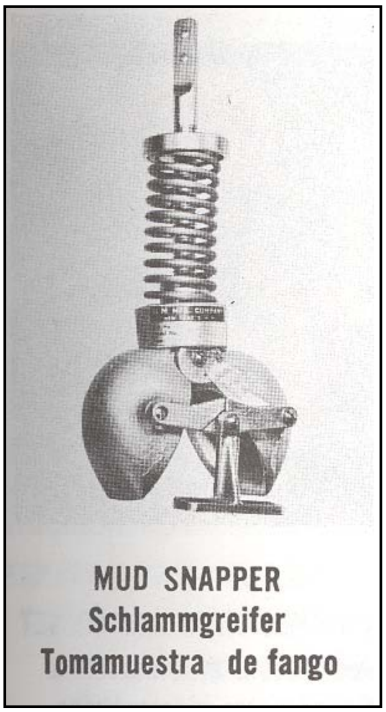

Figure A-12. Khalisco Mud Snapper

Figure A-13. Ponar Grab Sampler

A.10 Software Systems

Acquisition Software

Multibeam data were acquired using **Hypack 2010** software running on acquisition computers with the Windows XP operating system. Hypack is used to control real-time navigation, data time–tagging, and data logging. KLEIN 5000 side scan sonar data were acquired using KLEIN's **SonarPro** software running on acquisition computers with the Windows XP operating system. Moving Vessel Profiler data were acquired using **Brooke Ocean Technology MVP** software running on a computer with the Windows XP operating system.

Data Processing: Post-acquisition multibeam processing was performed on board the *Thomas Jefferson* using processing computers with Windows XP operating systems, which run **CARIS HIPS** software. Side scan sonar data were reviewed for targets, side scan mosaics and contact generation in **CARIS HIPS** software; Side-scan contacts were correlated with multibeam data in NOAA's **Pydro** software. CTD and MVP data were processed using NOAA **Velocwin** software. See Table A-5 below for software versions.

NOAA Ship Thomas Jefferson - Acquisition and Processing Software				
Acquisition Software	Date of Application	TJ	3101	3102
Hypack/Hysweep	May-10	v2010	v2010	v2010
SonarPro	Feb-10	v11.2	v11.2	v11.2
Velocwin	Mar-09	v8.96	v8.96	v8.96
Applanix MV POSView	Dec-09	v4.3.4.0	v4.3.4.0	v4.3.4.0
TSIP Talker	Aug-10	v2.00	v2.00	v2.00
MVP	Sep-09	v.2.351		
Kongsberg SIS	Jul-07	v3.4.3		
Processing Software	Date of Application	Version		
CARIS Hips and Sips		7.0, SP2, HF 3		
CARIS Bathy Database		3.0, HF 10		
Windows XP Professional	Mar-10	SP3		
Microsoft Office 2007	Mar-10	Professional		
MapInfo	Mar-10	10.0/10.5		
Adobe Acrobat	Mar-10	9.0		
Pydro	auto-updates	10.11 r3191		

Table A-5 – Acquisition and Processing Software versions and dates of application

CARIS HIPS AND SIPS

CARIS HIPS (Hydrographic Information Processing System) is used for all initial processing of multibeam and vertical beam echosounder bathymetry data, including tide, sound velocity, and vessel offset correction and data cleaning. CARIS HIPS uses statistical modeling to create Bathymetry with Associated Statistical Error (BASE) surfaces in one of three ways: swath-angle weighted grids, uncertainty-weighted grids, and Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm grids. Creation of grids as bathymetric products is discussed in section B of this report.

CARIS SIPS (Side-scan Information Processing System) is used for all processing of side-scan sonar imagery, including cable layback correction, slant range correction, contact selection, towpoint entry, and mosaic generation.

HSTP PYDRO

HSTP PYDRO is a program for the correlation and classification of side-scan sonar and multibeam bathymetry features and for the creation of preliminary smooth sheets. Multibeam features (designated soundings), side-scan sonar contacts, and detached positions are analyzed, grouped, and assigned S-57 classifications. High resolution BASE surface data is entered into the program and excessed to survey scale. The final product is a Preliminary Smooth Sheet file (PSS), which is delivered to the Atlantic Hydrographic Branch as part of the final submission package.

Pydro Versions 7.3 and later have functionality for TCARI installed. TCARI is described in detail in section C.2.1. The TCARI file for the area (when applicable) is received from NOS and loaded into Pydro along with the predicted, observed, or verified tide files for the corresponding stations. The use of TCARI is specified in the Project Instructions.

Pydro is also used for chart comparisons, generation of chartlets, generation of Danger to Navigation reports, generation of appendices to the Descriptive Report, compilation of survey statistics, and generation of standard NOAA forms such as the Descriptive Report cover sheet.

HSTP VELOCWIN

HSTP Velocwin is a program for the processing of sound velocity casts. This program uses Sea-Bird Electronics SeaSoft software to convert hexadecimal SeaCat data into ASCII conductivity-temperature-depth data, and then converts the ASCII data into a depth-binned sound velocity file. Velocwin software is also used to process Moving Vessel Profiler (MVP) sound velocity data into a CARIS compatible format. Velocwin allows for batch processing of the numerous .calc files generated by the MVP during multibeam echosounder acquisition. The resulting .svp files are applied in CARIS HIPS during post-processing to correct for sound velocity variation within the water column. These sound velocity files are applied to the data in CARIS HIPS. Velocwin is also used to check the accuracy of sound velocity casts and to archive sound velocity information for the National Oceanographic Data Center.

MAPINFO Professional 10.0/10.5

MapInfo Professional is the Geographic Information System (GIS) software package used aboard *THOMAS JEFFERSON*. MapInfo is used for sheet management, line planning, final data analysis, and creating end-user plots.

CARIS Base Editor 2.3

Base Editor is used for feature preparation and compilation, surface review, and chart comparison.

CARIS Plot Composer 5.1

CARIS Plot Composer is used to create Navigation Interests Memos, which are submitted with each project.

A.11 Acquisition Procedures

Acquisition Types

All platforms acquire hydrographic data according to the Project Instructions for each survey. The Project Instructions for a given survey specify the acquisition method to be used, the coverage required, and give the field unit discretion as to the best method to achieve that coverage.

The following survey types are used during field operations by *THOMAS JEFFERSON* in the 2010 Field Season:

- Set Line Spacing
- Complete MBES Coverage
- Object Detection SSS Coverage
- Object Detection MBES Coverage

These coverage types are described in detail in the April 2009 Hydrographic Survey Specifications and Deliverables.

Line plans are designed by the field unit according to the coverage type specified in the Project Instructions. Line planning and coverage type are discussed in detail in the Descriptive Report for each survey.

Crosslines are acquired as an additional confidence check for bathymetry. Crosslines provide a meaningful comparison between nadir beams and outer beams of mainscheme acquisition lines in the case of multibeam, and nadir to nadir for vertical beam lines. Crosslines are compared to the mainscheme lines using the standard deviation layer and hypothesis count layer of the grids in CARIS HIPS and Base Editor.

Acquisition speeds are adjusted to balance data quality, productivity, and energy efficiency. The Thomas Jefferson's bathymetric sonars typically produce densities above that which is required in Specs and Deliverables for "skunk striped" and complete coverage surveys at all survey speeds. Survey speeds are reduced as necessary to achieve object detection coverage in the 15-20m depth range.

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Calibration

004988

Customer:	NOAA - Marine Operations Center Atlantic
Asset Serial Number:	004988
Asset Type:	004988 (Smart SV&P)
Calibrated Pressure Range:	1000 dBar

Certification Date:	03/03/2010 (dd/mm/yyyy)
Certified By:	

Robert Haydock,
President
AML Oceanographic

AML Oceanographic certifies that the equipment described above has been calibrated with equipment referenced to traceable standards. Any repairs / calibrations completed on this instrument were approved by the instrument owner under purchase order.

This instrument has been recalibrated. Please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software (ie. Smart Talk) that you use. Instrument configuration files are available at our Client Service & Support Portal (see web address below).

For a complete service history of this instrument, please consult our on-line Client Service & Support Portal at http://www.AMLoceanographic.com/customers/index.htm

AML Oceanographic
2071 Malaview Avenue
Sidney B.C. V8L 5X6 CANADA
Tel: +1-250-656-0771 Fax: +1-250-655-3655

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	57041	**Date of Report:**	12/17/2009
Model Number:	SBE 19	**Serial Number:**	192472-0285

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ **Performed** ☐ **Not Performed**

Date: 12/17/2009 **Drift since last cal:** -0.00190 **PSU/month***

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ **Performed** ☑ **Not Performed**

Date: **Drift since Last cal:** **PSU/month***

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	57041	**Date of Report:**	12/17/2009
Model Number:	SBE 19	**Serial Number:**	192472-0285

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 12/17/2009 **Drift since last cal:** -0.00134 **Degrees Celsius/year**

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **Degrees Celsius/year**

Comments:

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1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 17-Dec-09

SBE19 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS
```
g = -4.07971557e+000
h =  4.86612139e-001
i =  1.27342373e-003
j = -2.76779215e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS
```
a =  2.35233136e-002
b =  4.59105653e-001
c = -4.06199418e+000
d = -1.02469719e-004
m =  2.2
CPcor = -9.5700e-008 (nominal)
```

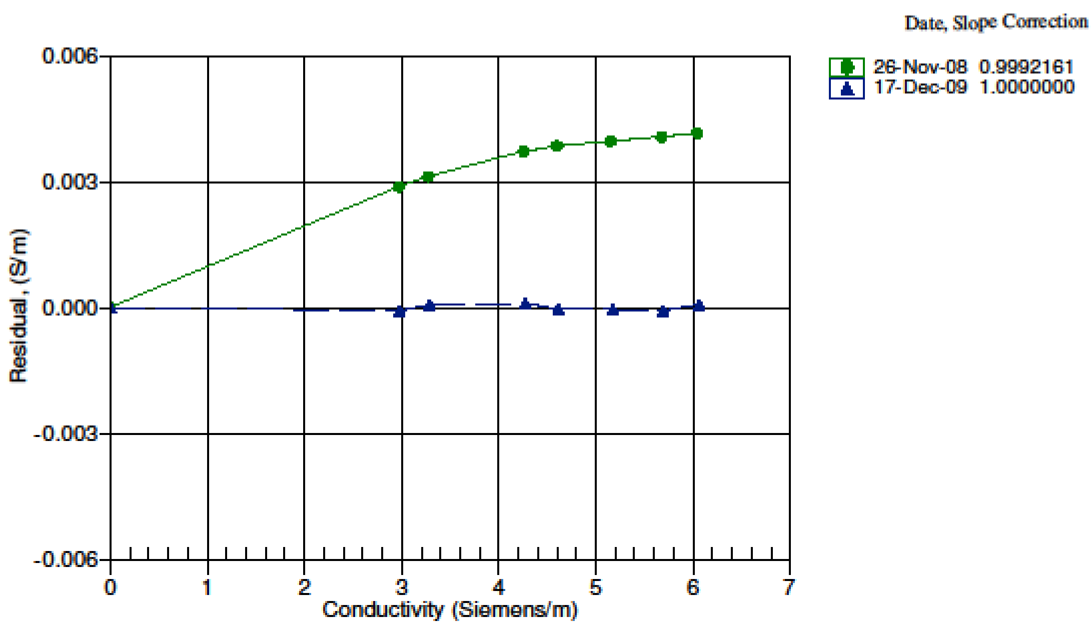
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88531	0.00000	0.00000
0.9999	34.8410	2.97787	8.26832	2.97779	-0.00007
4.5000	34.8208	3.28511	8.63296	3.28516	0.00006
14.9999	34.7776	4.26736	9.70555	4.26745	0.00010
18.5000	34.7681	4.61266	10.05492	4.61263	-0.00003
24.0000	34.7575	5.17085	10.59517	5.17080	-0.00005
29.0000	34.7505	5.69275	11.07615	5.69268	-0.00007
32.5000	34.7451	6.06498	11.40676	6.06505	0.00007

Conductivity = $(g + hf^2 + if^3 + jf^4)/10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



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1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 17-Dec-09

SBE19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.12520288e-003
h = 5.75807754e-004
i = -3.77214324e-007
j = -2.94509038e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.64763863e-003
b = 5.70457202e-004
c = 6.99565870e-006
d = -2.94498788e-006
f0 = 2297.604

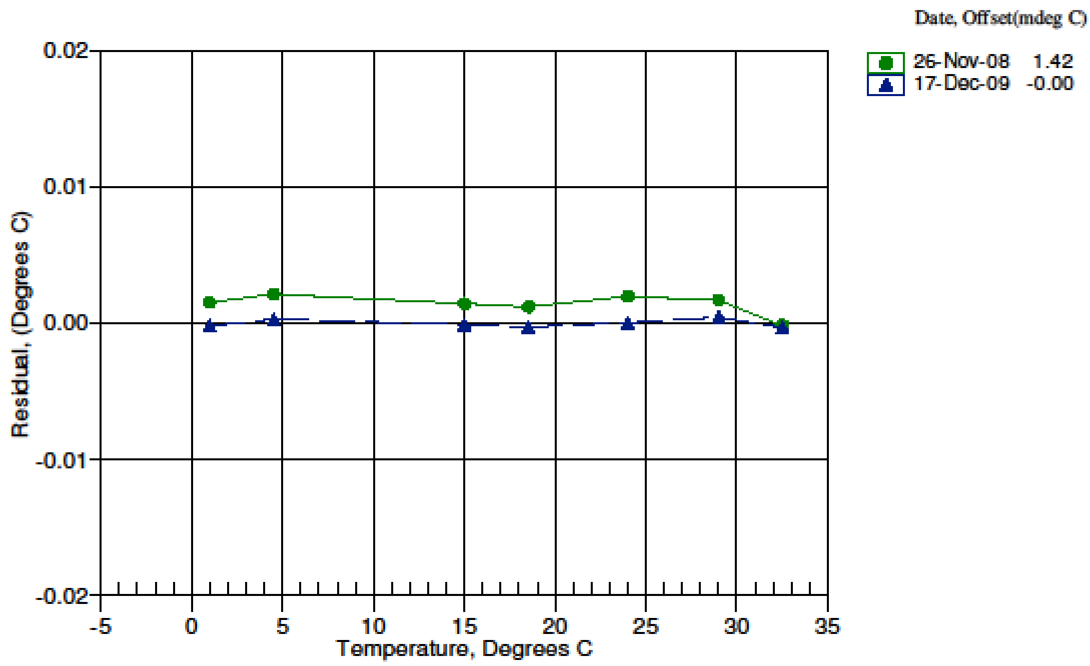
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
0.9999	2297.604	0.9997	-0.00018
4.5000	2490.756	4.5003	0.00031
14.9999	3139.176	14.9998	-0.00008
18.5000	3379.584	18.4997	-0.00026
24.0000	3783.314	24.0001	0.00005
29.0000	4178.917	29.0005	0.00046
32.5000	4472.551	32.4997	-0.00030

Temperature ITS-90 = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Temperature IPTS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0285
CALIBRATION DATE: 23-Dec-09

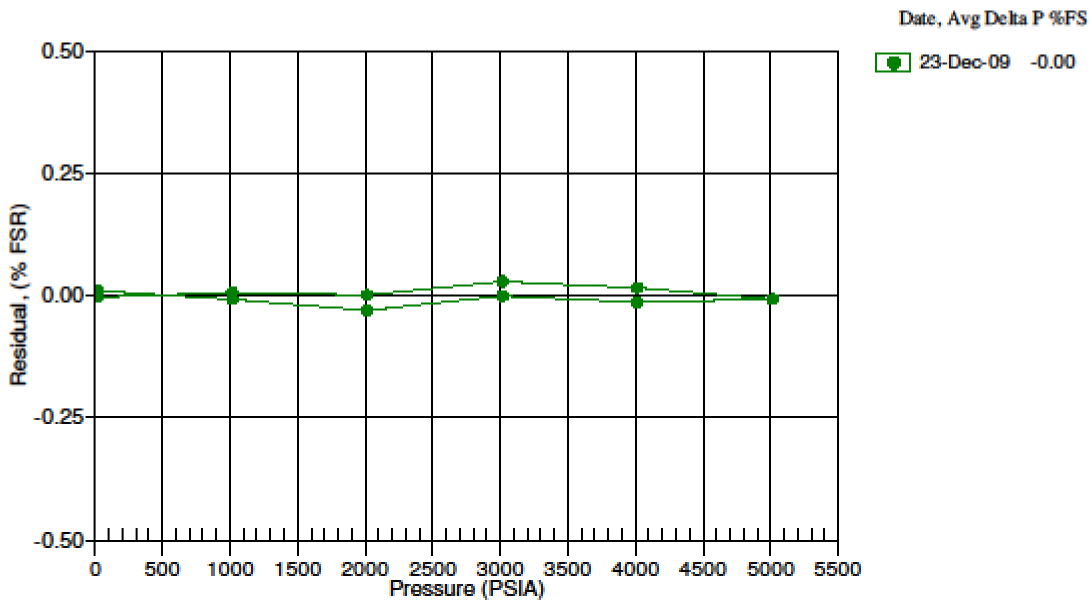
SBE19 PRESSURE CALIBRATION DATA
5000 psia S/N 133807 TCV: -121

QUADRATIC COEFFICIENTS:
PA0 = 2.491889e+003
PA1 = -6.503495e-001
PA2 = -4.657968e-008

STRAIGHT LINE FIT:
M = -6.503692e-001
B = 2.491608e+003

PRESSURE PSIA	INST OUTPUT(N)	COMPUTED PSIA	ERROR %FS	LINEAR PSIA	ERROR %FS
14.84	3807.0	15.33	0.01	15.65	0.02
1015.07	2271.0	1014.70	-0.01	1014.62	-0.01
2015.36	735.0	2013.86	-0.03	2013.59	-0.04
3015.42	-805.0	3015.39	-0.00	3015.16	-0.01
4015.41	-2342.0	4014.75	-0.01	4014.77	-0.01
5015.55	-3881.0	5015.19	-0.01	5015.69	0.00
4015.25	-2344.0	4016.05	0.02	4016.07	0.02
3015.26	-807.0	3016.69	0.03	3016.46	0.02
2015.11	733.0	2015.16	0.00	2014.89	-0.00
1015.05	2270.0	1015.36	0.01	1015.27	0.00
14.84	3808.0	14.68	-0.00	15.00	0.00

Straight Line Fit:
Pressure (psia) = M * N + B (N = binary output)
Quadratic Fit:
pressure (psia) = PA0 + PA1 * N + PA2 * N^2
Residual = (instrument pressure - true pressure) * 100 / Full Scale Range



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Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	57041	**Date of Report:**	12/23/2009
Model Number:	SBE 19Plus	**Serial Number:**	19P33589-4486

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ **Performed** ☐ **Not Performed**

Date: 12/23/2009 **Drift since last cal:** +0.00040 **PSU/month***

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ **Performed** ☑ **Not Performed**

Date: **Drift since Last cal:** **PSU/month***

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	57041	**Date of Report:**	12/23/2009
Model Number:	SBE 19Plus	**Serial Number:**	19P33589-4486

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ **Performed** ☐ **Not Performed**

Date: 12/23/2009 **Drift since last cal:** -0.00006 **Degrees Celsius/year**

Comments:

'CALIBRATION AFTER REPAIR' ☐ **Performed** ☑ **Not Performed**

Date: **Drift since Last cal:** **Degrees Celsius/year**

Comments:

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4486
CALIBRATION DATE: 23-Dec-09

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.028915e+000
h = 1.433578e-001
i = -1.871225e-004
j = 3.484124e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

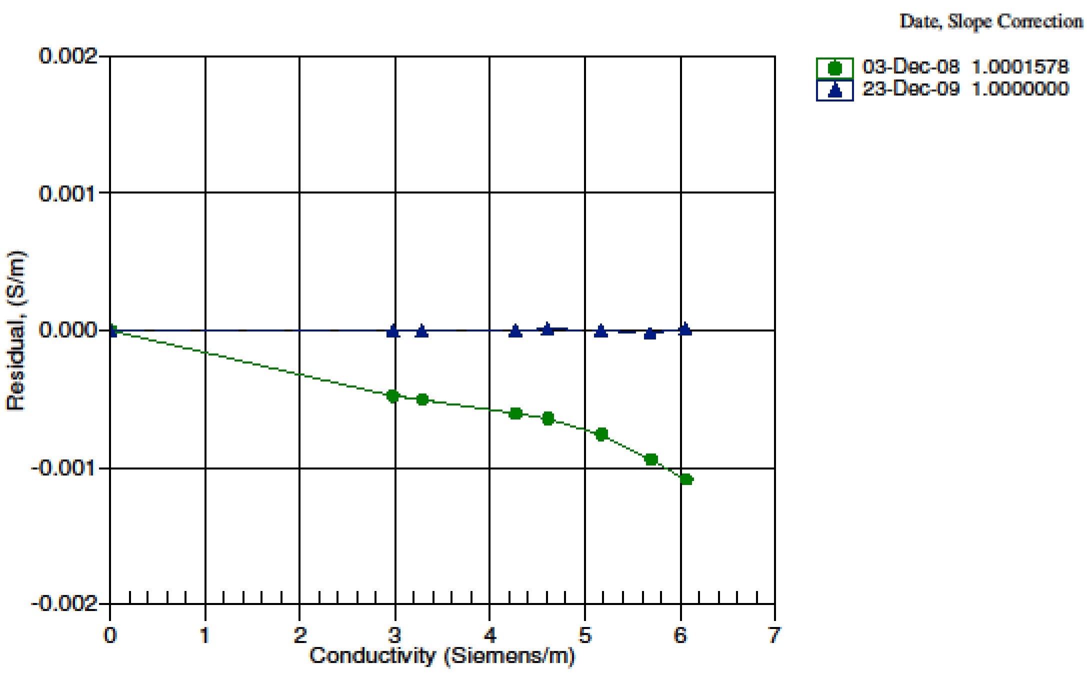
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2681.39	0.0000	0.00000
1.0000	34.7729	2.97261	5283.56	2.9726	-0.00000
4.5000	34.7530	3.27934	5481.64	3.2793	-0.00000
15.0000	34.7100	4.25995	6070.93	4.2600	-0.00000
18.5000	34.7005	4.60466	6264.65	4.6047	0.00001
24.0000	34.6895	5.16185	6565.41	5.1618	0.00000
29.0000	34.6811	5.68266	6834.25	5.6826	-0.00002
32.5000	34.6737	6.05393	7019.45	6.0539	0.00001

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \epsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ϵ = CPcor;

Residual = instrument conductivity - bath conductivity



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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4486
CALIBRATION DATE: 23-Dec-09

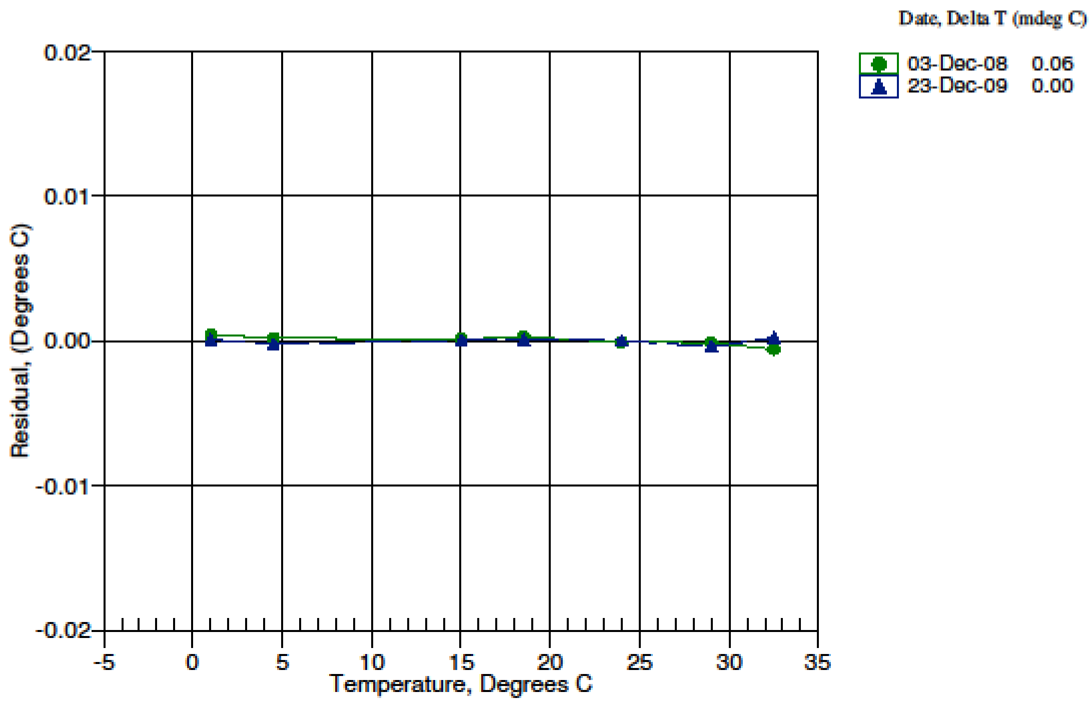
SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = 1.296457e-003
a1 = 2.514754e-004
a2 = 1.317289e-006
a3 = 9.670557e-008

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	604365.068	1.0001	0.0001
4.5000	535793.102	4.4998	-0.0002
15.0000	366326.576	15.0001	0.0001
18.5000	321006.220	18.5001	0.0001
24.0000	259606.017	24.0001	0.0001
29.0000	212969.661	28.9996	-0.0004
32.5000	184835.288	32.5002	0.0002

MV = (n - 524288) / 1.6e+007
R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)
Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4486
CALIBRATION DATE: 22-Dec-09

SBE19plus PRESSURE CALIBRATION DATA
508 psia S/N 2799

COEFFICIENTS:

PA0 =	3.393557e-002	PTCA0 =	5.246614e+005
PA1 =	1.549577e-003	PTCA1 =	2.803268e+000
PA2 =	7.090297e-012	PTCA2 =	-8.906986e-002
PTEMPA0 =	-7.542327e+001	PTCB0 =	2.468737e+001
PTEMPA1 =	4.833625e+001	PTCB1 =	-7.250000e-004
PTEMPA2 =	-2.486078e-001	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.65	534110.0	1.9	14.65	0.00
104.90	592301.0	1.9	104.90	0.00
204.92	656732.0	1.9	204.88	-0.01
304.92	721144.0	1.9	304.90	-0.00
404.93	785529.0	1.9	404.93	0.00
504.93	849846.0	1.9	504.91	-0.00
404.95	785560.0	1.9	404.98	0.01
304.94	721191.0	1.9	304.97	0.01
204.95	656783.0	1.9	204.96	0.00
104.97	592349.0	1.9	104.97	-0.00
14.65	534118.0	1.9	14.66	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	2.26	534375.39
29.00	2.19	534381.55
24.00	2.08	534392.60
18.50	1.96	534399.70
15.00	1.89	534399.37
4.50	1.67	534386.75
1.00	1.59	534380.38

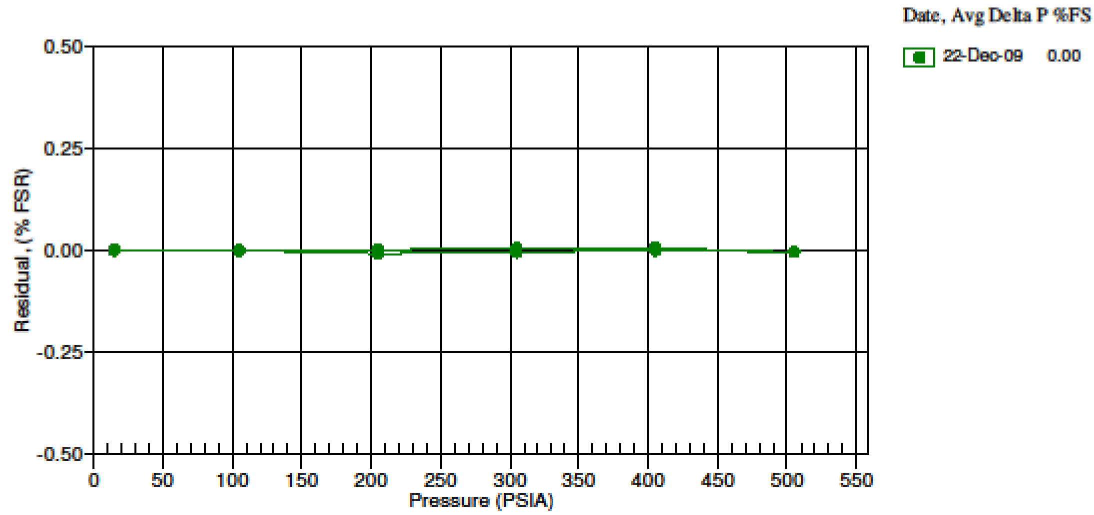
TEMP (ITS90)	SPAN (mV)
-5.00	24.69
35.00	24.66

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{pressure output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (psia)} = PA0 + PA1 * n + PA2 * n^2$



SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	57041	**Date of Report:**	12/23/2009
Model Number:	SBE 19Plus	**Serial Number:**	19P33589-4487

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 12/23/2009 **Drift since last cal:** -0.00110 **PSU/month***

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **PSU/month***

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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Temperature Calibration Report

Customer:	Atlantic Marine Center		
Job Number:	57041	**Date of Report:**	12/23/2009
Model Number:	SBE 19Plus	**Serial Number:**	19P33589-4487

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 12/23/2009 **Drift since last cal:** -0.00119 **Degrees Celsius/year**

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **Degrees Celsius/year**

Comments:

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 23-Dec-09

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.021037e+000
h = 1.393412e-001
i = -1.422501e-004
j = 3.071693e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

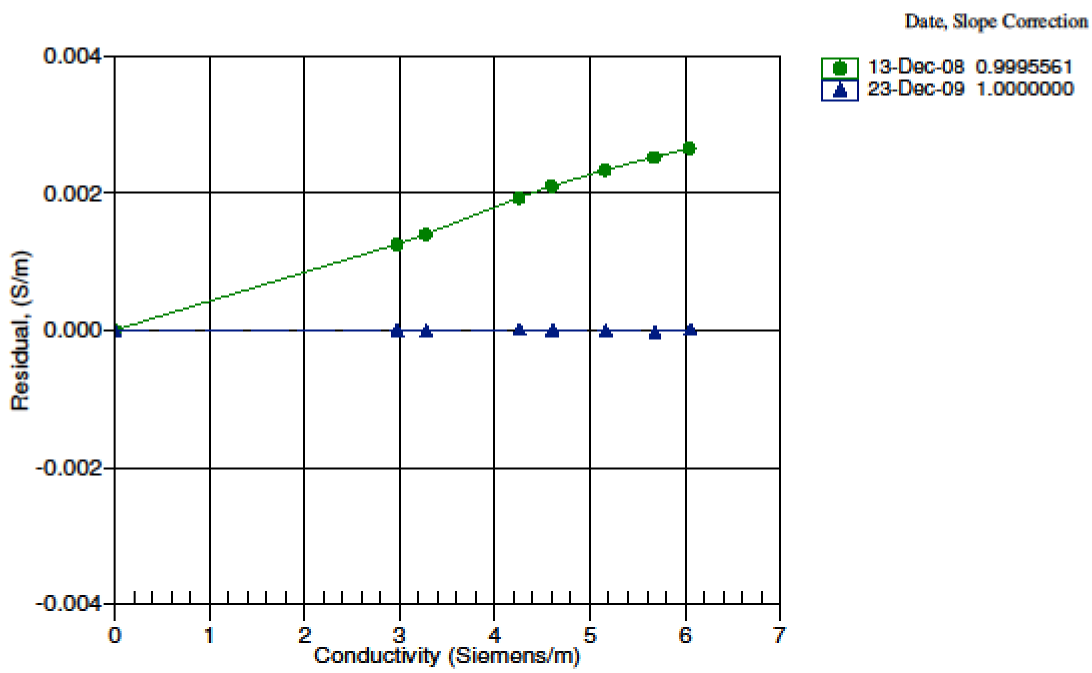
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2708.51	0.0000	0.00000
1.0000	34.7729	2.97261	5351.32	2.9726	-0.00000
4.5000	34.7530	3.27934	5552.27	3.2793	-0.00001
15.0000	34.7100	4.25995	6150.07	4.2600	0.00001
18.5000	34.7005	4.60466	6346.57	4.6047	0.00001
24.0000	34.6895	5.16185	6651.62	5.1618	-0.00001
29.0000	34.6811	5.68266	6924.29	5.6826	-0.00002
32.5000	34.6737	6.05393	7112.13	6.0539	0.00001

f = INST FREQ / 1000.0

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \epsilon p)$ Siemens/meter

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ϵ = CPcor;

Residual = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 23-Dec-09

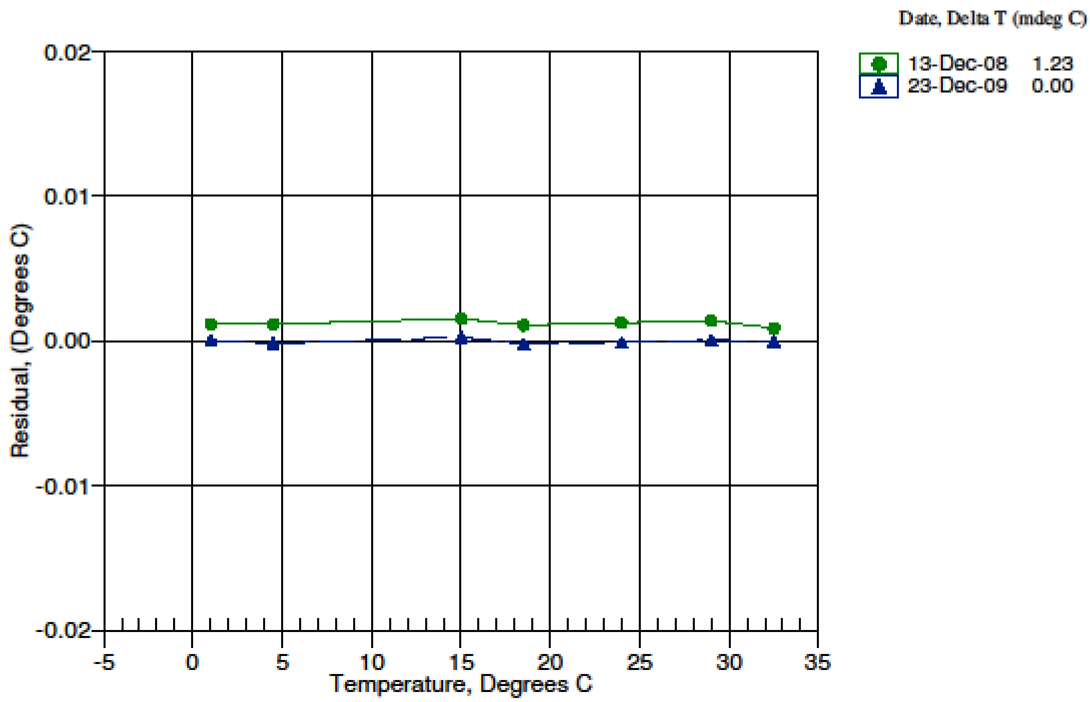
SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = 1.227720e-003
a1 = 2.562184e-004
a2 = 5.700844e-007
a3 = 1.218943e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	713474.441	1.0001	0.0001
4.5000	638157.017	4.4999	-0.0001
15.0000	447167.610	15.0003	0.0003
18.5000	394903.119	18.4998	-0.0002
24.0000	323263.085	23.9999	-0.0001
29.0000	268210.644	29.0001	0.0001
32.5000	234744.034	32.5000	-0.0000

MV = (n - 524288) / 1.6e+007
R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)
Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



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Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 22-Dec-09

SBE19plus PRESSURE CALIBRATION DATA
508 psia S/N 2837

COEFFICIENTS:

PA0 =	7.750613e-002	PTCA0 =	5.244329e+005
PA1 =	1.555474e-003	PTCA1 =	4.506914e+000
PA2 =	7.105278e-012	PTCA2 =	-9.364100e-002
PTEMPA0 =	-7.448119e+001	PTCB0 =	2.498675e+001
PTEMPA1 =	4.921478e+001	PTCB1 =	-5.000000e-005
PTEMPA2 =	-4.131304e-001	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.65	533849.0	1.9	14.65	-0.00
104.90	591847.0	1.9	104.90	-0.00
204.92	656069.0	1.9	204.89	-0.01
304.92	720267.0	1.9	304.90	-0.00
404.93	784438.0	1.9	404.93	-0.00
504.93	848549.0	1.9	504.92	-0.00
404.95	784466.0	1.9	404.97	0.00
304.94	720317.0	1.9	304.98	0.01
204.95	656121.0	1.9	204.97	0.00
104.97	591896.0	1.9	104.97	-0.00
14.65	533860.0	1.9	14.66	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	2.21	534142.85
29.00	2.14	534146.32
24.00	2.04	534148.25
18.50	1.92	534149.37
15.00	1.85	534139.29
4.50	1.63	534113.21
1.00	1.55	534099.52

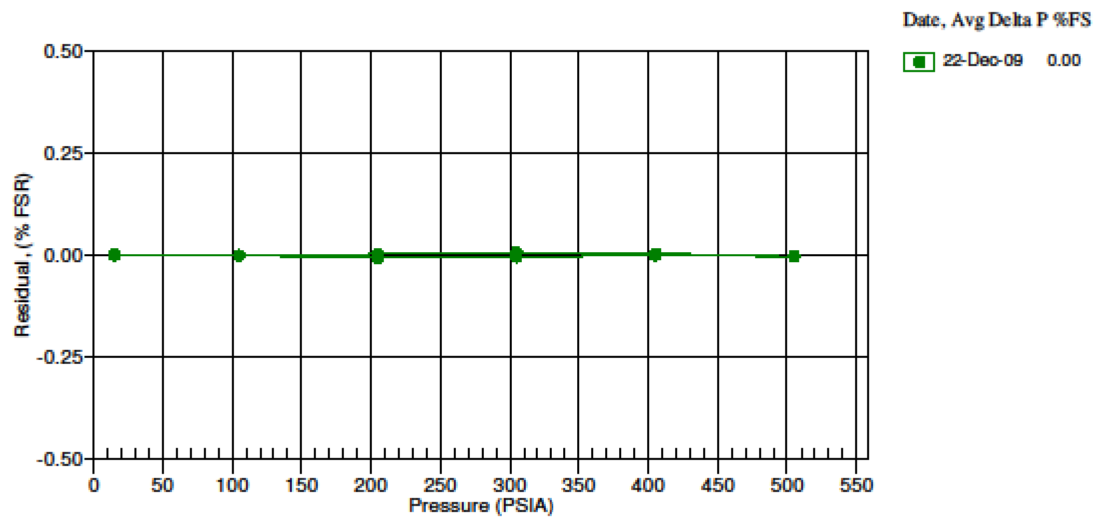
TEMP(ITS90)	SPAN(mV)
-5.00	24.99
35.00	24.98

y = thermistor output; t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2

x = pressure output - PTCA0 - PTCA1 * t - PTCA2 * t^2

n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)

pressure (psia) = PA0 + PA1 * n + PA2 * n^2



Spare - In ET Stores 8/11/09

Date: Jul 17 2008

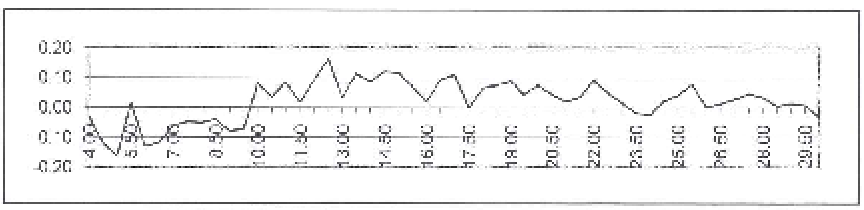
Serial #: 98129-071729

DIGIBAR CALIBRATION REPORT

ODOM HYDROGRAPHIC SYSTEMS, Inc.

STANDARD DEL GROSSO H_2O

TEMP	VELOCITY	MEASURED FREQUENCY	RES VEL	OBS-CAL	TEMP	VELOCITY	MEASURED FREQUENCY	RES_VEL	OBS-CAL
4.00	1421.92	6644.01	1421.83	-0.06	17.50	1474.38	5747.67	1474.38	0.00
4.50	1423.90	6653.35	1423.78	-0.12	18.00	1476.01	5754.48	1476.08	0.07
5.00	1426.15	6661.93	1426.05	-0.10	18.50	1477.62	5760.71	1477.69	0.07
5.50	1428.39	6671.09	1428.40	0.02	19.00	1479.21	5766.87	1479.29	0.08
6.00	1430.59	6679.06	1430.46	-0.13	19.50	1480.77	5772.72	1480.81	0.04
6.50	1432.75	6687.39	1432.63	-0.12	20.00	1482.32	5778.78	1482.39	0.07
7.00	1434.84	6695.07	1434.84	0.00	20.50	1483.84	5784.68	1483.88	0.04
7.50	1437.02	6604.08	1436.97	-0.05	21.00	1485.36	5790.22	1485.38	0.02
8.00	1439.12	6612.13	1439.07	-0.05	21.50	1486.83	5795.60	1486.88	0.04
8.50	1441.19	6620.14	1441.15	-0.04	22.00	1488.29	5801.63	1488.38	0.09
9.00	1443.23	6627.96	1443.17	-0.06	22.50	1489.74	5807.23	1489.79	0.05
9.50	1445.25	6635.66	1445.18	-0.07	23.00	1491.16	5812.07	1491.17	0.01
10.00	1447.25	6643.08	1447.33	0.08	23.50	1492.56	5817.65	1492.53	-0.02
10.50	1449.22	6651.34	1449.26	0.04	24.00	1493.95	5823.15	1493.93	-0.02
11.00	1451.17	6659.02	1451.20	0.06	24.50	1495.32	5828.00	1495.34	0.02
11.50	1453.09	6666.16	1453.11	0.02	25.00	1496.66	5833.63	1496.70	0.04
12.00	1454.98	6673.76	1455.04	0.06	25.50	1497.99	5839.00	1498.07	0.08
12.50	1456.87	6681.25	1457.00	0.10	26.00	1499.30	5843.62	1499.30	0.00
13.00	1458.72	6687.86	1458.76	0.05	26.50	1500.58	5846.82	1500.60	0.01
13.50	1460.55	6695.22	1460.67	0.11	27.00	1501.86	5853.77	1501.89	0.03
14.00	1462.36	6702.07	1462.45	0.09	27.50	1503.11	5859.66	1503.16	0.05
14.50	1464.14	6709.06	1464.26	0.12	28.00	1504.35	5861.28	1504.38	0.03
15.00	1465.91	6715.82	1466.02	0.12	28.50	1505.56	5867.80	1505.57	0.01
15.50	1467.65	6722.03	1467.71	0.07	29.00	1506.76	5872.57	1506.77	0.01
16.00	1469.36	6728.74	1469.38	0.02	29.50	1507.94	5877.09	1507.95	0.01
16.50	1471.06	6735.54	1471.15	0.09	30.00	1509.10	5881.41	1509.07	-0.02
17.00	1472.73	6742.04	1472.84	0.11					



Odom Hydrographic Systems, Inc.
1450 Seaboard Avenue, Baton Rouge, Louisiana 70810-3201, USA
Telephone: (225)-769-3051 Fax: (225) 766-5122
E-mail: email@odomhydrographic.com, HTTP: www.odomhydrographic.com

applanix
A TRIMBLE COMPANY

Certificate of Conformance

Applanix Corporation certifies that the material listed below has been tested in accordance with approved test procedures and was found to meet or exceed published specifications.

1) Description: **IMU LN200**
Applanix Part Number: **10002416**
IMU Serial Number: **407301 (Top Hat # 356)**

Return Material Authorization #: L09-051

Customer: NOAA
Atlantic Branch at MOC

Certified By:
Bruce Francis
Customer Support Engineer

2 February, 2010
Date:

AML OCEANOGRAPHIC
Xchange your old ideas

Certificate of Conformity
007834

Customer:	L-3 Communications Klein Associates, Inc
Our Reference:	Project 15483 L-3 Klein: Micro SV (Dec09)
Customer Purchase Order:	P100828
Asset Serial Number:	007834
Asset Type:	007834 (Micro SV -)
Calibrated Pressure Range:	________
Additional Description:	________

Certification Date:	04/06/2010 (dd/mm/yyyy)
Certified By:	

AML Oceanographic

Robert Haydock,
President
AML Oceanographic

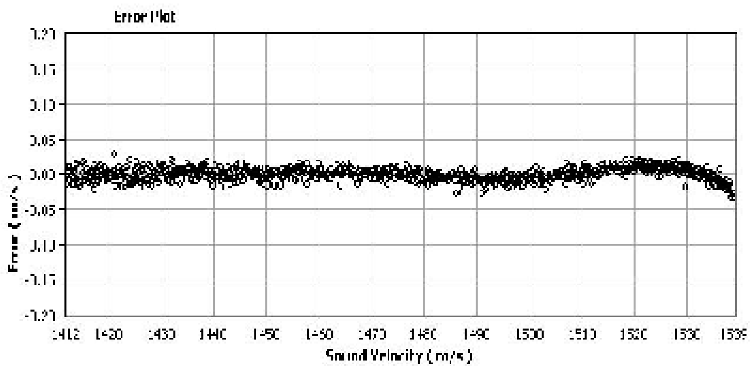
AML Oceanographic certifies that the above described equipment has been tested in accordance with the product's technical specifications, brochures, and / or relevant drawings. AML Oceanographic certifies that calibrations on this instrument have been completed with equipment reference to traceable standards.

Instrument configuration files and soft copy certificates are available at AML Oceanographic Client Service and Support Portal at http://www.AMLoceanographic.com/customers/index.htm

AML Oceanographic
2071 Malaview Avenue
Sidney, B.C. V8L 5X6 CANADA
Tel: +1-250-656-0771 Fax: +1-250-655-3655

Sound Velocity Calibration

Date	06/01/10
S/N	007834
Calibrator	Mike Delsey
RMS Error	0.009
Range	1400 to 1600 m/s



m/s=A+B*((NH-N)/(NH-NL))+C*((NH-N)/(NH-NL))^2+D*((NH-N)/(NH-NL))^3

A=7.230861E-4	G=0.000000E+00
B=-7.398694E-5	H=0.000000E+00
C=1.011705E-6	I=0.000000E+00
D=-6.809341E-7	J=0.000000E+00
E=0.000000E+00	K=0.000000E+00
F=0.000000E+00	L=0.000000E+00

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B. QUALITY CONTROL

B.1 Quality Management

A systematic approach to Quality Management has been instituted aboard the *THOMAS JEFFERSON*, starting well before the field season begins, through to the final packaging of Survey Deliverables and delivery to AHB.

Clear and concise communication is critical at all stages of the survey, and is established between all relevant parties[1] at the earliest stage of the process. Figure 1 represents the parties involved at all stages of the Quality Management process.

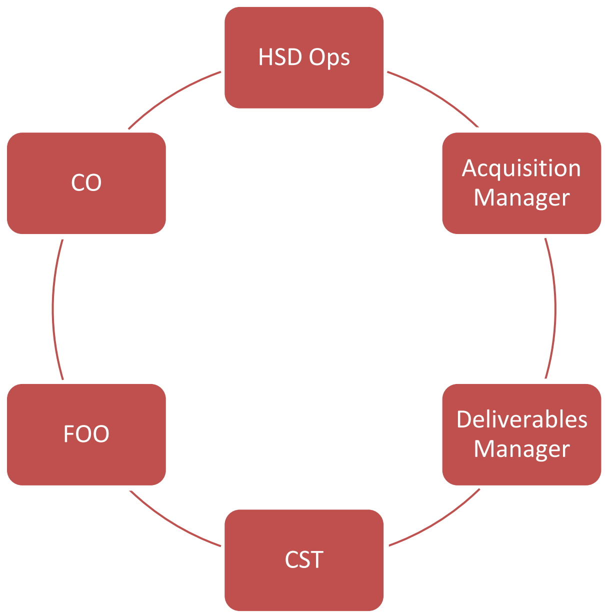

Figure B-1: Quality management loop

[1] Note on Personnel:
CO – Commanding Officer, FOO – Field Operations Officer, CST – Chief Survey Technician, HSD OPS – Hydrographic Surveys Division, Operations Branch

Below is a graphic showing the Quality review steps used aboard the *Thomas Jefferson*.

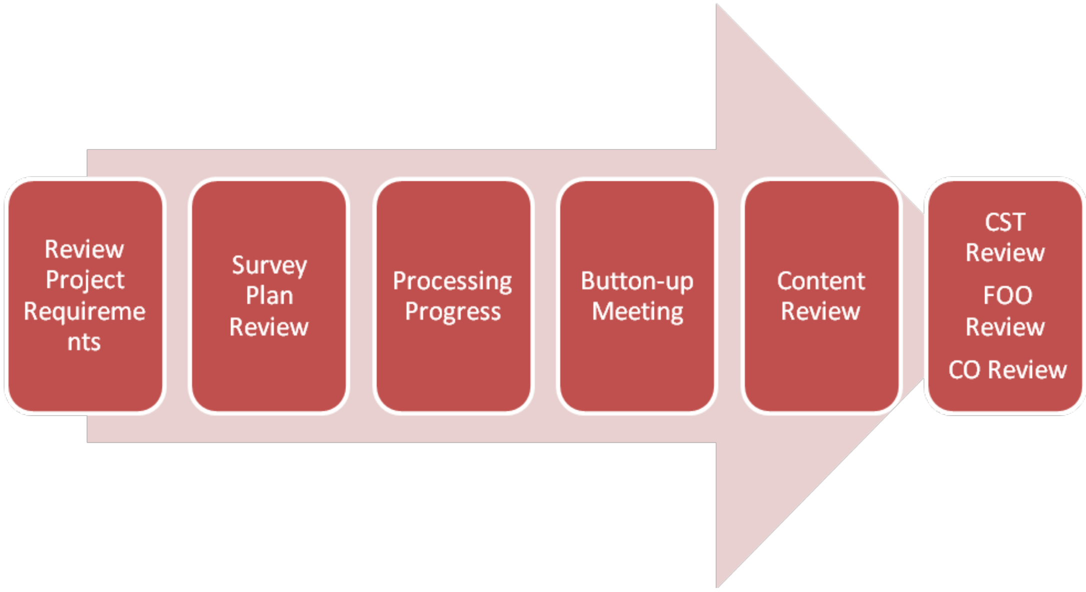

Figure B-2: Quality Review Stages

In the Review Project Requirements stage, the final project instructions are reviewed for specific criteria. Some of these are:

- Is the Survey fit for the Purpose?
- Are all charted features and AWOIS in the Composite Source File (CSF)?
- Are there any extraneous or unassigned features in CSF?
- Is the Survey a reasonable size (2 weeks)?
- Does the work assigned fit within allowed time period?
- Are the resources available for the job?
- Do we have the right equipment, spares, qualified staff, OT, software and specs?
- Are there any special requirements from HSD OPS?

If any of these elements are found to be in question, dialogue is opened with HSD OPS, in order to resolve them. Once these questions have been answered, the Acquisition manager can prepare the survey plan. This would include the following requirements:

- Line plans/Polygons, Crossline plans, Bottom Sample plan
- Feature requirements as addressed in the Composite Source File (CSF) or ENC.
- Safety of Operations, i.e. where we can and cannot go.
- The plan's effectiveness and efficiency.
- Proper or maximum platform utilization.
- Survey Specific Sensor configurations, staffing plans, line plans, target files, etc.

All aspects of the survey plan are carefully reviewed by the CST, FOO and CO for any required changes initiated by the Acquisition manager before survey begins.

A weekly progress review of all planned and open surveys is conducted to evaluate and incorporate the following factors into the acquisition and deliverables schedule:

- Ship schedule (inports/transits)
- Completion rate, estimated survey end date
- Weather factors
- Equipment failures
- Processing backlog (if any)

The goal is to continuously manage multiple surveys and to establish a projected survey shipment date which accurately reflects all known factors. If processing is not keeping pace with acquisition, then additional resources can be deployed to reduce backlogs. This in turn allows for better quality assessment of collected data.

A Progress review of the survey occurs shortly before completion, with the following goals:

- Review remaining work
- Evaluate density coverage (5 Pings per grid node?)
- Confirm that all assigned features have coverage
- Prioritize remaining work for time remaining
- Adjust personnel and platform schedules as necessary
- Evaluate grids for systematic errors (Std Dev, Uncertainty)
- Review initial field sheet layout

After acquisition is complete and the Deliverables manager has applied final tides to all data, a Content Review is performed on the initial results of the survey, primarily surfaces and feature reports. Some of the particular items addressed are:

- Systematic errors evident in the child layers of the grids (Density, Std Dev, Hypothesis Count) that need to be addressed in the DR.
- Review feature report and advise changes or revisions.
- Consider any feature candidates for DtoN's.
- Determine any unusual acquisition or processing issues that need to be discussed in DR.

The final stage of the Quality Management system is a multiple review of the deliverables, by the CST, FOO and CO, each ensuring that all Specs have been met and that any revisions or changes identified in the Content Review have been made. These checks include:

- Examine finalized/thresholded grids for flyers or unresolved systematic issues. Are they discussed in the DR?
- Final check of feature report inclusions, relevance, S-57 attribution, image quality and general completeness.
- Vetting of the final DR. Does it reflect the Content Review discussion?

- Housekeeping – are all the ancillary reports, documents and data included and in the proper place?

B.2 Data Management

A daily tracking of data has been developed to maintain data quality and integrity. Several forms identify and track the flow of data as it is collected and processed. These forms are presented in the Separates section under data acquisition and processing logs, included with the data for each survey.

During data collection, watch standers continuously monitor acquisition systems, checking for errors and alarms. Thresholds set in Hypack/Hysweep, POSPAC, RESON and SonarPro alert the watch stander by displaying alarm messages when error thresholds or tolerances are exceeded. These alarms, displayed as they occur, are reviewed and acknowledged on a case-by-case basis. Alarm conditions that may compromise survey data quality are corrected and then noted in acquisition log. Warning messages such as the temporary loss of differential GPS, excessive cross track error, or vessel speed approaching the maximum allowable survey speed are addressed by the watch stander and corrected before further data acquisition occurs.

Following data acquisition, initial processing begins. See figure B.3 for an example of the typical multibeam data processing procedures. The following checks are performed to insure proper data handling throughout the process:

- A one to one comparison of raw data to acquisition logs is performed.
- Correctors, including tide files, true heave, and SVP files are checked for completeness and accuracy.
- Application of all correctors is tracked by line and by application.

Figure B.3 shows the general processing flow for Multibeam data after collection.

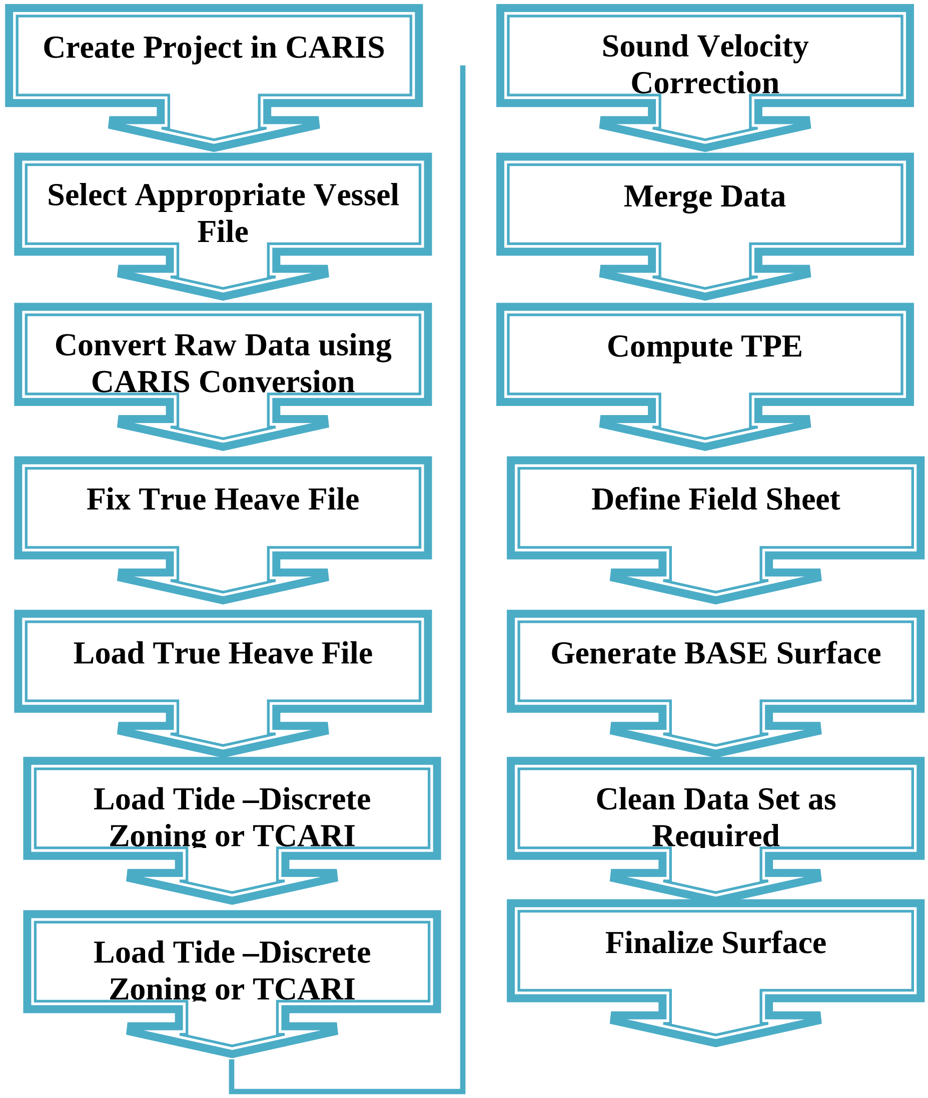

Figure B-3: MB Data processing flow

BASE surfaces are generated to ensure adequate data density, identify areas of high standard deviation and note any obvious problems with correctors.

Results of the processing are reviewed to determine adequacy of data and sounding correctors. Additional processing in preparation of data deliverables includes the following steps:

- Generation of side scan Contact Files and a Contact Plot
- Subset editing and review of multibeam data
- Application of verified tide correctors to multibeam data
- Application of true heave
- Cross line analysis of multibeam data
- Comparison with prior surveys
- Generation of shoal biased selected soundings at the scale of the survey

- Comparison with existing charts
- Quality control reviews of side scan data and contacts
- Final Coverage mosaic plots of side scan sonar data
- Correlation of side scan contacts with multibeam data
- Final quality control of all delivered data products

Processing and quality control procedures for multibeam and side scan data acquisition are described in detail below.

B.3 Bathymetry

Raw bathymetry data, (Simrad .all, Hypack .raw and .hsx) are converted into CARIS HDCS data format upon completion of daily acquisition. Conversion parameters vary for each data format, and are stored in the LogFile of each HDCS processed line folder. After data conversion, attitude, and navigation are reviewed for outliers, and true heave, water level, and sound velocity are applied. Bathymetry lines are then merged. Following merge, Total Propagated Uncertainty (TPU) is calculated for each sounding. For a more detailed explanation of TPU calculation of multibeam and vertical beam echosounder data, refer to Section 4.2.3.6 of the 2010 NOAA Field Procedures Manuals.

Depending on acquisition type, MBES bathymetry may be processed using either an uncertainty-weighted navigation surface or a CUBE surface. Uncertainty-weighted BASE surfaces and CUBE surfaces are described in detail in the 2010 NOS Field Procedures Manual and the CARIS HIPS/SIPS Users Manual.

When the primary source of bathymetry for a survey area is a combination of VBES and MBES, a collection of finalized uncertainty-weighted mean bathymetric surfaces is generated as the product of the survey. CUBE is not permitted for this type of survey. When the primary source of bathymetry for this type of survey is set line spacing MBES data (also known as “skunk striped”), CUBE shall be used. The use of CUBE in this situation is required to guarantee proper nodal propagation distances as described in section 5.2.1, Gridded Data Specifications, of the 2010 HSSD. In most instances 95% of the nodes in a CUBE grid contain a minimum of 5 soundings/node to adequately represent the seafloor depth in a given area.

When Complete or Object Detection (OD) MB is the primary source of bathymetry, data are processed using CUBE grids. The use of CUBE is mandatory to ensure compliance with the specification described in the paragraph above. Table 1 shows the required resolution in various survey depths.

Object Detection Coverage

Depth Range (m)	**Resolution (m)**
0-22	0.5
20-40	1

(Object Detection is rarely needed in depths greater than 30 meters).

Complete Multibeam Coverage

Depth Range (m)	**Resolution (m)**
0-22	1
20-44	2
40-88	4
80-176	8
160-350	16
320-640	32

Table B-1. Multibeam resolution requirements by depth and coverage type

Each resolution has its own CUBE parameter settings, and the hydrographer uses the appropriate resolution based CUBE parameters settings when computing each grid. CUBE parameters were distributed with the project instructions for each survey. See Figure B-4, CUBEParams_2010.xml on the following page.

Figure B-4. CUBEParams_2010.xml


```
- <CARIS_CUBE_Parameters version="2.0">
  - <ParameterSet Configuration_Name="NOAA_0.5m">
      <Comment value="The 2010 field season parameters for NOAA field units for the CUBE algorithm on a 0.5 meter surface." />
      <Distance_Exponent value="2.0" />
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      <Null_Hypothesis_Ratio value="3.0" />
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      <Discount_Factor value="1.0" />
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      <Run_Length_Threshold value="5" />
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      <Locale_Radius value="1" />
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      <Quotient_Limit value="255.0" />
      <Discount_Factor value="1.0" />
      <Estimate_Offset value="4.0" />
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      <Queue_Length value="11" />
      <Quotient_Limit value="255.0" />
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      <Estimate_Offset value="4.0" />
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      <Null_Hypothesis_Min_Neighbours value="3" />
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      <Null_Hypothesis_Strength_Max value="2.5" />
      <Enable_Null_Hypothesis value="False" />
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      <Queue_Length value="11" />
      <Quotient_Limit value="255.0" />
      <Discount_Factor value="1.0" />
      <Estimate_Offset value="4.0" />
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      <Capture_Distance_Min value="22.627" />
      <Horiz_Error_Scalar value="1.96" />
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      <Null_Hypothesis_Ratio value="3.0" />
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    </ParameterSet>
</CARIS_CUBE_Parameters>
```

B.4 Error Modeling in CARIS HIPS

CARIS computes TPU based on both the static and dynamic measurements of the vessel and survey-specific information including tidal zoning uncertainty estimates and sound speed measurement uncertainties. Offset values are entered into the CARIS *.hvf file. During processing, the tidal zoning and speed of sound measurement errors are applied.

Tidal Uncertainty

For most surveys, tidal zoning values are provided with the Water Level Instructions, Tide Component Error Estimation included with the Hydrographic Survey Project Instructions. Tide zoning uncertainty values were not provided in the Project Instructions for OPR-H355-TJ-10, Final zoning for these surveys were based off Smith Shoal Light (8724671). An initial estimate of the probable zoning error made by the field unit prior to final zoning was insufficient to eliminate the spawning of multiple hypothesis in CUBE grids. Once final zoning were received, zoning uncertainty estimates were calculated by taking the root summed squares of the maximum 6min change in tide height and 5% of tide range as indicated from the Final Zoned Tides files (H1219XCORF.zdf, see Appendix 4 of any survey from OPR-H355-TJ-10). This resulted in a tide zoning uncertainty value of 12.5cm. This value was entered as the 2 sigma value and applied for surveys H12191, H12192, H12193, and H12194, because of their relative proximity to the tide station on Smith Shoal Light. The zoning uncertainty value of 12.5 cm was sufficient to eliminate the spawning of multiple hypothesis due to tidal artifacts for these surveys.

The Florida Keys area is a complex tidal area, caught between diurnal and semi-diurnal tidal regimes. The area can best be described as mixed semi-diurnal. The value of 12.5cm used for H12191, H12192, H12193, and H12194 was insufficient for survey areas a greater distance from the Smith Shoal Station. As distance from the station increased, the tidal signal measured at the station no longer accurately portrayed the tidal signal in the survey area. Tidal artifacts of up to 80cm were observed as a result. A scaled tidal comparison of the tidal signals at St.Petersburg, FL and Smith Shoal Light was performed for DN193. The comparison indicated a difference of ~0.46m between the two stations at 0930 UTC (See figure B-5 below). An examination of a mainscheme survey line from H12197 at 0920 on DN193 (448_0920) and a crossline from DN189, in Hips Subset Editor, indicated a difference of ~0.36m (See figure B-6 below). These results indicate that during certain phases of the lunar cycle, the tides observed in some parts of the survey area are fundamentally different from data observed at the Smith Shoal Light tide station. While this single scaled comparison is not scientifically robust enough to declare zoning uncertainties at distance from the Smith Shoal Light station, it does give a measure of validity to a tidal uncertainty value of 25cm (double the original 12.5cm value). 25cm was used for the estimated zoning uncertainty for surveys H12194, H12196, H12197, and H12198.

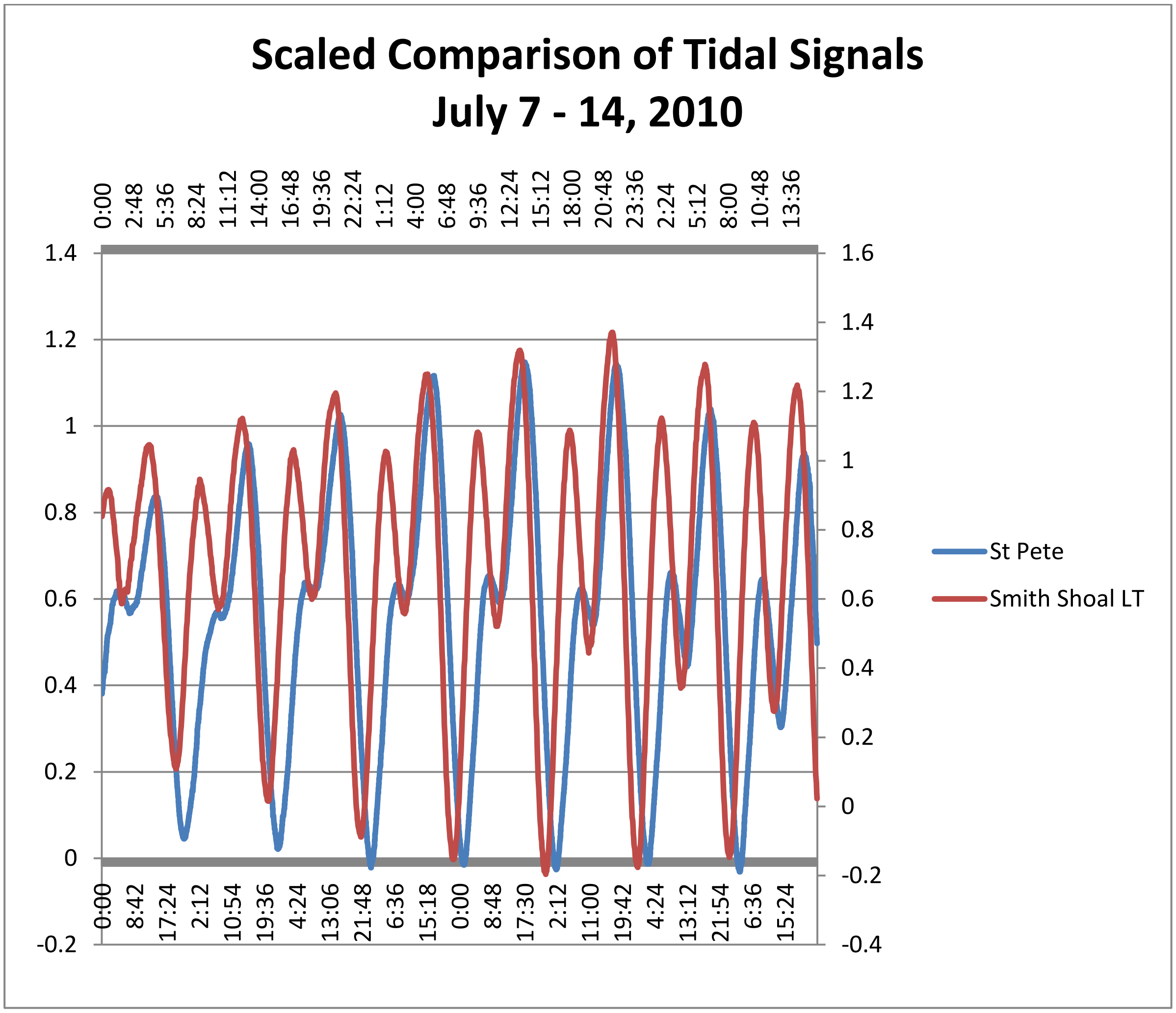

Figure B-5. Scaled comparison of tidal signals, St Petersburg and Smith Shoal Light

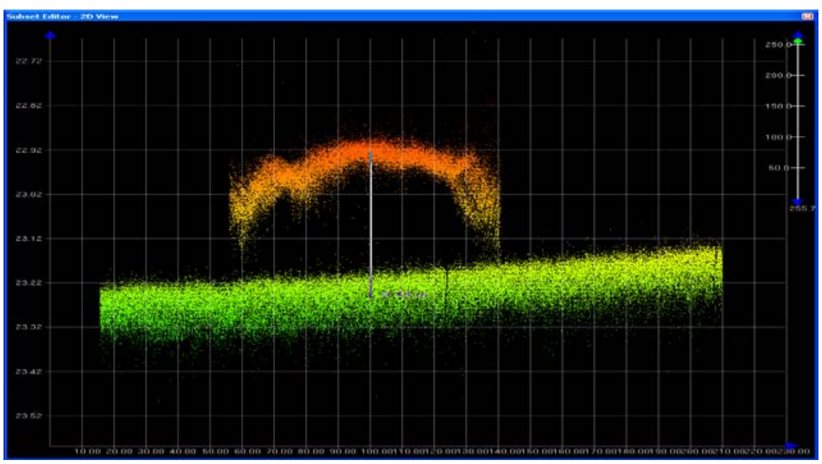

Figure B-6. Subset illustrating tidal artifact due to mixed semi-diurnal tides

TPU parameters for tidal uncertainty are listed in each survey's Descriptive Report.

Sound Speed Uncertainty

Sound speed uncertainty for *THOMAS JEFFERSON* is calculated for each project area. Because the intake for the SSVS is not located at the transducer, it is necessary to account for the difference in sound speed due to the vertical offset of the transducer with respect to the intake, the effects of roll due to the athwartship offset between the transducer and intake, and the time delay between water entering the intake and the SSVS unit registering the change.

On DN 203 a test was designed to measure the latency in the AML Smart SV&T. The experiment determined that it takes approximately 3 minutes for the SSVS in the seachest to register a change in sound speed from the intake. Based on the latency value of approximately 3 minutes and based on the athwartship and vertical offsets between the sea chest intake and the Reson 7125 transducer on the ship, uncertainty values for the speed of sound were calculated for projects OPR-H355-TJ-10, OPR-E350-TJ-10, and OPR-D304-TJ-10. These uncertainty values were compared to the default value of 0.2m/s, and when deemed significant, were applied during TPU processing in CARIS Hips and Sips. The calculated values for surface sound speed were derived from the following equation:

$$Uncertainty_{ssv} = \sqrt{[(\Delta sv/t_{latency})]^2 + [(\Delta sv/\Delta z)]^2 + [(\Delta sv/(\Delta y)\tan\Theta_{roll})]^2}$$

Where $(\Delta sv/t_{latency})$ is the change in sound speed along track due to the approximately 3 minute lag time associate with the plumbing of the SSVS and the seachest configuration on the ship; $(\Delta sv/\Delta z)$ is the difference in sound speed due to the static vertical offset between the intake and the transducer ; and $([(\Delta sv/(\Delta y)\tan\Theta_{roll})$ is the change in sound speed attributable to roll of the ship with regard to the athwartship offset.

TPU Parameters for sound speed uncertainties are documented in each survey's Descriptive Report.

Additional Uncertainties

Instrument-specific uncertainty values are obtained from either the CARIS TPU resource website or per HSD guidance. These uncertainty values are recorded in the Hips Vessel File (.hvf) for each vessel and sonar configuration. TPU values for each vessel's .hvf are listed and described below.

TJ_S222_Reson7125_STBD.hvf

TPU - Offsets

Date	MRU to Trans x (m)€	MRU to Trans y (m)€	MRU to Trans z (m)€	Nav to Trans x (m)€€	Nav to Trans y (m)€€	Nav to Trans z (m)€€	Trans Roll (deg)*
2010_182	8.499	-2.364	5.062	7.663	6.951	27.444	0
2010_252	8.499	-2.364	5.062	7.663	6.951	27.444	0

TPU - StdDev

Date	Motion Gyro (deg)**	Heave % Amplitude**	Heave (m)**	Roll (deg)**	Pitch (deg)**	Position Nav (m)***
2010_182	0.02	5	0.05	0.05	0.05	0.5
2010_252	0.02	5	0.05	0.05	0.05	0.5

TPU - StdDev (Cont.)

Date	Timing Trans (s)**	Nav Timing (s)**	Gyro Timing (s)**	Heave Timing (s)**	Pitch Timing (s)**	Roll Timing (s)**
2010_182	0.005	0.005	0.005	0.005	0.005	0.005
2010_252	0.005	0.005	0.005	0.005	0.005	0.005

TPU - StdDev (Cont.)

Date	Offset x (m)†	Offset y (m)†	Offset z (m)†	Vessel Speed (m/s)††	Loading (m)†††
2010_182	0.05	0.05	0.015	0.53	0.05
2010_252	0.05	0.05	0.015	0.53	0.05

TPU - StdDev (Cont.)

Date	Draft (m) Δ	Delta Draft (m) ΔΔ	RU Align StdDev gyro	MRU Align StdDev Roll/Pitch ΔΔΔ
2010_182	0.1	0.05	0.1	0.1
2010_252	0.1	0.05	0.1	0.1

TPU - StdDev (Cont.)

Comments
€ values taken from partial NGS offset survey of 2005 and in house measurements from 2006 dry dock
€€ values for antenna to IMU derived from SBETs processed in POS MMS 5.3, IMU to transducer values from NGS partial survey and 2006 in house measurements
* the Transducer Roll column is for recording large angular offsets such as the angle of a tilted sonar - not to record roll biases measured by patch tests.
** values from the POS/MV manual and Uncertaintly values specified in 2010 FPM - except for Roll and Pitch which inadvertantly entered as 5cm, retained since more conservative
*** 0.5m used because DGPS quality anticipated to be better than recommended 1m - analysis of POSPac data inidcates that ~0.7m would have been more appropriate, reprocess w/ 0.7m did not occur
† offsets in x, y, z were estimated Std Dev values based on methodology used during the NGS survey
†† vessel speed is the 0.03 m/s plus the currents of approximately 0.5 m/s at 1 sigma - this is an over-estimation in some survey areas, kept for all to be conservative
††† loading changes based on launches on/off is approx 2cm, draft measured weekly and before/after ballasting/fueling so not included in loading - 5cm used as conservative measure
Δ draft value was increased because of difficulty in taking consistent draft readings in rough seas - 0.1m at 1 sigma used to address total waterline height variation of ~20cm during 2010
ΔΔ the delta draft value of 5cm exceeds the 3cm upper limit in FPM recommendations, but is supported by the ERS Dynamic Draft Method statistics.
ΔΔΔ the value of 0.1 was recommended by a PS from AHB until such time as a proper survey of vessel reference frame can be made - requires an NGS survey during next dry dock

Figure B-7. TPU offsets and standard deviation values – *S222* Reson 7125

TJ_3101_Reson7125_400khz.hvf

TPU - Offsets

Date	MRU to Trans x (m)€	MRU to Trans y (m)€	MRU to Trans z (m)€	Nav to Trans x (m)€€	Nav to Trans y (m)€€	Nav to Trans z (m)€€	Trans Roll (deg)*
2010-067	-0.472	0.072	0.541	0.319	0.807	4.371	0
2010-104	-0.472	0.072	0.541	0.319	0.807	4.371	0

TPU - StdDev

Date	Motion Gyro (deg)**	Heave % Amplitude**	Heave (m)**	Roll (deg)**	Pitch (deg)**	Position Nav (m)***
2010-067	0.02	5	0.05	0.02	0.02	0.1
2010-104	0.02	5	0.05	0.02	0.02	0.5

TPU - StdDev (Cont.)

Date	Timing Trans (s)**	Nav Timing (s)**	Gyro Timing (s)**	Heave Timing (s)**	Pitch Timing (s)**	Roll Timing (s)**
2010-067	0.005	0.005	0.005	0.005	0.005	0.005
2010-104	0.005	0.005	0.005	0.005	0.005	0.005

TPU - StdDev (Cont.)

Date	Offset x (m)†	Offset y (m)†	Offset z (m)†	Vessel Speed (m/s)††	Loading (m)†††
2010-067	0.015	0.015	0.015	0.53	0.02
2010-104	0.015	0.015	0.015	0.53	0.02

TPU - StdDev (Cont.)

Date	Draft (m) Δ	Delta Draft (m) ΔΔ	RU Align StdDev gyro	Align StdDev Roll/Pitch ΔΔΔ
2010-067	0.02	0.02	0	0
2010-104	0.02	0.02	0.1	0.1

TPU - StdDev (Cont.)

Comments
€ values taken from partial NGS offset survey of 2005 and in house measurements from 2006 dry dock
€€ values for antenna to IMU derived from SBETs processed in POS MMS 5.3, IMU to transducer values from NGS partial survey and 2006 in house measurements
* the Transducer Roll column is for recording large angular offsets such as the angle of a tilted sonar - not to record roll biases measured by patch tests.
** values from the POS/MV manual and Uncertaintly values specified in 2010 FPM - except for Roll and Pitch which inadvertantly entered as 5cm, retained since more conservative
*** 0.5m used because DGPS quality anticipated to be better than recommended 1m - analysis of POSPac data inidcates that ~0.7m would have been more appropriate, reprocess w/ 0.7m did not occur
† offsets in x, y, z were estimated Std Dev values based on methodology used during the NGS survey
†† vessel speed is the 0.03 m/s plus the currents of approximately 0.5 m/s at 1 sigma - this is an over-estimation in some survey areas, kept for all to be conservative
††† loading changes based on launches on/off is approx 2cm, draft measured weekly and before/after ballasting/fueling so not included in loading - 5cm used as conservative measure
Δ draft value was increased because of difficulty in taking consistent draft readings in rough seas - 0.1m at 1 sigma used to address total waterline height variation of ~20cm during 2010
ΔΔ the delta draft value of 5cm exceeds the 3cm upper limit in FPM recommendations, but is supported by the ERS Dynamic Draft Method statistics.
ΔΔΔ the value of 0.1 was recommended by a PS from AHB until such time as a proper survey of vessel reference frame can be made

Figure B-8. TPU offsets and standard deviation values – *3101*Reson 7125SV

TJ_3102_Reson7125_400KHZ.hvf

TPU - Offsets

Date	MRU to Trans x (m) ‹	MRU to Trans y (m) ‹	MRU to Trans z (m) ‹	Nav to Trans x (m) ‹‹	Nav to Trans y (m) ‹‹	Nav to Trans z (m) ‹‹	Trans Roll (deg)*
2010-067	-0.522	-0.033	0.545	0.127	0.809	4.359	0
2010-071	-0.522	-0.033	0.545	0.127	0.809	4.359	0

TPU - StdDev

Date	Motion Gyro (deg)**	Heave % Amplitude**	Heave (m)**	Roll (deg)**	Pitch (deg)**	Position Nav (m)***
2010-067	0.02	5	0.05	0.02	0.02	0.1
2010-071	0.02	5	0.05	0.02	0.02	0.5

TPU - StdDev (Cont.)

Date	Timing Trans (s)**	Nav Timing (s)**	Gyro Timing (s)**	Heave Timing (s)**	Pitch Timing (s)**	Roll Timing (s)**
2010-067	0.005	0.005	0.005	0.005	0.005	0.005
2010-071	0.005	0.005	0.005	0.005	0.005	0.005

TPU - StdDev (Cont.)

Date	Offset x (m) ƚ	Offset y (m) ƚ	Offset z (m) ƚ	Vessel Speed (m/s) ƚƚ	Loading (m) ƚƚƚ
2010-067	0.015	0.015	0.015	0.53	0.02
2010-071	0.015	0.015	0.015	0.53	0.02

TPU - StdDev (Cont.)

Date	Draft (m) Δ	Delta Draft (m) ΔΔ	MRU Align StdDev gyro ΔΔΔ	MRU Align StdDev Roll/Pitch ΔΔΔ
2010-067	0.02	0.02	0	0
2010-071	0.02	0.02	0.1	0.1

TPU - StdDev (Cont.)

Comments
‹ values taken from partial NGS offset survey of 2005 and in house measurements from 2006 dry dock
‹‹ values for antenna to IMU derived from SBETs processed in POS MMS 5.3, IMU to transducer values from NGS partial survey and 2006 in house measurements
* the Transducer Roll column is for recording large angular offsets such as the angle of a tilted sonar - not to record roll biases measured by patch tests.
** values from the POS/MV manual and Uncertaintly values specified in 2010 FPM - except for Roll and Pitch which inadvertantly entered as 5cm, retained since more conservative
*** 0.5m used because DGPS quality anticipated to be better than recommended 1m - analysis of POSPac data inidcates that ~0.7m would have been more appropriate, reprocess w/ 0.7m did not occur
ƚ offsets in x, y, z were estimated Std Dev values based on methodology used during the NGS survey
ƚƚ vessel speed is the 0.03 m/s plus the currents of approximately 0.5 m/s at 1 sigma - this is an over-estimation in some survey areas, kept for all to be conservative
ƚƚƚ loading changes based on launches on/off is approx 2cm, draft measured weekly and before/after ballasting/fueling so not included in loading - 5cm used as conservative measure
Δ draft value was increased because of difficulty in taking consistent draft readings in rough seas - 0.1m at 1 sigma used to address total waterline height variation of ~20cm during 2010
ΔΔ the delta draft value of 5cm exceeds the 3cm upper limit in FPM recommendations, but is supported by the ERS Dynamic Draft Method statistics.
ΔΔΔ the value of 0.1 was recommended by a PS from AHB until such time as a proper survey of vessel reference frame can be made

Figure B-9. TPU offsets and standard deviation values – *3102* Reson 7125SV

TPU - StdDev

Date	Motion Gyro (deg)**	Heave % Amplitude**	Heave (m)**	Roll (deg)**	Pitch (deg)**	Position Nav (m)***
2010-067	0.02	5	0.05	0.02	0.02	0.5
2010-180	0.02	5	0.05	0.02	0.02	0.5

TPU - StdDev (Cont.)

Date	Timing Trans (s)**	Nav Timing (s)**	Gyro Timing (s)**	Heave Timing (s)**	Pitch Timing (s)**	Roll Timing (s)**
2010-067	0.005	0.005	0.005	0.005	0.005	0.005
2010-180	0.005	0.005	0.005	0.005	0.005	0.005

TPU - StdDev (Cont.)

Date	Offset x (m) ƚ	Offset y (m) ƚ	Offset z (m) ƚ	Vessel Speed (m/s) ƚƚ	Loading (m) ƚƚƚ
2010-067	0.015	0.015	0.015	0.53	0.02
2010-180	0.015	0.015	0.015	0.53	0.02

TPU - StdDev (Cont.)

Date	Draft (m) Δ	Delta Draft (m) ΔΔ	MRU Align StdDev gyro ΔΔΔ	MRU Align StdDev Roll/Pitch ΔΔΔ
2010-067	0.02	0.02	0	0
2010-180	0.02	0.02	0	0

TPU - StdDev (Cont.)

Comments
‹ values taken from NGS offset survey of 2010.
‹‹ values for antenna to IMU from NGS survey from 2010.
* the Transducer Roll column is for recording large angular offsets such as the angle of a tilted sonar - not to record roll biases measured by patch tests.
** values from the POS/MV manual and Uncertaintly values specified in 2010 FPM
*** 0.5m used because DGPS quality anticipated to be better than recommended 1m - analysis of POSPac data inidcates that ~0.7m would have been more appropriate, reprocess w/ 0.7m did not occur
ƚ offsets in x, y, z were estimated Std Dev values based on methodology used during the NGS survey
ƚƚ vessel speed is the 0.03 m/s plus the currents of approximately 0.5 m/s at 1 sigma - this is an over-estimation in some survey areas, kept for all to be conservative
ƚƚƚ loading changes result in ~2cm or less based on fuel and personnel
Δ draft is measured daily via sight tube, 2 cm at 1 sigma is very conservative
ΔΔ the delta draft value of 2cm at 1 sigma accounts for over 25% of the total delta draft of the vessel, when combined with the vessel speed uncertainty when entering the table, this proves to be very conservative
ΔΔΔ MRU alignment is largely irrelevant for a wide beam angle VBES system such as the Odom CV200

Figure B-10. TPU offsets and standard deviation values – *3101* Odom CV200

TJ_3102_Odom_ETCV200_VB.hvf

TPU - Offsets

Date	MRU to Trans x (m)‘	MRU to Trans y (m)‘	MRU to Trans z (m)‘	Nav to Trans x (m)‘‘	Nav to Trans y (m)‘‘	Nav to Trans z (m)‘‘	Trans Roll (deg)*
2010-067	-1.004	0.867	0.081	-0.035	1.709	3.895	0
2010-074	-1.004	0.867	0.151	-0.035	1.709	3.965	
2010-103	-1.004	0.867	0.14	-0.035	1.709	3.954	0

TPU - StdDev

Date	Motion Gyro (deg)**	Heave % Amplitude**	Heave (m)**	Roll (deg)**	Pitch (deg)**	Position Nav (m)***
2010-067	0.02	5	0.05	0.02	0.02	0.5
2010-074	0.02	5	0.05	0.02	0.02	0.5
2010-103	0.02	5	0.05	0.02	0.02	0.5

TPU - StdDev (Cont.)

Date	Timing Trans (s)**	Nav Timing (s)**	Gyro Timing (s)**	Heave Timing (s)**	Pitch Timing (s)**	Roll Timing (s)**
2010-067	0.005	0.005	0.005	0.005	0.005	0.005
2010-074	0.005	0.005	0.005	0.005	0.005	0.005
2010-103	0.005	0.005	0.005	0.005	0.005	0.005

TPU - StdDev (Cont.)

Date	Offset x (m)‡	Offset y (m)‡	Offset z (m)‡	Vessel Speed (m/s)‡‡	Loading (m)‡‡‡
2010-067	0.015	0.015	0.015	0.03	0.02
2010-074	0.015	0.015	0.015	0.53	0.02
2010-103	0.015	0.015	0.015	0.53	0.02

TPU - StdDev (Cont.)

Date	Draft (m) Δ	Delta Draft (m) ΔΔ	MRU Align StdDev gyro ΔΔΔ	MRU Align StdDev Roll/Pitch ΔΔΔ
2010-067	0.02	0.02	0	0
2010-074	0.02	0.02	0	0
2010-103	0.02	0.02	0	0

TPU - StdDev (Cont.)

Comments
‘ values taken from NGS offset survey of 2010.
‘‘ values for antenna to IMU from NGS survey from 2010.
* the Transducer Roll column is for recording large angular offsets such as the angle of a tilted sonar - not to record roll biases measured by patch tests.
** values from the POS/MV manual and Uncertaintly values specified in 2010 FPM
*** 0.5m used because DGPS quality anticipated to be better than recommended 1m - analysis of POSPac data inidcates that ~0.7m would have been more appropriate, reprocess w/ 0.7m did not occur
‡ offsets in x, y, z were estimated Std Dev values based on methodology used during the NGS survey
‡‡ vessel speed is the 0.03 m/s plus the currents of approximately 0.5 m/s at 1 sigma - this is an over-estimation in some survey areas, kept for all to be conservative
‡‡‡ loading changes result in ~2cm or less based on fuel and personnel
Δ draft is measured daily via sight tube, 2 cm at 1 sigma is very conservative
ΔΔ the delta draft value of 2cm at 1 sigma accounts for over 25% of the total delta draft of the vessel, when combined with the vessel speed uncertainty when entering the table, this proves to be very conservative
ΔΔΔ MRU alignment is largely irrelevant for a wide beam angle VBES system such as the Odom CV200

Figure B-11. TPU offsets and standard deviation values – *3102* Odom CV200

TJ_1701_Odom_CVM200_VB.hvf

TPU - Offsets

Date	MRU to Trans x (m) *	MRU to Trans y (m) *	MRU to Trans z (m) *	Nav to Trans x (m) **	Nav to Trans y (m) **	Nav to Trans z (m) **	Trans Roll (deg)‡
2010-281	0	0	0	0.05	-2	2.12	0

TPU - StdDev

Date	Motion Gyro (deg)*	Heave % Amplitude*	Heave (m)****	Roll (deg)*	Pitch (deg)*	Position Nav (m)***
2010-281	0	0	0.3	0	0	1

TPU - StdDev (Cont.)

Date	Timing Trans (s)*****	Nav Timing (s)*****	Gyro Timing (s)*	Heave Timing (s)*	Pitch Timing (s)*	Roll Timing (s)*
2010-067	0.1	0.1	0	0	0	0

TPU - StdDev (Cont.)

Date	Offset x (m) **	Offset y (m) **	Offset z (m) **	Vessel Speed (m/s) ***	Loading (m) Δ
2010-067	0.05	0.15	0.15	1	0.05

TPU - StdDev (Cont.)

Date	Draft (m) Δ	Delta Draft (m) ΔΔ	MRU Align StdDev gyro *	MRU Align StdDev Roll/Pitch *
2010-067	0.05	0.05	0	0

TPU - StdDev (Cont.)

Comments
* the Odom CVM200 does not have an IMU or MRU and therefore any TPU value referencing an MRU has been zeroed - any zeroed value is considered to mean NOT APPLICABLE
** the utility boat was not professionally surveyed, a steel tape was used to measure the offsets while the boat was in the cradle; as the boat was not level during measurements it is likely that the uncertainties are high, values used are a best guess
*** 1m used because the Raven Invicta 210 reports a sub-meter accuracy - 1m used as a conservative estimate,
****Heave was calculated by taking the maximum anticipated wave height and multiplying by 0.707 - this is a conservative estimate because FPM states to take half the wave height and multiply it by 0.707
***** Timing has been estimated. Nav time experiments indicated a 0.25 second latency - 0.1 is considered reasonable, but has not been empirically validated.
‡ the transducer roll column is intended to capture large angular offsets of a transducer such as a tilted sonar and is not intended to capture the uncertainty in which a roll angle is measured;
Δ Loading and draft were estimated based on casual observation of the boat as personnel walked about the boat while underway
ΔΔ A crude dynamic draft measurement was made, but it does not have sufficient points to provide an adequate trend line, the value listed is half the maximum observed dynamic draft and is considered conservative

Figure B-12. TPU offsets and standard deviation values – *1701* Odom CVM200

B.5 Bathymetry Analysis and Feature Classification

Least depths of navigationally significant features are flagged as “designated soundings,” which both identifies the object as a navigationally significant object for import into Pydro and forces the depth of the grid to match the least depth of the feature.

Following data cleaning in CARIS HIPS, Designated soundings and Side Scan contacts are inserted into a PYDRO Preliminary Smooth Sheet (PSS). DP and GP features are inserted using the "Generic Data Parser" tool. Images of contacts exported from CARIS are displayed in the Image Notebook Editor in PYDRO. Contacts are arranged by day and line and can be selected in the data "Tree" window. Information concerning a specific contact is reviewed in the Editor Notebook Window in PYDRO. This information includes contact positions, AWOIS item positions, contact cross references, and charting recommendations.

Contacts are classified according to type of contact (e.g. MBES, SSS, DP, etc), confidence, and proximity to other contacts. Although this will vary from survey to survey, the following general rules apply for classification of contacts:

- MBES contacts will be classified as primary contacts over SSS, DP, and GP contacts;
- If there are two or more MBES contacts for the same feature, the MBES contact of least depth is classified as the primary contact;
- If there is no bathymetry contact for a feature, then the SSS position will be classified as primary contact over DP and GP contacts;
- If there are two or more SSS contacts for the same feature, then the SSS contact that best represents the feature is classified as the primary contact;
- If there are no bathymetry or imagery contacts, then the DP contact that best represents the feature is classified as the primary contact.

Multiple representations of one distinct feature (e.g. contacts from two or more SSS lines on a known wreck) may be grouped. For a group of features, one representation is selected as the primary contact, and all others are selected as secondary contacts with respect to the primary contact.

Significant features are defined by the Hydrographic Survey Specifications and Deliverables as an object rising more than 1m above the seafloor in water depths of 0-20m, and an object rising 10% of depth above the seafloor in water depths greater than 20m. Either echosounder least depth or side-scan sonar acoustic shadow height may be used to determine height of an object off the water bottom.

Contacts appearing significant are further investigated with a MBES system capable of meeting NOAA object detection specifications. If there is no known least depth of good confidence on a significant feature, then the feature will be flagged as "Investigate." Features with such a tag must be further developed, in order of preference, with multibeam echosounder, diver least depth gauge, or vertical beam echosounder.

Any items that are to be addressed in the Feature Report (Appendix II) of the Descriptive Report are flagged as "Report". Examples of Report items include position of new or repositioned Aids to Navigation, permanent man-made features which do not pose a danger to surface navigation, or dynamic sedimentary bed forms which have not been previously noted on the chart. Items which have the “Report” flag set could also be further designated for inclusion in the Danger to Navigation Report by choosing the “DTON” flag. Dangers to Navigation are submitted to the Commanding Officer for review prior to submission to the Marine Charting Division (MCD).

After a feature is fully classified, primary features are flagged as “Resolved.” If a primary feature is flagged “Resolved,” then the secondary features correlated to that primary feature are automatically flagged “Resolved” and are given the same full classification as the primary feature.

B.6 Imagery

Side scan sonar data are converted from *.sdf (Sonarpro raw format) to CARIS HDCS. Processing side scan data includes examining and editing fish height, vessel heading (gyro), and vessel navigation records. When side scan sonar is towed, fish navigation is recalculated using CARIS SIPS. Tow point offsets (C-frame and cable out), fish depth, fish attitude, and water depth are used to calculate horizontal layback.

After towfish navigation is recalculated, side scan imagery data are slant-range corrected to 0.1m with beam pattern correction. The slant-range corrected side scan imagery data are closely examined for any targets. Targets-of-interest are evaluated as potential contacts based upon apparent shadow height and appearance, particularly targets which do not appear to be natural in origin. Contacts are selected and saved to a contact file for each line of SSS data. Contact selection includes measuring apparent height and width, selecting contact position, and creating a contact snapshot (*.tif) image.

Side scan sonar coverage is determined by creating mosaics using Mosaic Editor in CARIS SIPS. Mosaic Editor uses the accurately modeled backscatter correction algorithms of the Geocoder engine to process source data. This processed imagery data is stored in SIPS as Georeferenced Backscatter Rasters, or GeoBaRs. GeoBaRs are the basis for all mosaics created in SIPS. From the GeoBaRs, mosaics are created which can be examined and edited in Mosaic Editor. Once imagery has been corrected, a full mosaic can be compiled from the data. If any deficiencies in the side scan sonar data are found, a holiday line file is created from the mosaics and additional lines of SSS are acquired.

B.7 Survey Deliverables and Ancillary Product Generation

The ship’s final bathymetric deliverables to the Atlantic Hydrographic Branch are a collection of BASE surfaces, the Pydro PSS (including S-57 feature classifications), the Descriptive Report, side scan sonar mosaics (when applicable), and two sun-illuminated digital terrain models of the multibeam bathymetry. The resolution of surfaces varies according to acquisition type specified in the Project Instructions.

The Pydro Preliminary Smooth Sheet (PSS) contains a set of features and other data which best represent the survey area at survey scale. Along with the Descriptive Report, the PSS is the ship’s record of the survey, from which the final survey product is created at the Atlantic Hydrographic Branch

C. Corrections to Echo Soundings

C.1 Sound Velocity

Sound speed data acquired by the surface sound velocity sensors on *THOMAS JEFFERSON* and *Survey Launch 3101/3102* are recorded in the raw Hypack .hsx files and are used to calculate launch and receive angles for the ray tracing algorithm. The surface sound velocity sensors are discussed in Section A and will not be discussed further in this section.

CTD Profiles

Sound velocity profiles for the *THOMAS JEFFERSON* and for Launches *3101* and *3102* are processed using the program HSTP Velocwin version 8.96 which generates sound velocity profiles for CARIS HIPS. Sound velocity correctors are applied to MBES and VBES soundings in CARIS HIPS during post processing only.

The speed of sound through water is determined by a minimum of one cast per week (although one per day is usually acquired) for VBES acquisition and one cast every three to four hours of MBES acquisition, in accordance with the NOS Hydrographic Surveys Specifications and Deliverables (HSSD). Casts are conducted more frequently when changing survey areas, or when environmental conditions such as changes in weather, tide, current, or significant spatial and/or temporal variation in the speed of sound is observed in the survey area that would warrant additional sound velocity profiles.

The sound velocity casts are extended in HSTP Velocwin and applied to all bathymetric data in CARIS HIPS during post processing.

Brooke Ocean MVP

The SV data acquired by the MVP is transmitted to a raw SV file folder, where the hydrographer conducts a basic check of the data for correct day number, sound velocity data, and file format/integrity. The SV cast may also be graphically viewed and compared with other casts using the Sound Velocity vs. Depth graph in the MVP controller software.

Like CTD casts, MVP casts are processed and/or extended for use in CARIS HIPS using HSTP Velocwin.

C.2 Water Level Correctors

Zoned Tides

Soundings are initially reduced to Mean Lower-Low Water (MLLW) using preliminary (observed) water level data. Data may be obtained from the primary tide gauge through the Center for Operational Oceanographic Products and Services (CO-OPS) website.

Observed water level files are converted to CARIS tide files (.tid) and/or text files and applied to all sounding data using either discrete tide zoning in CARIS HIPS or the TCARI module in Pydro. The type of water level correction used in a survey is specified in the Water Level Instructions, provided by CO-OPS.

When discrete tide zoning is specified in the Tide Note, THOMAS JEFFERSON personnel use verified water levels and final tide zoning from the Zone Definition File (ZDF) provided by CO-OPS for hydrographic product generation.

TCARI

Tidal Constituents and Residuals Interpolator (TCARI) grid files, when applicable, are submitted to THOMAS JEFFERSON as part of the Project Instruction package. A TCARI grid is computed using the shoreline, a limiting boundary, and the positions of two or more water level gauges. Harmonic constants, residual water levels, and gauge weights are interpolated for each grid point, using the data from the water level gauges as control points. Water level corrections are applied in Pydro using the TCARI tools found in Pydro 7.3 and beyond. When using TCARI for datum reduction, water level corrections are not applied to echosounder data in CARIS. Following TCARI water level correction in Pydro, data is merged and processed as described in Section B.

Ellipsoid Referenced Surveys and VDATUM

When ERS methods are assigned, processed SBETs, as described in Section A of this DAPR, are applied in CARIS Hips and Sips. First, the smoothed attitude and navigation are loaded by using the "Process-Load Attitude/Navigation data" option. Next, the error data is loaded by using the "Process-Load Error data" option. Once these steps have been completed successfully, the TPU must be recomputed and "Error Data" must be checked instead of "Vessel Settings". Following TPU computations, GPS Tide must be computed. This is accomplished by selecting the "Process-Compute GPS Tide" option and loading the .csv separation model. This separation model is either included with the project instructions, or generated by the field unit by utilizing the VDATUM tool built into Pydro. Once created, the .csv file contains a node by node offset between the ellipsoid and MLLW. If no model is applied, and the height offset is left at 0.0, then all soundings remain referenced to the ellipsoid. However, since the current guidance from the Office of Coast Survey is to reduce all soundings to MLLW, a .csv model shall be used when computing GPS Tide. The final step is to Merge the data and apply the GPS Tide computed in the previous step.

H12180 is the only survey covered by this DAPR in which the ERS method has been applied.

C.3 Multibeam Calibration Procedures

Heave, pitch, roll, yaw, and navigation latency biases for each vessel are corrected during a multibeam bias calibration test (patch test). MBES vessel offsets, dynamic draft correctors, and system bias values are contained in HIPS Vessel Files (HVFs). These offsets and biases are applied to the sounding data during processing in CARIS HIPS. A Patch Test or verification of certain biases is typically performed at the start of each field season and re-verified for each project before acquiring MBES data in the new survey area. Calibration reports are generated for initial calibrations at the beginning of the field season, but reports are not necessarily generated for each project when values are re-verified. Small changes in the roll bias are common, but also are not necessarily documented by official reports. Changes in .HVFs not accompanied by full calibration reports are instead documented in the comments column of the HVF entry by the date in which the change took effect. Screen captures from HVFs for each vessel and configuration are listed below. For full access to details in the HVFs, please refer to the actual HVFs submitted with each survey.

Swath 1
Navigation
Gyro
Heave
Pitch
Roll
Draft
TPU values
SVP 1
Waterline Height

	Date	Time	Time Correction (s)	X (m)	Y (m)	Z (m)	Pitch (deg)	Roll (deg)	Yaw (deg)
6	2009-209	00:00	0.00	8.499	-2.364	5.064	-1.70	0.18	-0.32
7	2009-215	00:00	0.00	8.499	-2.364	5.064	-1.70	0.18	-0.32
8	2010-069	00:00	0.00	8.499	-2.364	5.064	-1.70	0.21	-1.10
9	2010-106	01:50	0.00	8.499	-2.364	5.064	-1.70	0.21	-1.10
10	2010-182	00:00	0.00	8.499	-2.364	5.062	-1.70	0.131	-1.10
11	2010-221	00:00	0.00	8.499	-2.364	5.062	-1.70	0.131	-1.10
12	2010-252	00:00	0.00	8.499	-2.364	5.062	-1.70	0.185	-1.10
13		00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure C-1. TJ_S222_Reson_7125_STBD.hvf offsets and biases

Swath 1
Navigation
Gyro
Heave
Pitch
Roll
Draft
TPU values
SVP 1
Waterline Height

	Date	Time	Time Correction (s)	X (m)	Y (m)	Z (m)	Pitch (deg)	Roll (deg)	Yaw (deg)
1	2010-067	00:00	0.00	-0.472	0.072	0.541	1.567	-0.418	1.033
2		00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure C-2. TJ_3101_Reson7125_400khz.hvf offsets and biases

Swath 1
Navigation
Gyro
Heave
Pitch
Roll
Draft
TPU values
SVP 1
Waterline Height

	Date	Time	Time Correction (s)	X (m)	Y (m)	Z (m)	Pitch (deg)	Roll (deg)	Yaw (deg)
1	2010-067	00:00	0.00	-0.522	-0.033	0.545	1.80	-0.84	-0.897
2	2010-071	00:00	0.00	-0.522	-0.033	0.545	1.80	-0.92	-0.897
3		00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure C-3. TJ_3102_Reson7125_400khz.hvf offsets and biases

C.4 Vessel Offsets, Static Draft, and Dynamic Draft Correctors

A partial re-survey of *THOMAS JEFFERSON* vessel offsets was conducted on 10 March 2005 by NGS personnel, and no physical changes in offsets have occurred since then. However, during ERS processing on survey H12180, it was determined that the 2005 partial survey did not adequately take into account the alignment of the antennas with respect to vessel reference frame. This was evident in the Calibrated Installation Parameters report generated by the GNSS processor in POS MMS. X, Y, and Z offsets were settling in on values that differed from the installation parameter values entered in MV/POSView based on the 2005 NGS survey. The differences in offsets are insignificant for surveys reduced to MLLW via tradition tides application because the vertical offset of the antenna does not affect survey depths. Only horizontal positioning was affected by the inaccuracies of the antenna offsets. Since the horizontal offsets determined for the antennas is significantly smaller than the horizontal positioning requirement for IHO Order 1 surveys, no reprocessing is necessary for surveys submitted via traditional discrete zoning. For ERS surveys, the antenna heights do affect the final survey depths because the soundings are referenced to the ellipsoid based on the 3-D positioning determined calculated by the GNSS processing of POSPac data, which are then reduced to MLLW via a SEP model, which is a grid of the difference between the ellipsoid and MLLW for a given area.

Through an iterative process by which calibrated installation parameters were applied and the SBET re-processed using the GNSS processor, precise values for the antenna positions with respect to the IMU were determined. The values listed in Table XX below are the values for the IMU to Primary GNSS (port antenna) lever arms that were entered into MV/POSView at the beginning of the fieldseason compared to the values that were calculated during post processing.

Coordinate (direction)	**NGS Values**	**Post Processed Values**
X (fore and aft)	-10.282	-10.027
Y (port and starborad)	1.356	1.548
Z (vertical)	-22.320	-22.382

Table C-1. IMU to Primary GPS antenna offsets for *Thomas Jefferson*

Preliminary static draft measurements are made at the beginning of each leg and weekly thereafter. Static draft for *THOMAS JEFFERSON* is measured using a sight tube located in lower survey stores in the vicinity of frame 33. Additional static draft measurements are made as needed with changing conditions, such as changes in the ship's ballasting or loading. Lower survey stores is not vented to the atmosphere, and as a result, air pressure inside the ship can introduce an error in static draft measurements. As a result, a value of 0.1m was entered into the CARIS HVF as the uncertainty for static draft for the ship.

3101

Vessel offset measurements were made on *HSL 3101* on January 13, 2010 by NGS personnel. The NGS survey measured from established benchmarks on the vessel back to the reference point, in this case, the cross hairs on top of the IMU. From the surveyed benchmarks, the new RESON 7125SV, SSVS, and Odom CV200 installation offsets were measured using a steel tape. The Klein 5000 side scan was surveyed in a similar manner and offsets for the "heavy weight" and "light weight" systems were recorded.

Static draft measurements for HSL 3101 and HSL 3102 are determined using a sight tube to measure the waterline with respect to the reference point on the top of the IMU. These measurements are made at the beginning and end of each working day while the vessel is dead in the water.

3102

Vessel offset measurements were also made on *HSL 3102* on January 13, 2010 by NGS personnel. The NGS survey measured from established benchmarks on the vessel back to the reference point on top of the IMU in the same manner as the survey of HSL 3101. From the surveyed benchmarks, the new RESON 7125SV, SSVS, and Odom CV200 installation offsets were measured using a steel tape. The Klein 5000 side scan was surveyed in a similar manner and offsets for the “heavy weight” and “light weight” systems were recorded.

Dynamic Draft

During the 2010 hydrographic systems readiness review, *Thomas Jefferson* performed an evaluation of an Ellipsoid Referenced Survey (ERS) method for measuring dynamic draft for the ship, HSL 3101, and HSL 3102. This method has been termed Ellipsoid Referenced Dynamic Draft Measurement (ERDDM). The Echosounder method of determining dynamic draft was used to verify ERDDM results. Post-processed Smoothed Best Estimate Trajectory (SBET) altitude heights with respect to the ellipsoid were created in POSPac MMS 5.3 and used to measure dynamic draft. The Echosounder method is described in the 2009 and 2010 FPM section 1.4.2.1. 2.1.

The ERDDM was conducted by acquiring POSPac data while acquiring survey lines for the Echosounder method. The Echosounder method was modified slightly to provide additional drift values to isolate the effects of tide. This was achieved by going all stop at the end of each line and drifting dead in the water for 1 – 3 minutes. These all stop values provided visual break points for reference in the continuous POSPac data that was logged for the duration of survey operations for the day. During the ERDDM for HSL 3101, at rest periods were not acquired at the end of some of the lines. In these instances, vessel heading was used for visual break points in the POSPac data.

For the Echosounder method, all multibeam data were processed using standard procedures in Caris HIPS. Dynamic draft was computed for each RPM level. The speed at each RPM was calculated by querying the speed of the lines run at that RPM and taking the average (note, this differs from using the median value as detailed in FPM 1.4.2.1.2.1). Three different regions on the line were sampled for depth soundings; the regions were at 1/4, 1/2, and 3/4 along the line. The sampled regions were queried by line for depth soundings. Depth soundings acquired at similar RPMs were combined and the median depth sounding and the average depth were found. This approach was utilized to provide an additional “sanity” check on the data. This sounding was used in the calculation of the vessel draft. To determine the change in vessel draft at each speed the difference between the median depth sounding at that speed and the median depth sounding at drift speed was found. Dynamic draft for each vessel was computed by three different people and the results were averaged and the standard deviations between each individual’s calculations were recorded. .

For the ERS method, the POSPac data was processed in POSPac MMS 5.3 and an SBET file was created. The vessel speed and the altitude plots were examined and data corresponding to the lines described in the Echosounder method above were exported into a spreadsheet and analyzed. The average vessel speed for each line and the average difference between at speed altitudes and at rest altitudes were computed and used to create a dynamic draft table.

Comparisons of the results of the Echosounder method and the ERDDM method indicated that there was greater variability in the Echosounder method of determining dynamic draft. The ERDDM method matched the trends of the Echosounder method extremely well for the ship and for HSL 3102. However, the dynamic draft for HSL 3101 had a great amount of variability between individual examiners and between echosounder and ERDDM methods. Because the ERDDM is less subjective it was deemed to be a more accurate and repeatable measurement. For this reason, ERDDM values were entered into the HVFs for all vessels for the 2010 field season.

APPROVAL SHEET

This Data Acquisition and Processing Report is respectfully submitted for the following projects:

OPR-K380-TJ-10 Approaches to Galveston, TX
OPR-H355-TJ-10 Approaches to Key West, FL
OPR-E350-TJ-10 Southern Chesapeake Bay, VA (H12180 only)
OPR-D304-TJ-10 Approaches to Chesapeake Bay, VA.

As Chief of Party, I have ensured that standard field surveying and processing procedures were adhered to during these projects in accordance with the Hydrographic Surveys Specifications and Deliverables (**4/2010**), Hydrographic Survey Technical Directives **HTD 2010-06**, and the Field Procedures Manual for Hydrographic Surveying (**4/2010**,).

I acknowledge that all of the information contained in this report is complete and accurate to the best of my knowledge.

This DAPR applies to all surveys completed in 2010 for the projects listed above.

Approved and Forwarded:

Mark Blankenship
2011.03.07
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