OPR-K354-KR-12

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

DATA ACQUISITION & PROCESSING REPORT

Type of Survey: Hydrographic Multibeam & 200% Sidescan

Project Number: OPR-K354-KR-12

Time Frame: May - December 2012

LOCALITY

State: Louisiana

General Locality: Gulf of Mexico

2013

CHIEFS OF PARTY
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A. EQUIPMENT

A.1. MAJOR OPERATIONAL SYSTEMS

The major operational systems used to acquire hydrographic data were two Kongsberg EM3002 multibeam echo sounders (MBES) and the Klein 5000 V2 side scan sonar (SSS). A list of the survey equipment is shown in Table 1.

Table 1. Survey equipment list.

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM3002	Transducer: 211 Topside: 1076
Multibeam Echo Sounder (Starboard)	Kongsberg	EM3002	Transducer: 369 Topside: 1076
Side Scan Sonar (Primary)	Klein	5000 V2	377
Side Scan Sonar (Back –up)	Klein	5000 V2	376
Single Beam Echo Sounder (Port)	ODOM	Echotrac MK III	Transducer: TR7212 Topside:21646
Single Beam Echo Sounder (Starboard)	ODOM	Echotrac MK III	Transducer: TR7211 Topside: 21646
Attitude and Positioning System	CodaOctopus	F180	F0904015
Attitude and Positioning System	Coda Octopus	F180	F0803009
Positioning System	CNAV	3050	CNAV Receiver:13769
Positioning System	CNAV	3050	CNAV Receiver: 13752
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	99B0559, 04M1615
CTD	Sea-Bird Electronics, Inc	SBE 19	2791,1174, 2645
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221,5222
Cable Payout Indicator	Subsea Systems	PI-5600	234, 235

A.2. SURVEY VESSEL

Survey operations were conducted aboard the R/V *Sea Scout.* The R/V *Sea Scout* is a 134 foot (40.84 m) catamaran survey vessel based out of New Iberia, LA. Vessel profile and vessel specification information is shown in Table 2. A vessel diagram with all measured offsets from the central reference point is shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Table 2. Vessel Profile and Specifications.

Owner/Operator	C & C Technologies, Inc.
Home Port / Flag	New Iberia, Louisiana / USA
United States Coast Guard Official Number	1237094
Year Built	2011
Place Built	Bellingham, Washington
Builder	All American Marine
Intended Service	Oceanographic Research
Operational Area	Gulf of Mexico
Length	134 Feet
Beam	37’ 4”
Draft	6’ 6”
Freeboard	7’ 7.5”

A.3. MULTIBEAM ECHOSOUNDER OPERATIONS

Two hundred percent (200%) side scan sonar coverage with concurrent set line spacing MBES coverage was acquired, as outlined in the Project Instructions. Multibeam crossline data was acquired along transects perpendicular to the mainscheme lines. Crossline mileage consisted of at least 8% of the mainscheme mileage, in accordance with Section 5.2.4.3 of the HSSD (2012). Refer to section B.1.3.1 for details on crossline comparisons.

Multibeam survey operations were generally conducted using a dual head configuration comprised of two Kongsberg EM3002 multibeam echo sounders. The transducers are mounted on rams in each catamaran pod 6.44 m apart. These transducers are not mounted with any intended angular offsets. The rams operate such that the transducers can be lowered and raised as needed for survey operations and transit. Pertinent operational specifications of the EM3002 multibeam systems are shown in Table 3. These specifications were obtained from the EM3002 product specification documentation.

Table 3. EM3002 Operational Specifications

Frequencies	292, 300, 307 kHz
Number of soundings per ping Single Sonar Head	Max 254
Number of soundings per ping Dual Sonar Heads	Max 508
Maximum Ping Rate	40 Hz
Maximum Angular Coverage Single Sonar Head	130 degrees
Maximum Angular Coverage Dual Sonar Heads	200 degrees
Pitch and Roll stabilization	Yes
Heave compensation	Yes
Pulse Length	150 µs

The port transducer (serial number 211) was operated at a frequency of 307 kHz and the starboard transducer (serial number 369) was operated at a frequency of 293 kHz. The multibeam sonars were operated in high-density equidistant beam spacing mode. The high density mode increased the number of soundings to 254 per ping per head, for a total of 508 soundings per ping.

The angular coverage of the sonars was typically set at 64 degrees from nadir on the outer sector and 54 degrees on the inner, provided there was sufficient water depth for overlapping beams; in shallow water the inner angular sector could be increased. This configuration can provide up to 5x times water depth bottom coverage depending on water depth.

The maximum ping rate was user adjusted based on water depth and sediment type to obtain the best quality data; the ping rate was kept between 10 – 20 pings per second. Changes in settings are noted in the project logs for each sheet.

Lead line comparisons were conducted at least once daily for the majority of survey operations as an independent check on the multibeam bottom-detect and single beam systems. Lead lines were not taken in larger sea conditions and water depths greater than 15 – 20 meters in order to avoid a misreading. The lead line logs are included in Separates I – Acquisition and Processing Logs for each Sheet.

An Odom Echotrac MK III was used to collect single beam data. This data was continuously recorded and monitored in real-time as an independent check of the nadir beam (bottom-detect) of the multibeam sonar system.

Object Detection coverage was obtained over all potentially significant features, in accordance with section 5.2.2.3 of the HSSD (2012). In addition, continuous along-track coverage was obtained, with no gaps greater than 3 nodes long. If gaps were found to be more than 3 nodes long, fill-in lines were conducted.

Object Detection coverage (full bathymetric coverage) was also obtained over all AWOIS items assigned for full investigation in the Project Reference File (PRF).

A.4. SIDE SCAN SONAR OPERATIONS

The Klein 5000 V2 side scan sonar was operated in a towed configuration. A hanging sheave mounted to a retractable A-frame at the stern of the vessel was used as the tow point for the side scan sonar. Refer to Section C.2: Vessel Offset Measurements and Configuration and Appendix I: Vessel Reports – Vessel Layback Report for additional side scan sonar offset and layback information. The side scan sonar range scale did not exceed 100 m, in accordance with Section 6.2.4 of the HSSD (2012). In general, the survey speed of the towed side scan sonar would be limited by the range scale. However, according to the Klein 5000 V2 product specifications, the sonar fish can be towed at higher speeds with no loss of bottom coverage. The survey speed did not reach the limits as stated in the product specifications (Table 4), and survey operations were conducted at speeds between 4 and 8.5 knots. The side scan sonar data was continuously monitored during acquisition to ensure coverage.

Table 4. Klein 5000 V2 Product Specifications

Number of Beams	5 port and 5 starboard
Frequency	455 kHz
Resolution (along track)	10 cm at 38 m, 20 cm at 75 m, 36 cm at 150 m
Resolution (across track)	3.75 cm at all pulse lengths
Operating Speed Envelope	2 to 10 knots at 150 m

Line spacing was generally set to 40 meters in water depths of 0 to 25 feet (7.62 m), 60 meters in depths between 25 and 35 feet (7.62 – 10.67 m), and 90 meters in depths greater than 35 feet (10.67 m). The side scan sonar was operated at range scales of 50, 75, or 100 meters for line spacing of 40, 60, and 90 m, respectively. The shallowest charted depth determined the range scale and line spacing used. For example, if the shallowest charted depth is 21 feet while the deepest charted sounding on that line is 34 feet, a line spacing of 40 m and a range scale of 50 m would be used for the entire line. The criteria of acquiring 200% SSS coverage for object detection was accomplished using the aforementioned parameters and Technique 1 as set forth in Section 6.1 of the HSSD (2012). In this technique a single survey was conducted with the tracklines separated by about half the distance required for 100-percent coverage. Coverage mosaics were developed using an odd/even numbering system to ensure that 200% coverage was obtained.

A Subsea Systems Cable Payout Indicator was used to digitally record the tow cable length from the sheave. The cable out values were recorded in the side scan .xtf files, and later used for layback calculations. Cable out was also noted in the acquisition logs. The side scan sonar was generally towed at heights in accordance with the required 8 to 20 percent of the range scale, although due to factors such as water depth and data quality, the side scan sonar was occasionally towed at heights of less than 8 to 20 percent of the range scale. Confidence checks were observed and recorded in the logs.

A.5. ACQUISITION AND PROCESSING SOFTWARE

A list of data acquisition and processing software systems are shown in Table 5. All systems on the network are synced using 1PPS strings from GPS.

Table 5. Data Acquisition and Processing Software

Purpose	Software	Version	Date of Installation
Multibeam data recording and monitoring	Hydromap	n/a	05-4-2012
Multibeam control Software	Seafloor Information System (SIS)	3.4.2	05-4-2012
Side Scan Collection	SonarWiz5	V5.04.0012	05-4-2012
Side Scan Processing (Field and Office	SonarWiz5	V.5.04.0031	05-4-2012 (field) 05-01-2012 (office)
Multibeam Processing (Field)	CARIS HIPS/SIPS	7.1	05/4/2012 (SP2 installed on 06-07-2012)
Multibeam Processing (Office)	CARIS HIPS/SIPS	7.1	03-22-2012 (SP2 installed on 06-07-2012)
Multibeam Processing (Office)	Notebook	3.1 with SP1	09-08-2011 (new NOAA attributes 06-05-2012)
CTD Conversion Tool (Field)	Seabird Electronics Sea Term	1.59	05-4-2012
CTD Conversion Tool (Field)	Seabird Electronics Data Conversion	7.21f	05-4-2012
CTD Conversion Tool (Field)	SVTool	1.2	05-4-2012
IMU control software	F180 Series	3.04.0002	05-4-2012

Simrad's Seafloor Information System (SIS) software version 3.4.3 was used as the control software for the multibeam. This software allowed sound speed, attitude and position to be applied to the data in real time. Data was sent from SIS to C & C Technologies' proprietary software, Hydromap, to be recorded. Hydromap software was used for multibeam data collection, quality assurance, and quality control. The Hydromap display includes a coverage map, bathymetric and backscatter display waterfalls, and other parameter displays. These tools allowed the operator to monitor coverage, compare between single beam and multibeam depths, compare between the different positioning systems, and identify any ray-bending effects in real time. Corrective measures were made whenever necessary, ensuring that only high-quality data was collected. In cases where reruns were necessary due to degraded quality of data or due to lack of coverage, this was recorded and additional data collected. The Hydromap software was also used to monitor the survey line plan and maintain on-line control.

Multibeam data processing was conducted using CARIS HIPS and SIPS 7.1. Service Pack 2 was installed in the office and in the field on June 7, 2012; SP2 hotfixes 1 through 6 were downloaded and installed periodically as they became available through the CARIS support website. CARIS Notebook 3.1 was used for contact correlation purposes and feature verification using the composite source file (CSF). All features in this file were updated based on the results of the survey and submitted as the Final Feature File. The multibeam processing workflow is detailed in Section B.1.3.

Chesapeake Technologies SonarWiz Map5 V5.04.0012 software was used for side scan sonar data collection. C&C Technologies' proprietary Hydromap software was used to

layback correct the side scan sonar data. Following layback correction, side scan sonar data was processed, evaluated and contacts identified using SonarWiz5 V5.04.0031. Details on the side scan sonar processing workflow are outlined in section B.2.

B. QUALITY CONTROL

B.1. MULTIBEAM

All multibeam data collected for OPR-K354-KR-12 was processed using CARIS HIPS. One CARIS project was created for each sheet. CARIS project directory structures were created according to the format required by CARIS. Prior to importing any sounding data into CARIS, a HIPS vessel file (.hvf) was created. This vessel file includes uncertainty estimate values for all major equipment integral in the collection of the data. Uncertainty estimates assigned are further described in the following sections. The vessel file(s) used for this project are included in the Data\Processed\HDCS folder for each sheet.

CARIS HIPS was used to apply tides, merge, compute TPU, and create BASE surfaces. CARIS HIPS was also used for multibeam data cleaning, quality control, crossline comparison, chart comparisons and side scan sonar contact correlation. These steps are described in following sections.

B.1.1. CARIS VESSEL FILES

Two vessel files were created, one (1) for a minority of the data (in H12434 - Sheet 2) that was collected with one multibeam transducer and one (1) that represents the majority of the data collected with a dual head multibeam transducer configuration. The dual head vessel file is called SeaScout.hvf for Sheets 1 (H12433), 3 (H12435) and 4 (H12436). In Sheet 2, the single head vessel file is called SeaScout1.hvf and the dual head vessel file is called SeaScout2.hvf. In order to optimize the new systems and configurations aboard the R/V *Sea Scout*, several system configuration changes were made throughout the survey; these are explained in more detail for each vessel file in B.1.1.1 and B.1.1.2.

B.1.1.1. Dual Transducer CARIS Vessel File

The dual head vessel file contains the following active sensors: Swath 1, Swath 2, Navigation, Gyro, Heave, Pitch, Roll, Draft, TPU, SVP1, SVP2, and Waterline Height. The vessel file contains five (5) entries for Swath 1, Swath 2 and the TPU values section. These correspond to the dates and events in Table 6. The input values for each sensor are further explained in the following text.

Table 6. The dates and events of the five (5) entries for Swath 1, Swath 2 and the TPU values section in the vessel file.

	Date	Julian Day	Comments	Primary Navigation
Initial Patch Test	May 5, 2012	126		CNAV 3050
Lowered the multibeam heads, before data collection began in Sheet 2	May 15, 2012	136	This was not accounted for in SIS for JD 136 and 137; SVP section required in .hvf file	CNAV 3050
Change from CNAV to F180 primary positioning system (no other offsets changed)	May 25, 2012	146	Beginning of Sheet 3	F180
Lowered MB heads	May 31, 2012	152		F180
2nd Patch Test	June 9, 2012	161	Quality control check	F180

Swaths 1 and 2: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) for Swath 1 and 2 because the locations of the transducers are entered in the SIS control software prior to data acquisition. The Roll/Pitch/Yaw fields (mounting misalignments resolved with the patch test) are zero (0) for Swath 1 and 2 because the data is corrected for these during data acquisition using the SIS control software.

Navigation: The Navigation X/Y/Z fields (location of the navigation source from the reference point) are set to zero (0) because the locations of the navigation sources are entered in the SIS control software during data acquisition.

Gyro: No Gryo fields are edited because no offset was applied and the F180 IMU aligned to the ship coordinate reference frame.

Heave/Pitch/Roll: Heave, Pitch, and Roll are compensated for by the F180 IMU and the respective X/Y/Z fields are set to zero (0) and the Apply switches are set to 'No' because the dynamic values are applied during data acquisition.

Draft: A squat and settlement test was performed in order to correct for the dynamic draft of the vessel. The values input into the CARIS vessel file are shown in Table 7. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 7. Vertical displacement of *R/V Sea Scout* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.17
0.00	2.23
0.02	2.94
0.03	3.66
0.05	4.67
0.07	5.19

SVP: The multibeam rams were lowered on May 15, 2012 (JD 136). However, the settings were not saved in the SIS control software for data acquisition on May 15 and 16 (JD 136 and 137) and SVP 1 and 2 were added to the CARIS vessel file. The transducer offsets in these sections were set at the correct values (Tables 8 and 9) and the pitch, roll and azimuth

kept at 0.0 because the transducers do not have large mounting offsets and the patch test values are corrected for during acquisition and already in the file. Only the lines that needed to be re-processed were selected and processed with the CARIS Sound Velocity Correction (SVC) tool.

Table 8. SVP section offsets for the port transducer (serial number 211)

JD	Offset X (m)	Offset Y (m)	Offset Z (m)	Pitch (deg)	Roll (deg)	Azimuth
136	-3.23	-1.86	6.853	0.0	0.0	0.0
137	-3.23	-1.86	6.853	0.0	0.0	0.0

Table 9. SVP section offsets for the starboard transducer (serial number 369)

JD	Offset X (m)	Offset Y (m)	Offset Z (m)	Pitch (deg)	Roll (deg)	Azimuth
136	3.21	-1.87	6.906	0.0	0.0	0.0
137	3.21	-1.87	6.906	0.0	0.0	0.0

Waterline Height: A value of 4.86 m was entered in the Waterline Height for JD 136 and 137; this value was obtained from the waterline to CRP value in the logs, which was the same for both days. Although the apply flag is set to 'No' the SVC (Sound Velocity Correction) uses the value for processing Kongsberg data.

TPU Offsets: For consistency, this section contains the same date and event entries as Swaths 1 and 2. The offsets were calculated from known locations of the equipment from CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information). The MRU to Transducers in X and Y directions remain constant. The only fields that changed are the MRU to Transducers in the Z direction because the multibeam heads were lowered (Table 10).

Table 10. MRU to Transducer offsets.

Date	Event	MRU to Trans X (m)	MRU to Trans2 X (m)	MRU to Trans Y (m)	MRU to Trans2 Y (m)	MRU to Trans Z (m)	MRU to Trans2 Z (m)
May 5	Initial Patch Test	-2.93	3.51	-1.54	-1.55	6.705	6.755
May 15	Lowered the multibeam heads	-2.93	3.51	-1.54	-1.55	6.973	7.026
May 25	Change from CNAV to F180 primary positioning system (no other offsets changed)	-2.93	3.51	-1.54	-1.55	6.973	7.026
May 31	Lowered multibeam heads	-2.93	3.51	-1.54	-1.55	7.205	7.255
June 9	2nd Patch Test	-2.93	3.51	-1.54	-1.55	7.205	7.255

On May 25, 2012, the primary navigation for the multibeam system was changed from C-Nav to the F180. The Navigation to Transducer fields documents this change (Table 11).

Table 11. NAV to Transducer offsets.

Date	Event	Nav to Trans X (m)	Nav to Trans2 X (m)	Nav to Trans Y (m)	Nav to Trans2 Y (m)	Nav to Trans Z (m)	Nav to Trans2 Z (m)
May 5	Initial Patch Test	-1.36	5.08	3.66	3.65	11.295	11.345
May 15	Lowered the multibeam heads	-1.36	5.08	3.66	3.65	11.563	11.616
May 25	Change from CNAV to F180 primary positioning system (no other offsets changed)	-2.93	3.51	-1.54	-1.55	6.973	7.026
May 31	Lowered MB heads	-2.93	3.51	-1.54	-1.55	7.205	7.255
June 9	2nd Patch Test	-2.93	3.51	-1.54	-1.55	7.205	7.255

According to CARIS correspondence (refer to Project Reports\Project Correspondence), the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducers aboard the R/V *Sea Scout* are mounted flat and therefore the values entered in the Trans Roll and Trans Roll 2 fields are equal to the Roll Calibration Values obtained from the patch Test. These changed only on June 9, 2012 when a new patch test was performed (Table 12).

Table 12. Values entered in the Transducer Roll fields of the TPU Offsets section.

Date	Event	Trans Roll (deg)	Trans Roll 2 (deg)
May 5	Initial Patch Test	-0.17	-0.19
May 15	Lowered the multibeam heads	-0.17	-0.19
May 25	Change from CNAV to F180 primary positioning system (no other offsets changed)	-0.17	-0.19
May 31	Lowered MB heads	-0.17	-0.19
June 9	2nd Patch Test	-0.17	-0.15

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 13. Explanation and reasoning are further explained in the following text.

Table 13. Values entered for the TPU Standard Deviation section of the HVF.

Field	Value	Reason
Motion Gyro:	0.05°	based upon manufacturers' specifications (2m Baseline)
Heave % Amplitude:	5%	based upon manufacturers' specifications
Heave (m):	0.05 m	based upon manufacturers' specifications
Roll:	0.025°	based upon manufacturers' specifications
Pitch:	0.025°	based upon manufacturers' specifications
Position Nav:	*0.05 m or **0.34 m	*CNAV or **F180 (see text for explanation)
Timing Trans:	0.01 s	serial connections
Nav Timing:	0.01 s	serial connections
Gyro Timing:	0.01 s	serial connections
Heave Timing:	0.01 s	serial connections
Pitch Timing:	0.01 s	serial connections
Roll Timing:	0.01 s	serial connections
Offset X:	0.0017 m	accuracy of total station + human error
Offset Y:	0.0037 m	accuracy of total station + human error
Offset Z:	0.0009 m	accuracy of total station + human error
Vessel Speed:	0.544 m/s	1 knot current (0.514 m/s) + 0.03m/s
Loading:	0.20 m	difference between max and min draft measurements throughout survey
Draft:	0.044 m	standard deviation of port and starboard draft measurements, averaged together.
Delta Draft:	0.013 m	standard deviation of each set of values for each RPM setting used for calculating the dynamic draft, averaged together
MRU Align StdDev Gyro:	0.21°	average of the standard deviations of each set of resolved yaw biases
MRU Align StdDev Roll/Pitch:	0 .06°	average of the averaged standard deviations of each set of resolved pitch and roll biases

The motion Gyro, Heave % Amplitude, Heave (m), Roll (deg) and Pitch (deg) values are based upon manufacturers' specifications as listed within the TPU resource link provided on the CARIS web page http://www.caris.com/tpu/navigation_tbl.cfm. These match the specifications in the F180 user's manual.

The Position NAV (m) was 0.05 m for survey operations conducted using the C-Nav 3050 as the primary navigation and 0.34 m for survey operations conducted using the F180 as the primary navigation with the following reasoning, since it is different than what is currently listed on the CARIS TPU website; CARIS confirmed that this is an acceptable value (refer to Project Reports\Project Correspondence).

F180 TPU positional accuracy value: The CodaOctopus website (http://www.codaoctopus.com/octopus-f180-series/specifications/) states that the positional

accuracy (CEP) of the F180 is 0.4 m (with DGPS). This would give a 1-signma positional accuracy of approximately 0.34 m:

$$CEP = 0.5887(\sigma_{x1} + \sigma_{x2})$$
$$CEP = 0.5887(2\sigma)$$
$$0.4 = 0.5887(2\sigma)$$
$$\frac{0.4}{0.5887} = 2\sigma$$
$$\frac{0.6795}{2} = \sigma$$
$$0.33975 = \sigma$$

The Timing Trans and Nav, Gyro, Heave, Pitch and Roll Timing values were set to 0.01s because they are serial connections, and 0.01s is an appropriate value according to Appendix 4 of the 2012 NOAA Field Procedures Manual.

The X/Y/Z Offset values: The survey of the vessel was carried out with a Leica TPS 1200+ total station. This instrument has a 1" (1-second) angular accuracy and a range accuracy of 1mm + 1.5ppm. The errors of the measured vessel offsets were estimated by comparing the relative geometry of the offsets measured during nine (9) independent total station setups (Table 14).

Table 14. Errors of measured vessel offsets.

No of reference points	47
Smallest misclosure	0 mm
Largest misclosure	9 mm
Standard deviation (X-offsets)	1.7 mm
Standard deviation (Y-offsets)	3.7 mm
Standard deviation (Z-offsets)	0.9 mm

Vessel Speed: According to Appendix 4 of the Field Procedures manual, this value is 0.03 plus the average current in the area; a value of 1 knot (0.514 m/s) was used for the average current.

Loading: Difference between the maximum and minimum draft measured for the duration of the survey.

Draft: The standard deviation was calculated separately for the port draft measurements and the starboard draft measurements taken for the duration of survey operations. The two standard deviation values were then averaged together for a final value.

Delta Draft: The dynamic draft data consists of 7 lines run at varying RPM values and the squat of the vessel at each RPM. The standard deviation of the set of squat values for a specific RPM setting (ex. 0000 RPMs) was calculated. The standard deviations of the squat values for each RPM setting were then averaged together for a final value. Only runs 3 – 7 were used (refer to section C3 for additional information).

According to the 2012 Field Procedures Manual, both the MRU Align. StdDev gyro and MRU Align StdDev Roll/Pitch can be estimated by calculating the standard deviation of a large sample of angular bias values resolved with a patch test. In this case several people resolved biases several times for each of the two patch tests using the CARIS calibration tool (Refer to Appendix II: Echosounder Reports – Patch Test Report for more information). The average of the standard deviations of each set of resolved yaw biases were used for the gyro MRU Align gyro value. The average of the averaged standard deviations of each set of resolved pitch and roll biases was used for the MRU Align Roll/Pitch value (Table 15).

Table 15. Statistical information of resolved biases from the CARIS calibration tool (units are degrees).

120505-SH1-211	Pitch Std Dev	Roll Std Dev	Yaw Std Dev
Trial 1	0.02	0.02	0.08
Trial 2	0.06	0.01	0.10
Trial 3	0.05	0.03	0.25
12505-SH2-369	Pitch Std Dev	Roll Std Dev	Yaw Std Dev
Trial 1	0.10	0.02	0.15
Trial 2	0.12	0.03	0.14
Trial 3	0.29	0.20	0.37
120609-SH1-211	Pitch Std Dev	Roll Std Dev	Yaw Std Dev
Trial 1	0.04	0.02	0.04
Trial 2	0.03	0.02	0.13
Trial 3	0.05	0.01	0.08
120609-SH2-369	Pitch Std Dev	Roll Std Dev	Yaw Std Dev
Trial 1	0.03	0.02	0.24
Trial 2	0.10	0.01	0.78
Trial 3	0.02	0.02	0.13
Average of Std Dev Pitch	0.08		
Average of Std Dev Roll		0.03	
Average of Std Dev Yaw			0.21
Average of pitch and roll average of standard deviations	0.06 degrees		

B.1.1.2. Single Transducer CARIS Vessel File

The single transducer vessel file is identical to the values for Swath 1 (Transducer 1) of the dual head vessel file; there is also no SVP or Waterline Height sensor. 54 lines in H12434 (Sheet 2) were collected with only the port transducer (serial number 211) and the C-Nav 3050 as the primary navigation source; the survey lines were imported into CARIS with the navigation source as (1).

B.1.2. TPU

CARIS HIPS was used to compute the Total Propagated Uncertainty (TPU) for each sounding using the parameters shown in Figure 1.

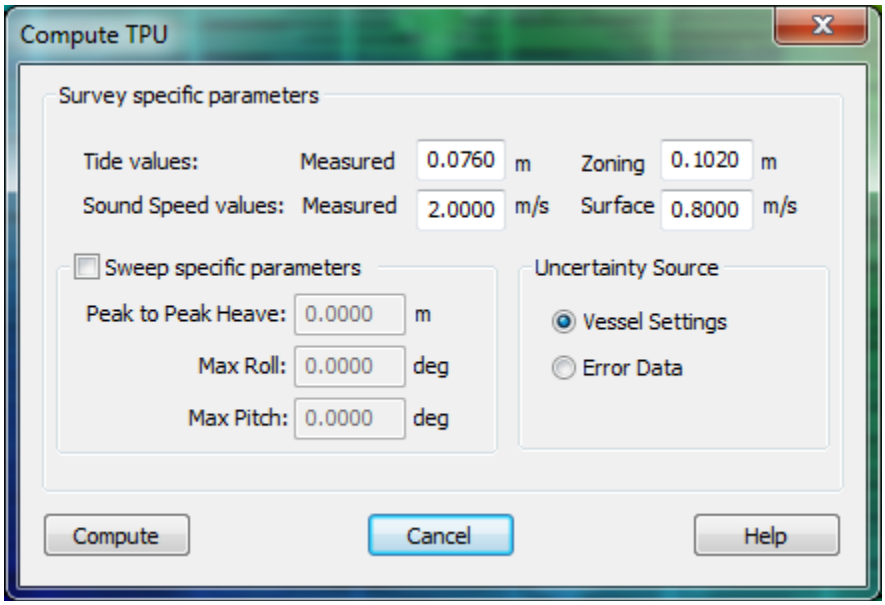


Figure 1. Total Propagated Uncertainty (TPU) values.

B.1.2.1. TIDE COMPONENT

The primary tide gauge at Calliou Bay (8763535) is an Aquatrak acoustic sensor. According to the CARIS HIPS/SIPS user's manual, the measured tide value is the error for the tide station, which is equivalent to the standard deviation of the tide gauge measurements. The output file of the Aquatrak sensor provides the 6-minute water level as well as the standard deviation (1-sigma) of the measurements used to calculate the 6-minute water level. An average of these standard deviations for duration that the tide gauge was operational between April 24 and December 18, 2012 was calculated to be 0.025 m. This is within the range of values (0.01 – 0.05 m) provided in the CARIS HVF Uncertainty Values document in Appendix 4 of the Field Procedures Manual. This is also in accordance with the 0.1 m measurement error at the 95% confidence interval stated in Section 4.1.6 of the HSSD (2012). This section also provides a processing error for the interpolation of the water level at the time of the soundings, which is also 0.1 m at the 95% confidence interval. This is 0.051 at the 1-sigma level. Adding this to the measurement error of 0.025 m provides the final value of 0.076 m to be used as the measured tide TPU value.

According to NOAA correspondence for the 2011 field season (refer to Project Reports\Project Correspondence), the tidal zoning error is not expected to exceed the 0.45 m tolerance as listed in Section 4.1.6 of the HSSD (also the same for 2012). However, this section also states that typical errors associated with tidal zoning are 0.20 m at the 95% confidence level if tidal characteristics are not complex and are well-defined. Because of the small overall height variation in the Gulf of Mexico, a 0.2 m at the 95% confidence level is the zoning error used for this survey. All error values entered in CARIS for the TPU

calculation are assumed to be at the 1 sigma level and the 0.2 m zoning error value was divided by 1.96, according to the Field Procedures Manual Section 4.2.3.8. Therefore, a final value of 0.102 m was entered as the zoning tide value for the CARIS TPU calculation.

Although the sum of the tide factors (0.102 m (zoning) + 0.077 m (measurement & processing) + 0.056 m (error in computation of tidal datum)) is 0.235 m (1-sigma) and exceeds the 0.25 m at the 95% confidence level as stated in section 1.3.3 of the Tides and Water Levels Statement of work, the estimates used for the CARIS TPU computation are conservative.

B.1.2.2. SOUND SPEED COMPONENT

The measured sound speed value TPU value is 2 m/s. The sound speed calculated at the transducer is compared to the sound speed calculated by the previous CTD cast. If the difference is 2 m/s or greater, it is necessary to obtain a new sound speed cast.

The surface sound speed value was set at 0.8 m/s with the following reasoning:

The YSI 600R sonde is used to calculate the sound speed at the multibeam transducer. The resultant sound speed is a function of temperature and salinity (ignoring the effects of depth/pressure because the sensor is near the sea surface). The Law of the Propagation of Variances states that the uncertainty associated with an unknown (sound speed) can be calculated if the variance associated with a series of known variables (salinity and temperature) is known.

The specifications for the 600R (http://www.ysi.com/productsdetail.php?600R-9) are shown in Table No. 16 and the known amount by which a certain change in salinity and temperature affect sound speed are shown in Table No. 17.

Table 16. Accuracies associated with salinity and temperature measured by the YSI 600R sonde.

Parameter	Accuracy
Salinity	± 1% of reading or 0.1 ppt (whichever is greater)
Temperature	± 0.15 °C

Table 17. The amount that sound speed changes with changes in salinity and temperature.

Parameter	Change in parameter	Change in Sound Speed
Salinity	1 ppt	1.3 m/s
Temperature	1 °C	4.5 m/s

A value of 30 ppt is used as a general surface salinity value. The uncertainty surrounding this measurement (using values in Table 16) is: 30 * .01 = ± 0.30 ppt; this value is used in the following calculations because it is greater than 0.1 ppt. The amount that 0.3 ppt salinity would change sound speed is:

$$0.3\ ppt * \left(\frac{1.3\frac{m}{s}}{1ppt}\right) = 0.39\frac{m}{s}$$

The accuracy associated with the temperature measurement is ± 0.15 °C (Table No. 16) and the amount that this value would change the sound speed is:

$$0.15°\text{C} * \left(\frac{4.5\frac{m}{s}}{1°\text{C}}\right) = 0.675\frac{m}{s}$$

The total uncertainty of the sound speed measurement is determined by calculating the square root of the quadratic sum of the individual uncertainty sources.

$$\sigma_{ss}^2 = \sigma_{sal}^2 + \sigma_{temp}^2$$
$$\sigma_{ss}^2 = (0.39\frac{m}{s})^2 + (0.675\frac{m}{s})^2$$
$$\sigma_{ss}^2 = (0.607735\frac{m}{s})^2$$
$$\sigma_{ss} = 0.7795\frac{m}{s}$$

This value of approximately $0.8\frac{m}{s}$ is within the range of values provided in the CARIS HVF Uncertainty Values document in Appendix 4 of the Field Procedures Manual, which is 0.2 to 2 m/s.

The CARIS TPU command applies both a horizontal TPU (HzTPU) and depth TPU (DpTPU). According to section 3.1.1 of the HSSD (2012), the Total Horizontal Uncertainty (THU) in the position of the soundings will not exceed 5 m + 5 % of the depth. According to section 5.1.3 of the HSSD (2012) the Total Vertical (or depth) Uncertainty (TVU) is calculated using the following formula:

$$\pm\sqrt{a^2 + (b + d)^2}$$

For IHO Order 1 surveys, in depths less than 100 meters, a = 0.5 m and b = 0.013. Several values are shown in Table 18.

Table 18. Maximum IHO Order 1 TVU values for water depths of 5 – 25 m in increments of 5 m; water depths of 3 and 4 m were added in order to include all depths of the OPR-K354-KR-12 surveys.

a	b	Water Depth (m)	Maximum (TVU)
0.5	0.013	3	0.502
		4	0.503
		5	0.50
		10	0.517
		15	0.537
		20	0.564
		25	0.596

The TPU was evaluated to ensure that the values are within the specifications above. In accordance with section 5.1.2 of the HSSD (2012), all depths reported in the deliverables are accompanied by the estimate of TPU.

B.1.3. MULTIBEAM PROCESSING

Upon commencement data acquisition for a Sheet, a CARIS project was created for the Sheet and multibeam lines converted on a shift by shift basis. All lines converted were assigned a project, vessel, and day. In the CARIS conversion wizard (Step 7 of the Simrad conversion), the EM 3000 Positioning System was set to (1) if the C-Nav was used as the primary positioning system and (3) if the F180 was used as the primary positioning system.

Preliminary tidal data from the Texas Gas Platform gauge in Calliou Bay (Station 8763535) was downloaded from the JOA website and applied to all data in CARIS using the preliminary tidal zoning file supplied by JOA (Refer to Section C.6 for detailed tide correction information). The lines were merged, TPU was computed and a BASE surface created.

One overall BASE surface was created for each sheet. BASE surfaces were named as <Survey registry number>_<units of resolution>. All BASE surfaces were created as uncertainty surfaces with a single resolution of 2 meters; water depths throughout the survey did not exceed 20 m. All BASE surfaces were created based upon the IHO Order 1a standards.

Once the CARIS project and BASE surface for the particular survey area had been created, the field team would continue to add data to the project, update the tide file and update the BASE surface.

Multibeam data was reviewed using the CARIS HIPS swath editor with the BASE surface and pertinent background data open. Background data included the chart (11356_1.KAP), the line files (OPR-K354-KR-12_base_UTM15LineFiles.dwg) and the Project Reference file that is supplied by NOAA (OPR-K354-KR-12_PRF.000). The LineFiles.dwg is useful in correlation with the side scan sonar data. The PRF is a file provided by NOAA that contains reference materials such as survey limits, junctions, bottom sample locations and features specifically targeted, such as AWOIS items. The preferred multibeam review method involves the ability to simultaneously review the side scan sonar data. When this was not possible, potential contacts were noted in multibeam processing log for future review of the side scan sonar data. In swath editor, erroneous and noisy data was rejected from the project.

In addition, the contact S-57 file (Refer to section B.2.4 for additional information) was evaluated in the CARIS map window with BASE surfaces of the mainscheme lines and completed investigations to ensure complete coverage over significant targets. Object Detection Coverage (investigation data) was obtained over all potentially significant features. All contact investigation data was incorporated into a BASE surface and then cleaned in swath editor and subset editor. All investigations in a sheet were incorporated into one BASE surface named <Survey registry>_<Investigations>_<units of resolution>. The BASE surfaces were created as uncertainty surfaces with a single resolution of 0.5 m to ensure that a 1 x 1 x 1 m object would appear in the grid. The investigation data was reviewed with respect to mainscheme multibeam lines, charted data and side scan sonar contact information. If necessary, a designated sounding was assigned to the least depth sounding of an identified contact and the contact submitted in a Danger to Navigation Report.

Once all multibeam data had been cleaned and incorporated into a BASE surface, the surface underwent additional quality control. The standard deviation layer of the BASE surfaces was evaluated and areas of high standard deviation were investigated by all means appropriate, including subset editor, swath editor, comparison to charts, side scan sonar data and side scan sonar contacts imported from SonarWiz. If data was found to misrepresent the seafloor, it was rejected. In addition, the BASE surface was evaluated using the CARIS 3D window with vertical exaggeration that can highlight outliers as well as potential contacts.

Crossline comparisons were generated on a regular basis as a quality control tool; these are explained further in the following sections.

B.1.3.1. CROSSLINE COMPARISONS

Crosslines were run perpendicular to mainscheme survey lines and comprised at least 8% of mainscheme line mileage, in accordance with Section 5.2.4.3 of the HSSD (2012). Crossline comparisons were performed as a quality control tool to identify systematic errors and blunders in the survey data. Comparisons were performed in the field using Hydromap and also in CARIS during field operations and during post-processing.

B.1.3.1.1. Hydromap Statistical Comparisons

Crossline statistical comparisons are performed for every line of multibeam data. Hydromap contains a tool that compares data from a main line with data from crosslines. The comparison calculates the mean difference and noise level as a function of cross-track position. The measurements are used for quantitative quality assurance of system accuracy and ray-bending analysis. In general, crosslines are used to produce reference data. The reference data is considered to be an accurate representation of the bottom. Since the data is taken from an orthogonal direction, the errors should at least be independent.

The crosslines are processed to produce the best possible data. Sound velocity profiles are taken to minimize any possible ray bending, and the multibeam swath angle is filtered to five degrees, which ensures that there are no measurable ray bending or roll errors. The data is binned and thinned using a median filter. The crossline swath data is then merged into a single file, and edited to ensure that there are no remaining outliers.

The line to be evaluated is processed to produce a trace file. Trace files are binned soundings that have not been thinned. The files contain x, y, and z data, as well as information on ping and beam numbers that is used for analysis. Processing parameters are set to use all beams with no filtering, and tidal affects are removed using predicted tides generated from Micronautics world tide software.

The effects of ray-bending can be measured by observing the values of the mean difference curve. Ray-bending produces a mean difference which curves upward or downward at the outer edges of the swath in a symmetric pattern around nadir. The value of the difference at a given across-track distance indicates the amount of vertical error being introduced by incorrect ray-bending corrections.

The accumulated statistics of all main line soundings compared to all crosslines is processed to produce four across-track profiles. The profiles represent the mean difference, standard deviation, root-mean-square difference, and percentile confidence interval. The data is provided in graphical form in a separate pdf document for each main line. These pdf's are found in Separates II of the reports.

B.1.3.1.2. CARIS Comparisons

Crossline comparisons were performed in CARIS HIPS and SIPS 7.1.2 using the surface difference tool. Separate 2-m BASE surfaces were generated for the mainscheme lines and crosslines and a difference surface between the mainscheme and crossline BASE surfaces computed. The difference surface was used as a data cleaning tool as well as a quality control tool. It was noted if the depth difference values differed by more than the maximum allowable Total Propagated Uncertainty (TVU), as outline in Section 5.2.4.3 of the HSSD (2012); refer to section B.1.1.3.2 for sample TVU values for certain depths. Areas were further evaluated where the depth values for the two datasets differed by more than the maximum allowable TVU and the source of error identified and explained.

Crossline comparisons were also generated using the CARIS QC report utility. Each crossline was compared to the depth layer of the 2-m BASE surface of the mainscheme lines (the reference surface). The crossline sounding data was grouped by beam number (1 – 508 in increments of 1). Survey statistic outputs included the total soundings in the range, the maximum distance of soundings above the reference surface, the maximum distance of soundings below the reference surface, the mean of the differences between the crossline soundings and the surface, the standard deviation of the mean differences, and the percentage of soundings that fall within the depth standards for a selected IHO Order. Although statistics were generated for all IHO Orders (Special Order, Order 1a, Order 1b and Order2), the percentage of crossline soundings that are within Order 1a specification is of primary interest for this project. The quality control statistics were evaluated for extreme values and are shown in Separates II: Digital Data.

The crossline and mainline BASE surfaces have been retained and submitted in the Fieldsheet directory (Refer to section B.1.2.1).

B.1.3.2. Reporting Products and Finalization

Junction analysis was conducted using the CARIS differencing tool. Difference surfaces were generated with the survey of interest as Surface 1 and the adjoining survey as Surface 2.

Chart comparisons were performed in CARIS HIPS 7.1.2 using cleaned BASE surfaces of mainscheme and investigation lines, colored depth ranges, and sounding layers. The data was compared to the largest scale chart in this area, summarized in Table No. 19 and 20. Note that the raster chart and ENC described below are the latest editions of the largest scale charts covering the project area. These differ from the charts described in the Project Instructions by one edition.

Table 19. Raster chart 11356

Chart Number	Scale	Edition Number	Edition Date	LNM Date	NM Date
11356	80000	39	06/2012	1/8/2013	1/19/2013

Table 20. ENC US4LA25M

ENC Name	Scale	Edition	Update Application Date	Issue Date	Preliminary
US4LA25M	80000	16	8/24/2012	12/12/2012	No

The sounding layer to which charted soundings were compared was generated from the 2-m BASE surface created for each Sheet. The shoal biased radius option was always selected and the radius was selected as distance on the ground (in m). A single-defined radius was chosen that generated a sufficient amount of soundings; the distance potentially varied from sheet to sheet and is detailed in each Descriptive Report.

After all data had been cleaned, and all least depths on significant contacts had been designated, the BASE surfaces were finalized for submission. The final BASE surfaces were generated from the higher of the standard deviation or uncertainty values in order to preserve a conservative uncertainty estimate, as outlined in section 4.2.6 of the 2012 Field Procedures Manual. The designated soundings were applied in order to maintain the shallowest soundings within the final BASE surface (Figure 2).

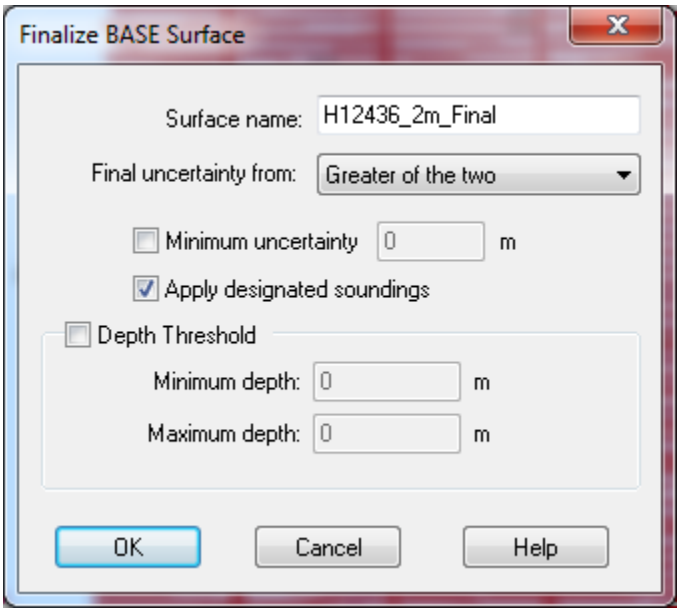


Figure 2. BASE surface finalization parameters.

B.2. SIDE SCAN SONAR

B.2.1. IMAGE PROCESSING

Side scan sonar data was processed using SonarWiz5 V5.04.0031. Side scan sonar data was layback corrected using C & C Technologies' proprietary Hydromap software. The layback corrected side scan sonar XTF file was then imported into SonarWiz 5; gains were applied to the data that potentially varied from subarea to subarea and even within subareas. The water column was auto tracked in the field and the data slant range corrected after importation into SonarWiz 5. The bottom track was also evaluated during post-processing. The side scan sonar data was evaluated and contacts identified; contacts were always selected from slant-range corrected data.

B.2.2. REVIEW PROCESS AND PROOF OF COVERAGE

The side scan operator reviewed all data during data acquisition and noted in the survey logs any significant features or surface/water column effects. All side scan data was also reviewed at least twice post-collection. Any lines or portions of lines that did not meet quality standards due to noise, thermals, etc. were re-run. During review, a coverage map was produced. Any gaps in coverage were noted, logged in the re-run log, and brought to the attention of the party chief and the operators on shift.

A mosaic for each 100% coverage was created and submitted for the requirement of the interim and final deliverables. The coverage mosaics were designated by an even/odd numbering system. These mosaics served as an additional quality control tool and were not only used for coverage but could be used to correlate contacts seen on adjacent lines.

B.2.3. CONTACT SELECTION

Sonar contacts were identified and recorded as each line was reviewed. All contacts with shadows were recorded. All existing infrastructure, such as pipelines, wells, platforms, and buoys was also documented.

In addition to measuring the dimensions of each contact in SonarWiz, each contact was assigned two attributes to aid in the processing workflow. The first attribute (UserClass1) provides the coverage from which the contact was identified. The coverages were designated by an even/odd numbering system and therefore each contact was described as either 100_ODD (first 100% coverage being odd line numbers) or 200_EVEN (second 100% coverage being even line numbers). The second attribute (UserClass2) was related to the nature of the contact and one of nine descriptors was chosen for each contact. These were: insignificant contact (INSCON), significant contact (SIGCON), offshore platform (OFSPLF), submerged pipeline (PIPSOL), submerged cable (CBLSUB), fish contact (FSHGRD), obstruction (OBSTRN), seabed area (SBAREA) and unknown contacts (UNKCON).

All contacts that displayed a height of 1 meter or greater, calculated from the shadow length in SonarWiz, were considered significant within water depths of 20 meters or less, in

accordance with Section 6.3.2 of the HSSD (2012); surveyed water depths did not exceed 20 m. These contacts were always given the attribute 'SIGCON'. Other contacts may have been deemed significant based on their characteristics (dimensions, strength of return, location etc.). Significant contacts had the potential to become obstructions (OBSTRN). All contacts not labeled as significant, but had some height off the bottom, were labeled insignificant (INSCON).

Large schools of fish were identified by shape, detached shadows and observations recorded in the acquisition logs. These contacts were noted as FSHGRD; however, fish were not generally picked as contacts. The second 100% SSS was evaluated to confirm the fish contact and to make sure no other contacts were obscured. The label 'seabed area' (SBAREA) was used to include seabed change and features such as canholes and drag scars. The 'unknown' (UNKCON) label was used in moderation and only if no shadow could be measured. The majority of the UNKCON are picked generally because of possible correlation to either a significant or insignificant feature found on an adjacent line based factors such as proximity, shape and size.

B.2.4. CONTACT CORRELATION

Once all contacts were recorded and assigned the aforementioned attributes and dimensions, the contacts were converted into an S-57 file using CARIS Notebook 3.1. All contacts were exported from SonarWiz as a .csv file in the form of Registry__Subarea_Contacts_date.csv. Separate csv files from different subareas were combined into one file in the form Registry_Contacts_date.csv. Contacts were brought into Notebook 3.1 using the Object Import Utility as points under the LNDMRK class with several attributes assigned. The contacts were exported as an S-57 file and brought into CARIS. In the CARIS selection window several columns were modified to display the attribute information of the contacts. Table 21 describes the attribute mapping for the S-57 contact file and associated CARIS column name.

Table 21. S-57 Contact Attribute Mapping

CSV Field	Notebook Attribute	CARIS column name
TargetName	OBJNAM	Object Name
ClickX	EASTING	n/a
ClickY	NORTHING	n/a
PingNumber	CARIS KEY	n/a
MapImageName	PICREP	Pictorial Representation
UserClass1	NINFOM	Information in national language
UserClass2	NTXTDS	Textual description in national language
Description	INFORM	Information

The S-57 file of contacts was evaluated in the CARIS map window with BASE surfaces of the mainscheme lines and completed investigations to ensure complete coverage over significant targets. All significant contacts not fully developed with multibeam data were investigated further. If necessary, Danger to Navigation Reports were submitted for uncharted, significant contacts and structures.

The .csv file exported from SonarWiz was also saved as a Microsoft Excel spreadsheet and served as the basis of the Side Scan Sonar Contact List contained in Separate III. The

columns were shifted in the order shown in Table 22. Many of these were retained for processing purposes in addition to the columns required as stated in Section 8.3.2 of the HSSD (2012); only the columns required by Section 8.3.2 of the HSSD were submitted as the final Side Scan Sonar Contact List (Table 23).

As shown in Table 22, Column S (Contact Correlation) was added to aid in the contact correlation process and columns T (Comparison with SWMB) and U (Contact Depicted in S-57 Feature File) added in accordance with Section 8.3.2 of the HSSD (2012). Once the multibeam BASE surfaces had been reviewed for anomalous data points in conjunction with charts and the side scan sonar contacts, the contacts were systematically reviewed in the CARIS HIPS map window with respect to BASE surfaces and charted features. The attributes of each contact were examined in the CARIS selection window and the final columns of the side scan sonar contact list populated as each contact was reviewed.

The ‘Contact Correlation’ column was filled in as (1) No duplicate contact, (2) Primary, or (3) Secondary to the <Target Name of Primary>. The Primary contact was chosen from the SSS as the image that best represented the contact. When a Primary contact was picked for a platform, not only was the image quality taken into account, but also the line from which the contact was selected. This was done to obtain the best possible position for the platform and to avoid picking a contact on lines that exhibited excessive turning.

The ‘Comparison with SWMB’ column is the result of comparing the side scan sonar data to the multibeam data. These were generally recorded as follows: (1) no multibeam coverage, (2) contact did not appear in MB or (3) least depth provided: least depth = x.x.

The column ‘Contact Depicted in S-57 Feature File’, was populated by 5 statements, 3 of which are provided in Section 8.3.2 of the HSSD (2012). These are: (1) yes, OBSTRN, (2) yes, sounding only, or (3) no. Additional options were added for platforms as (4) yes, OFSPLF and pipelines as (5) yes; PIPSOL. If a contact is represented by a primary and secondary contact and also represented in the S-57 Feature File, the column will say ‘yes’ for all primary and secondary contacts.

The processing spreadsheet is included in Separates I: Acquisition and Processing Logs: Processing Logs. An S-57 file of all the contacts was also generated from the spreadsheet in order to easily review and correlate contact with supporting data sets. The contacts were imported into CARIS Notebook 3.1 as points under the LNDMRK class and exported as an S-57 file; this file is included in the final deliverables in Separates III. The contact attribute mapping between Notebook and CARIS is shown in Table 22. The columns represented in the S-57 file were chosen to match the majority of the submission columns with the addition of the image links. The image links are set up as: C:\H12XXX_Contact_Images\<image name>.jpg. In order to be able to view the contacts, copy the H12XXX_Contact_Images folder from the Separates III onto the C drive of the working computer.

Table 22. Side Scan Sonar Contact List template for processing and associated attribute mapping.

Spreadsheet Column	Column Name	Notebook Attribute	CARIS Column Name
Column A	TargetName	OBJNAM	Object Name
Column B	LineName	----------	----------
Column C	EventNumber	CARIS_KEY	N/A
Column D	SonarDateTime	----------	----------
Column E	Total Layback	INFORM	Information
Column F	ClickLat	----------	----------
Column G	ClickLon	----------	----------
Column H	ClickX	EASTING	n/a
Column I	ClickY	NORTHING	n/a
Column J	FishAltitude	----------	----------
Column K	RangeToTarget	----------	----------
Column L	MeasuredHeight	NOBJNM	Object name in national language
Column M	MeasuredLength	----------	----------
Column N	MeasuredShadow	----------	----------
Column O	MeasuredWidth	----------	----------
Column P	UserClass1	----------	----------
Column Q	UserClass2	----------	----------
Column R	Description	----------	----------
Column S	Contact Correlation	----------	----------
Column T	Comparison with SWMB	NINFOM	Information in national language
Column U	Contact Depicted in S-57 Feature File	NTXTDS	Textual description in national language
Column V	MapImageName	PICREP	Pictorial Representation

Two (2) submitted side scan sonar contact lists are contained in Separates III. One contains all contacts and one contains all significant contacts (if applicable). The submitted side scan contact lists in Separates III match the column format outlined in section 8.3.2 of the HSSD (2012) (Table 23).

Table 23. Side Scan Sonar Contact List Template for Submission.

Spreadsheet/CSV Column	Column Name
Column 1	Search Track Number
Column 2	Contact Number
Column 3	Towfish Layback
Column 4	Contact Range
Column 5	Contact Position
Column 6	Contact Height
Column 7	Remarks
Column 8	Comparison with SWMB
Column 9	Contact Depicted in S-57 Feature File

B.3. DATA DIRECTORY STRUCTURE

During data processing separate directories were created for CARIS projects, CARIS Notebook files, SonarWiz projects and Report Deliverables. Upon submission, these were combined into a directory structure that was generated to closely match the structure specified in Appendix 12 of the 2012 HSSD (Figure 3).

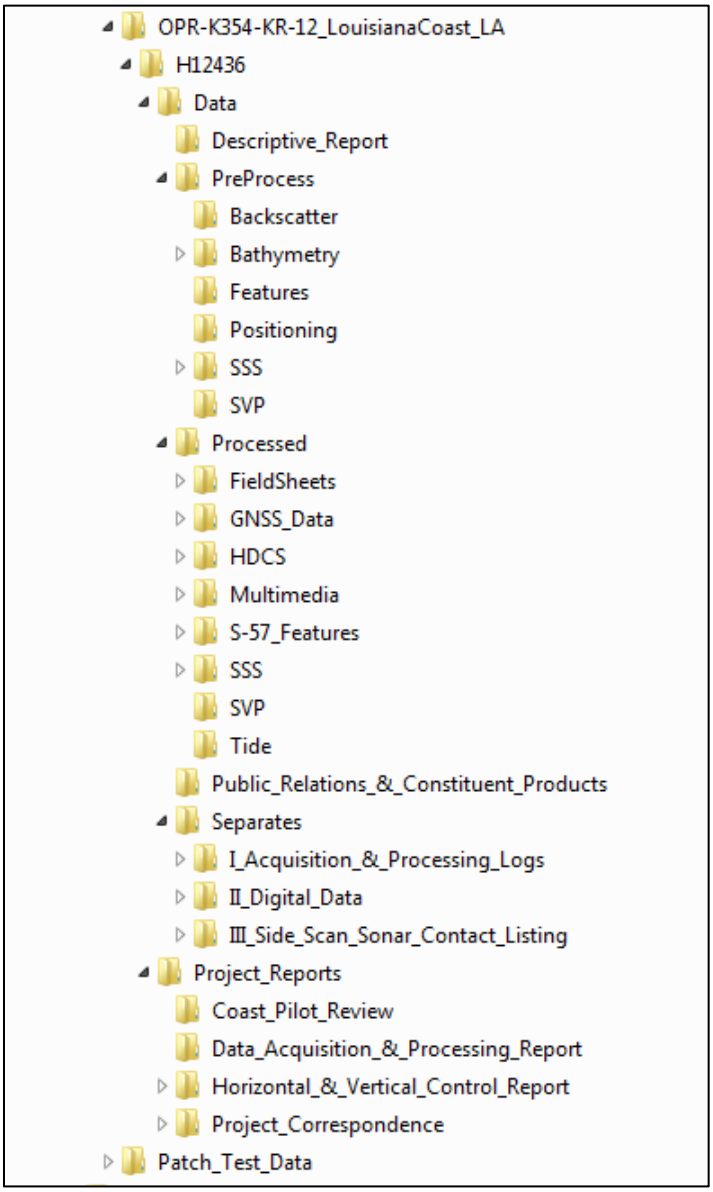


Figure 3. Overview of data directory structure.

A FieldSheets folder was added to the directory structure. No folders were removed from the directory structure as listed in Appendix 12; if no data exists for that particular folder, a text file explanation is included.

C. CORRECTIONS TO ECHOSOUNDINGS

C.1. INSTRUMENT CORRECTIONS

In order to ensure that the multibeam system was functioning properly, comparison checks were conducted regularly. Lead line comparisons were generally conducted once daily for the majority of survey operations as an independent check on the multibeam bottom-detect. In addition, the single beam Odom Echotrack MKIII was monitored in real-time as an independent check of the nadir beam of the multibeam sonar system.

C.2. VESSEL OFFSET MEASUREMENTS AND CONFIGURATION

C.2.1. VESSEL CONFIGURATION PARAMETERS AND OFFSETS

During construction of the R/V *Sea Scout* (Figure 4) a full survey was conducted in dry dock using a Leica TPS 1200+ total station to measure offsets from the Central Reference Point (CRP) to all survey equipment on the vessel. A vessel diagram with all measured offsets from the central reference point is shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Figure 4. R/V *Sea Scout*.

C.2.2. LAYBACK

Layback was applied to all sidescan XTF files using the Hydromap layback correction tool. Figure 5 explains the variables and the calculations for this process.

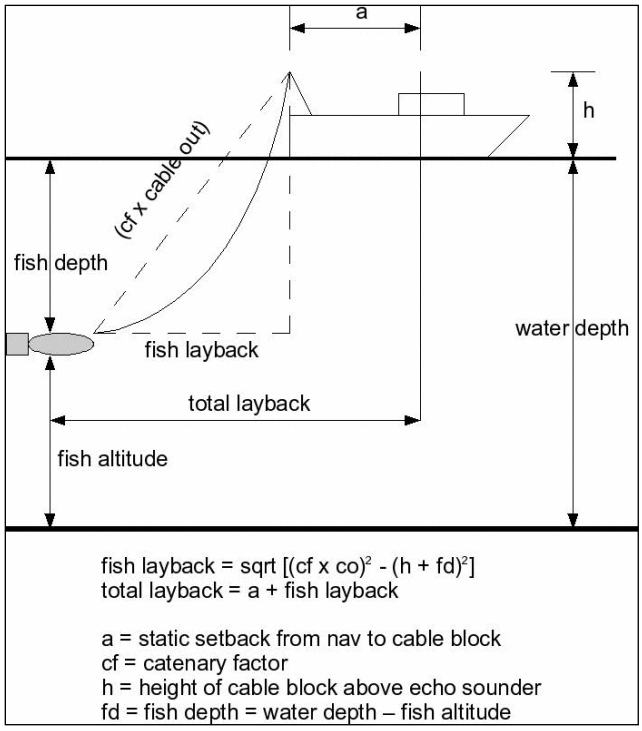


Figure 5. Hydromap layback correction diagram.

The catenary factor (cf) was set at 1.0 for all lines. This was done because the use of a depressor wing (Figure 6), combined with very little cable out, made it very unlikely that there was enough catenary to factor into the equation. The static setback from the navigation source to the A-frame cable block (a) is the along track distance from the primary positioning system to the fully extended sidescan sheave on the A-frame; the towfish/A-frame configuration (not in operation) is shown in Figure 7. The static setback was a value of 27.6 m for data using the F180 as the navigation source and 22.4 m for data that used C-Nav as the primary navigation source; this value is the distance from the primary C-Nav antenna. The primary side scan sonar navigation source used for each survey is detailed in the respective Descriptive Reports. The height of cable block above echo sounder (h) was also a constant value. A measurement of 6.9 meters from the waterline to the sheave was used for this value. Refer to Appendix I: Vessel Reports – Vessel Layback Report for additional information.

Figure 6. Towfish with depressor wing on deck.

Figure 7. Towfish and A-frame configuration.

C.3. STATIC AND DYNAMIC DRAFT

Static draft measurements were read at least once daily during survey operations. The R/V *Sea Scout* is equipped with two draft tubes on the port and starboard sides, near the MB rams. Each draft tube is marked 1.2 meters up from the hull. The distance from CRP to the 1.2 m mark is 5.14 m and 5.27 m on the port and starboard sides, respectively. Therefore, an addition of 1.2 m to each of these values (6.34 m and 6.47 m for port and starboard, respectively) provides the distance from CRP to the base of the draft tubes (the hull). The draft values observed from the draft tubes are subtracted from the 6.34 m and 6.47 m values to provide a waterline to CRP measurement for the port and starboard sides. These two values were averaged and input into the SIS software system as the waterline to CRP value (refer to Figure 9 in Section C.5).

In order to correct for the dynamic draft of the vessel, a squat and settlement test was performed south of Cameron, LA on October 5 – 6, 2012.

A C-Nav RTK base station was set up on land over an arbitrary point, and one hour of static GPS observations were made to establish an accurate base station position. A location with hard ground, good satellite visibility, and a clear line of site to the test area was chosen for this setup. The RTK rover was pole mounted on the vessel directly over top of the CRP.

Seven total lines were run for this test, with each line including three minutes of RTK data collection at 0000, 0600, 800, 1000, 1300, and 1500 RPMs. To run these seven lines and stay within range of the base station corrections, a single line was run back and forth along the shoreline. RTK ellipsoid heights were extracted from the GPS data, and then tide corrected using tide station 8760894 (Calcasieu Pass, LA). Only runs 3 – 7 were used in the final dynamic draft calculation. A graph of the results can be found in Figure 8. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

The vertical corrections varied with speed, as shown in Table 24. All values were applied to the data in CARIS during post-processing. Note that the values are negative, indicating that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, these values are positive in the vessel file.

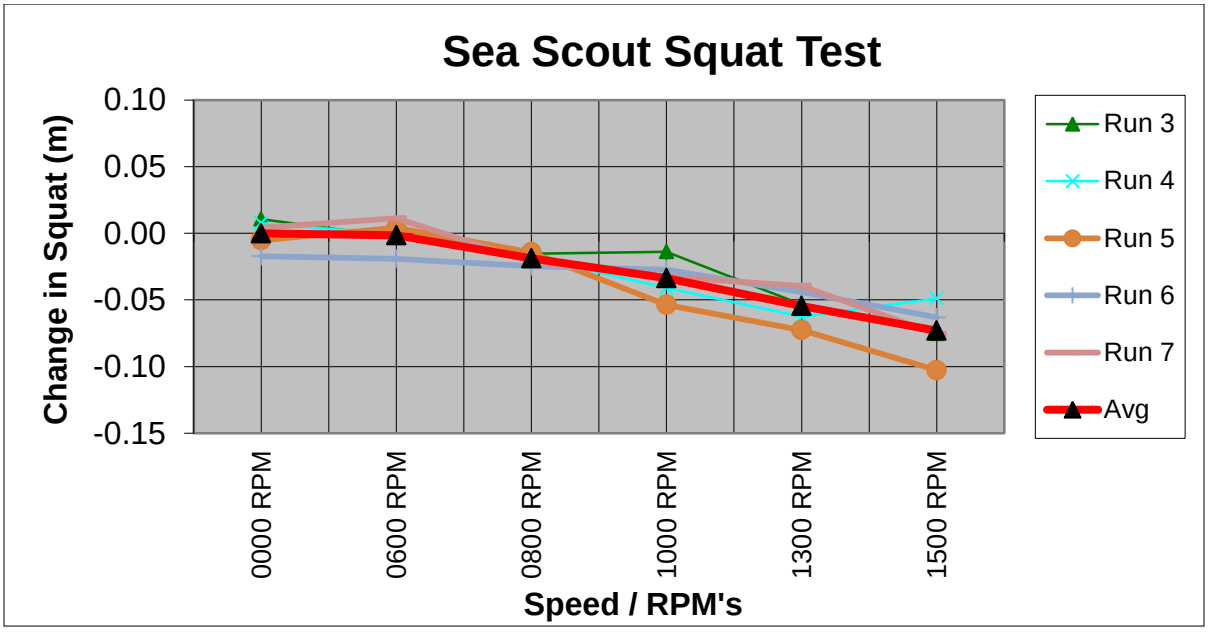


Figure 8. Sea Scout squat test results.

Table 24. Squat and Settlement test results for the *Sea Scout* South of Cameron, LA in the Gulf of Mexico (October 5 and 6, 2012)

Vertical Correction (m)	Speed (m/s)
0.00	0.17
0.00	2.23
-0.02	2.94
-0.03	3.66
-0.05	4.67
-0.07	5.19

C.4. POSITIONING AND ATTITUDE SYSTEMS

The R/V *Sea Scout* is equipped with three (3) GPS systems: two (2) C-Nav 3050 receivers and one (1) CodaOctopus F180 attitude and positioning system. All three GPS systems feed their position strings via serial interface to a serial splitter box. The position strings are then sent to multiple systems for logging and use. The F180 GPS is used for the serial and 1PPS strings that are used to sync all systems on the network.

The C-Nav 3050 receivers use the C-Nav Subscription Services, which can achieve decimeter accuracy. These systems are controlled and monitored with a C-Navigator system.

One (1) of the C-Nav receivers provides a DGPS correction via serial connection to the F180 system. The F180 is controlled and monitored using PC software via a network connection to the system. The F180 attitude and positioning system is integrated with the multibeam echo sounder to provide real-time heave, pitch, and roll corrections; heading is also obtained from the F180. Manufacturer accuracies are shown in Table 25.

Table 25. Manufacturer accuracies for the CodaOctopus F180 attitude and positioning system with an antenna baseline distance of 2 m.

Heading	Roll	Pitch	Heave
0.05º	0.025º	0.025º	The greater of 5% of heave amplitude or 5 cm

The F180 was used as the primary positioning system for the majority of survey operations mainly because the positioning system is located closer to center-line, resulting in improved motion corrected data. Variations in positioning systems will be documented in the B.1.2: Equipment section of respective Descriptive Reports.

C.5. EQUIPMENT OFFSETS

Equipment offsets from the CRP were entered directly into the Simrad SIS software (Figure 9). The Primary C-Nav 3050 GPS offsets were entered into POS, COM1 and the Secondary C-Nav offsets were entered into POS, COM3. The multibeam transducer offsets were entered in Sonar Head 1 and Sonar Head 2 for the port (serial number 211) and starboard (serial number 369) transducers, respectively. The F180 offsets were entered in POS, COM4 and Attitude 1, COM2.

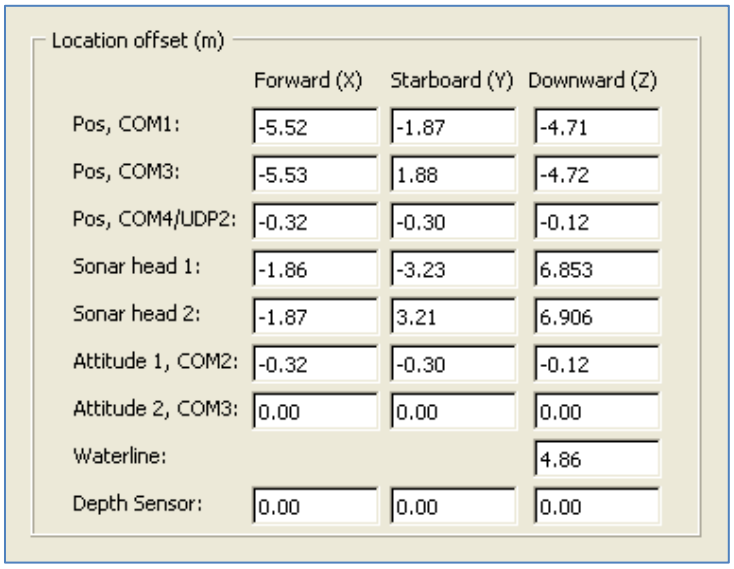


Figure 9. Equipment offsets entered into the SIS software.

The multibeam rams were lowered several times during the survey to find the optimal draft of which the effects of cavitation and possible vibration of the transducers were minimized. The Downward (Z) values for Sonar Head 1 and Sonar Head 2 that were input into the SIS software are shown in Table 26.

Table 26. Location of the transducers below CRP.

Date	Sonar Head 1(211) Downward (Z)	Sonar Head 2 (369) Downward (Z)
May 05, 2012 (Patch Test 1)	6.585 m	6.635 m
May 15, 2012	6.853 m	6.906 m
June 06, 2012	7.085 m	7.135 m

C.6. MULTIBEAM CALIBRATION

Prior to commencement of survey operations, a standard patch test was performed on May 05, 2012 in the vicinity of South Marsh Island to determine corrections for pitch, roll, and heading. A second patch test was conducted on June 9, 2012 as a quality check on the first because several settings such as the lowering of the multibeam heads had occurred since the first patch test.

C & C Technologies' proprietary software Hydromap was used in the field to determine results from the patch tests (Tables 27 and 28).

Table 27. Patch Test Results (R/V *Sea Scout* – May 5, 2012)

	Roll	Pitch	Heading
Port Head	-0.17	0.00	0.00
Starboard Head	-0.19	0.00	351.39

Table 28. Patch Test Results (R/V *Sea Scout* – June 9, 2012)

	Roll	Pitch	Heading
Port Head	-0.1724	0.00	359.811
Starboard Head	-0.15	0.00	350.23

Evaluation of the patch tests was also conducted using the CARIS calibration tool during post-processing. Refer to Appendix II: Echosounder Reports: Patch Test Report.

The angular offsets from the patch tests were entered directly into the Simrad SIS software under Sensor Setup → Angular Offsets for correction of data in real-time (Figure 10).

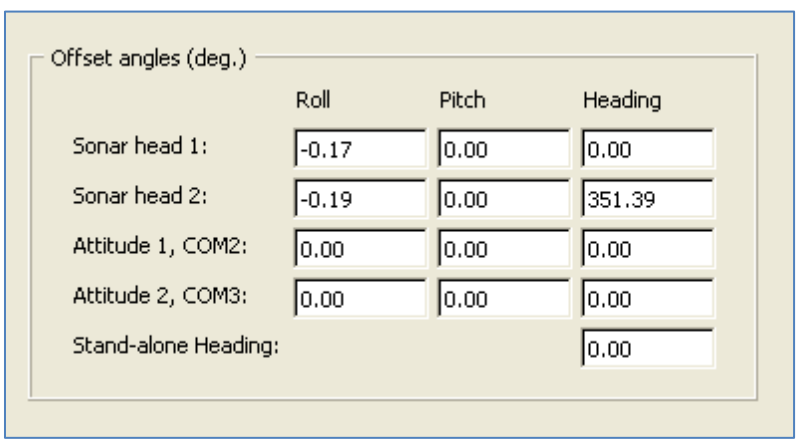


Figure 10. Patch test results from May 5, 2012 and the location where they were entered in SIS.

C.7. SOUND SPEED CORRECTIONS

Sea Bird Electronics SBE19 CTDs were used to calculate the speed of sound within the water column. Casts were performed at least twice daily and more often as needed. In general, two CTDs were simultaneously lowered within a cage structure during each cast (Figure 11).

Figure 11. CTD set-up.

Although only one profile is used at a given time, the simultaneous sound speed profiles were reviewed together as a quality control check. The chosen sound speed cast was extended by at least 50 feet beyond the deepest reading of the CTD. The intent of the extended data is strictly to avoid error messages associated with bad multibeam pings that were deeper than the sound speed cast. Extending the profile was accomplished by averaging the last ten to twenty data points in the profile. The onboard processor of the cast determined how many points to average in order to create an extension that accurately reflected the downward trend of the data. If water depths began to exceed the depth of the cast, another sound speed cast was taken. The chosen sound speed profile was entered into the SIS control software and the multibeam data was corrected for the water column sound speed in real-time. The mean water column sound speed generated from the chosen sound speed profile was applied to the singlebeam echo sounder data.

Dual Endeco YSI 600R sondes were used to calculate the sound speed at the transducer. The difference between the sound speed measured by the SBE19 CTD and the sound speed at the transducer was monitored in the SIS software. A difference of more than 2 m/s required a new cast to be taken.

A sound speed log for each survey area is included in Separates I: Acquisition and Processing Logs. In addition, the data was converted to a .csv file with an additional column

(dates and times for which the profiles were applied). The file was imported into Notebook 3.1 using the Object Import Utility as points under the LNDMRK class. The columns of the .csv file were assigned S-57 attributes (Table 29). The file was exported as an S-57 file to be easily brought into CARIS. This file is named <Registry>_CTD_Information; the .hob, .000 and .csv files are located in Separates II: Digital Data: Sound Speed Data: Sound Speed List.

Table 29. S-57 attribute mapping for the sound speed log.

CSV Field	Notebook Attribute	CARIS column name
Date (mm/dd/yyyy)	SORDAT	Source Date
Time	INFORM	Information
CTD_Name	OBJNAM	Object Name
Water Depth (m)	NINFORM	Information in national language
Cast Depth (m)	NTXTDS	Textual description in national language
X	EASTING	Easting
Y	NORTHING	Northing
CTD Serial Number	CARIS_KEY	n/a
Harmonic Mean (m/s)	n/a	n/a
YSI (m/s)	n/a	n/a
Dates and times for which the profiles were applied	NOBJNM	Object name in national language

C.8. TIDE AND WATER LEVEL CORRECTIONS

The operating National Water Level Observation Network (NWLON) station at Grand Isle, LA served as datum control for the short-term Texas Oil Platform, LA gauge. The operating water level station at Port Fourchon, LA also provides water level reducers for this survey. The Texas Oil Platform gauge was established and maintained throughout the survey by C & C Technologies' personnel.

Preliminary zoning was supplied by CO-OPS and revised by JOA Surveys, LCC. The preliminary zoning was provided to C & C Technologies by JOA on 5/1/2012. The geometry of the zoning was not changed but the zoning factors were modified to make them relative to Texas Oil Platform instead of Port Fourchon.

During survey operations, preliminary 6-minute tidal data from the Texas Oil Platform gauge in Caillou Bay (Station 8763535) was downloaded from the JOA website and incorporated into a .tid (ASCII) file consisting of date, time and tide values. These tide values were applied to all multibeam data in CARIS using the preliminary tidal zoning definition file supplied by JOA. These files were used for preliminary review of the data only.

Preliminary zoning is accepted as the final zoning for project OPR-K354-KR-12. JOA Surveys, LCC has maintained the preliminary CO-OPS zoning geometry, only changing the zoning factors. The preliminary tide zones and correctors for the Texas Oil Platform water level station and the Port Fourchon water level station, from which the Texas Oil Platform correctors are based, are shown in Tables 30 and 31 respectively.

Table 30. Port Fourchon Tide Zones and Correctors.

Tide Zone	Reference Station	Time Corrector	Range Ratio
WGM263	8762075	-42	1.21
WGM264	8762075	-36	1.21
WGM265	8762075	-30	1.21
WGM266	8762075	-24	1.24
WGM278	8762075	-42	1.33

Table 31. Texas Oil Platform Tide Zones and Correctors.

Tide Zone	Reference Station	Time Corrector	Range Ratio
WGM263	8763535	-48	0.963
WGM264	8763535	-42	0.963
WGM265	8763535	-36	0.963
WGM266	8763535	-30	0.963
WGM278	8763535	-48	1.059

JOA provided a final smoothed tide file referenced to MLLW which was applied to the data with the final zoning definition file for final evaluation and submission of the data.

D. LETTER OF APPROVAL

Data Acquisition and Processing Report

OPR-K354-KR-12

This report is respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report has been closely reviewed and is considered complete and adequate as per the Statement of Work.

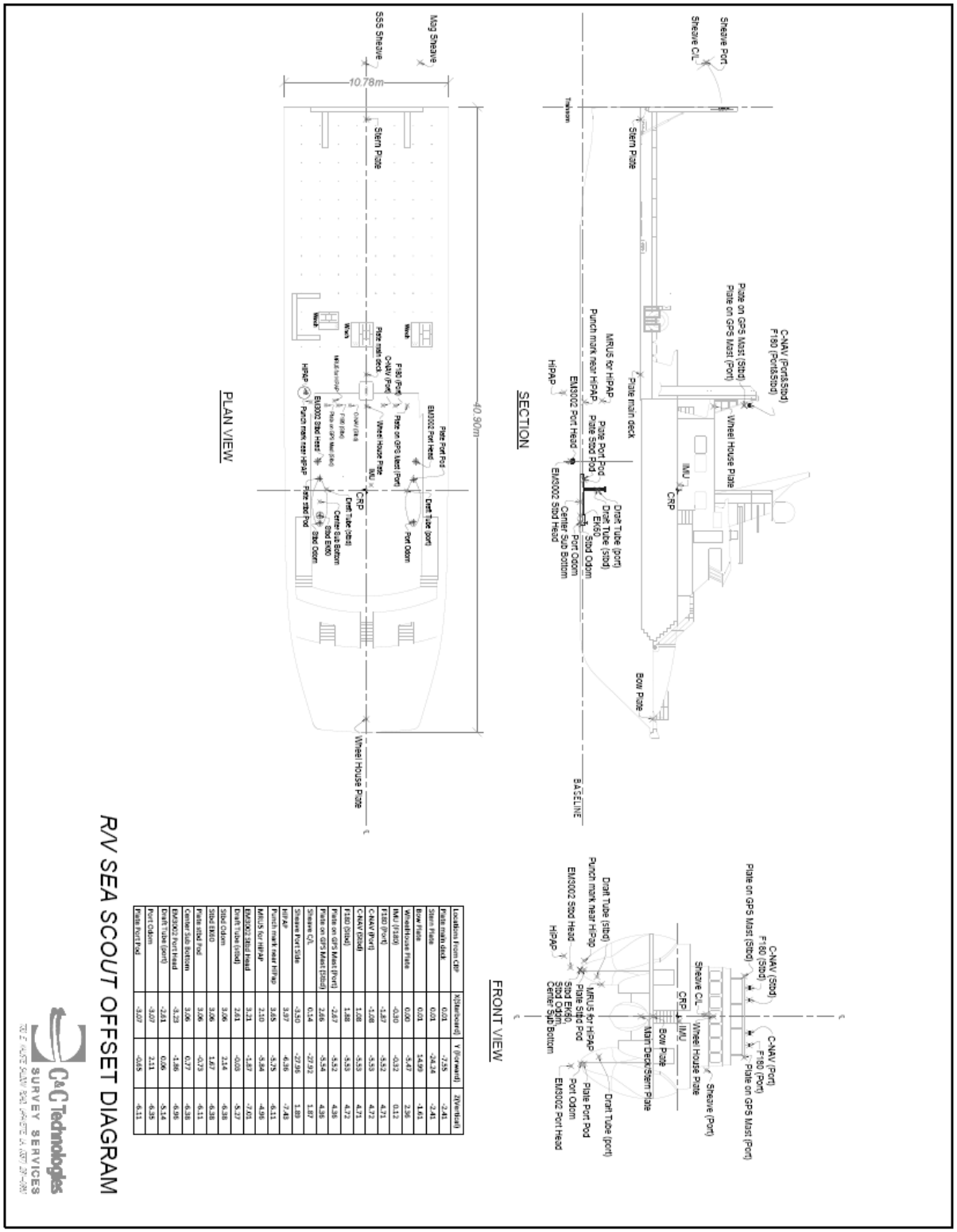
Tara Levy
Chief of Party
C&C Technologies
February 2013

APPENDIX I

Vessel Reports

Vessel Offset Reports

1. Vessel Diagram



Location From CRP	X(Transverse)	Y (Forward)	Z(Vertical)
Plate main deck	0.01	-17.55	-2.41
Stern Plate	0.01	-24.24	-2.41
Bow Plate	0.01	14.99	-1.61
Wheelhouse Plate	0.00	-5.47	2.36
IMU (F180)	-0.10	-0.32	0.12
F180 (Port)	-1.87	-5.53	4.71
C-NAV (Port)	-3.08	-5.53	4.72
C-NAV (Stbd)	1.08	-5.53	4.71
F180 (Stbd)	1.88	-5.53	4.72
Plate on GPS Mast (Port)	-2.87	-5.53	4.38
Plate on GPS Mast (Stbd)	2.86	-5.54	4.38
Sheave C/L	0.14	-27.32	1.87
Sheave Port Side	-3.50	-27.36	1.89
HiPAP	3.07	-6.36	-7.40
Punch mark near HiPap	3.65	-5.75	-6.11
MRUS for HiPAP	2.10	-5.84	-4.96
EM3002 Stbd Head	3.31	-5.87	-7.01
Draft Tube (stbd)	2.61	-0.09	-5.37
Stbd Odom	3.06	2.14	-6.38
Stbd EK60	3.06	1.67	-6.38
Plate stbd Pod	3.06	-0.73	-6.11
Center Sub Bottom	3.06	0.77	-6.38
EM3002 Port Head	-3.23	-1.26	-6.38
Draft Tube (port)	-2.61	0.06	-5.14
Port Odom	-3.07	2.11	-6.35
Plate Port Pod	-3.07	-0.65	-6.11

2. MRU to Transducer Calculations for HVF

The MRU to transducer offsets are entered into the CARIS vessel file (.hvf) in the TPU offsets section. The MRU to transducer offset calculations are shown in Table 4 and reference the MRU and transducer offsets from CRP, shown in Tables 1 – 4.

Table 1. MRU offsets from CRP

	X (pos stbd)	Y (pos bow)	Z (pos down)
IMU (F180)	-0.30 m	-0.32 m	-0.12 m

Table 2. Port Transducer (serial number 211) offsets from CRP

Port Transducer (SonarHead 1, serial number 211)				
		X (pos stbd)	Y (pos bow)	Z (pos down)
5-May-12	Patch Test 1	-3.23 m	-1.86 m	6.585 m
15-May-12	Lowered multibeam heads prior to commencing data collection	-3.23 m	-1.86 m	6.853 m
31-May-12	Multibeam heads lowered at dock between 5/30 and 06/02	-3.23 m	-1.86 m	7.085 m

Table 3. Starboard Transducer (serial number 369) offsets from CRP.

Starboard Transducer (SonarHead 2, serial number 369)				
		X (pos stbd)	Y (pos bow)	Z (pos down)
5-May-12	Patch Test 1	3.21 m	-1.87 m	6.635 m
15-May-12	Lowered multibeam heads prior to commencing data collection	3.21 m	-1.87 m	6.906 m
31-May-12	Multibeam heads lowered at dock between 5/30 and 06/02	3.21 m	-1.87 m	7.135 m

Table 4. MRU to transducer calculations.

MRU to Transducer 1 X direction	-3.23 m – (-0.30 m) = -2.93 m	Negative b/c go port from MRU to get to transducer
MRU to Transducer 1 Y direction	-1.86 m – (-0.32 m) = -1.54 m	Negative b/c go stern from MRU to get to transducer
MRU to Transducer 1 Z direction	6.585 m – (-0.12 m) = 6.705 m	Positive b/c transducer is positive down from MRU
	6.853 m – (-0.12 m) = 6.973 m	
	7.085 m – (-0.12 m) = 7.205 m	
MRU to Transducer 2 X direction	3.21 m – (-0.30 m) = 3.51 m	Positive b/c go starboard from MRU to get to transducer
MRU to Transducer 2 Y direction	-1.87 m – (-0.32 m) = -1.55 m	Negative b/c go stern from MRU to get to transducer
MRU to Transducer 2 Z direction	6.635 m – (-0.12 m) = 6.755 m	Positive b/c transducer is positive down from MRU
	6.906 m – (-0.12 m) = 7.026 m	
	7.135 m – (-0.12 m) = 7.255 m	

3. NAV to Transducer Calculations for HVF

The navigation to transducer offsets are entered into the CARIS vessel file (.hvf) in the TPU offsets section. The navigation to transducer offset calculations are shown in Tables 8 and 9 for C-Nav and F180 as the primary position sources, respectively. These reference the position source and transducer offsets from CRP, shown in Tables 5 – 7.

Table 5. Primary positioning system offsets from CRP

	X (pos stbd)	Y (pos bow)	Z (pos down)
GPS Antenna Port	-1.87 m	-5.52 m	-4.71 m
IMU (F180)	-0.30 m	-0.32 m	-0.12 m

Table 6. Port transducer (Sonar Head 1serial number 211) offsets from CRP

Date	Event	X (pos stbd)	Y (pos bow)	Z (pos down)
5-May-12	Initial Patch Test	-3.23 m	-1.86 m	6.585 m
15-May-12	Lowered the multibeam heads	-3.23 m	-1.86 m	6.853 m
25-May-12	Change from C -Nav to F180 primary positioning system (no offsets changed)	-3.23 m	-1.86 m	6.853 m
31-May-12	Lowered multibeam heads	-3.23 m	-1.86 m	7.085 m

Table 7. Starboard transducer (Sonar Head 2 serial number 369) offsets from CRP

Date	Event	X (pos stbd)	Y (pos bow)	Z (pos down)
5-May-12	Initial Patch Test	3.21 m	-1.87 m	6.635 m
15-May-12	Lowered the multibeam heads	3.21 m	-1.87 m	6.906 m
25-May-12	Change from C-Nav to F180 primary positioning system (no offsets changed)	3.21 m	-1.87 m	6.906 m
31-May-12	Lowered multibeam heads	3.21 m	-1.87 m	7.135 m

Table 8. Calculations from C-Nav to MB transducers.

Nav to Transducer 1 X direction	-3.23 m – (-1.87 m) = -1.36 m	negative b/c go port from Nav to get to transducer
Nav to Transducer 1 Y direction	-1.86 m – (-5.52 m) = 3.66 m	positive because go towards bow to get to transducer from Nav
Nav to Transducer 1 Z direction	6.585 m – (-4.71 m) = 11.295 m 6.853 m – (-4.71 m) = 11.563 m	positive b/c positive down from Nav
Nav to Transducer 2 X direction	3.21 m – (-1.87 m) = 5.08 m	positive b/c go starboard from Nav to get to transducer
Nav to Transducer 2 Y direction	-1.87 m – (-5.52 m) = 3.65 m	positive b/c go towards bow to get to transducer from Nav
Nav to Transducer 2 Z direction	6.635 m – (-4.71 m) = 11.345 m 6.906 m – (-4.71 m) = 11.616 m	positive b/c positive down from Nav

Table 9. Calculations from F180 to MB transducers.

Nav to Transducer 1 X direction	-3.23 m – (-0.30) = -2.93 m	Negative b/c go port from Nav
Nav to Transducer 1 Y direction	-1.86 – (-0.32) = -1.54 m	Negative because go towards stern to get to transducer from Nav
Nav to Transducer 1 Z direction	6.583 m – (-0.12 m) = 6.973 m 7.085 m – (-0.12 m) = 7.205 m	Positive b/c positive down from Nav
Nav to Transducer 2 X direction	3.21 – (-0.30) = 3.51 m	Positive b/c go starboard from Nav
Nav to Transducer 2 Y direction	-1.87 m – (-0.32 m) = -1.55 m	Negative b/c go towards the stern to get to transducer from Nav
Nav to Transducer 2 Z direction	6.906 m – (-0.12 m) = 7.026 m 7.135 m – (-0.12 m) = 7.255 m	Positive b/c positive down from Nav

Vessel Layback Report

Layback was applied to all side scan sonar XTF files using the C & C Technologies' proprietary Hydromap layback correction tool. Figure 1 explains the variables and calculations for this process.

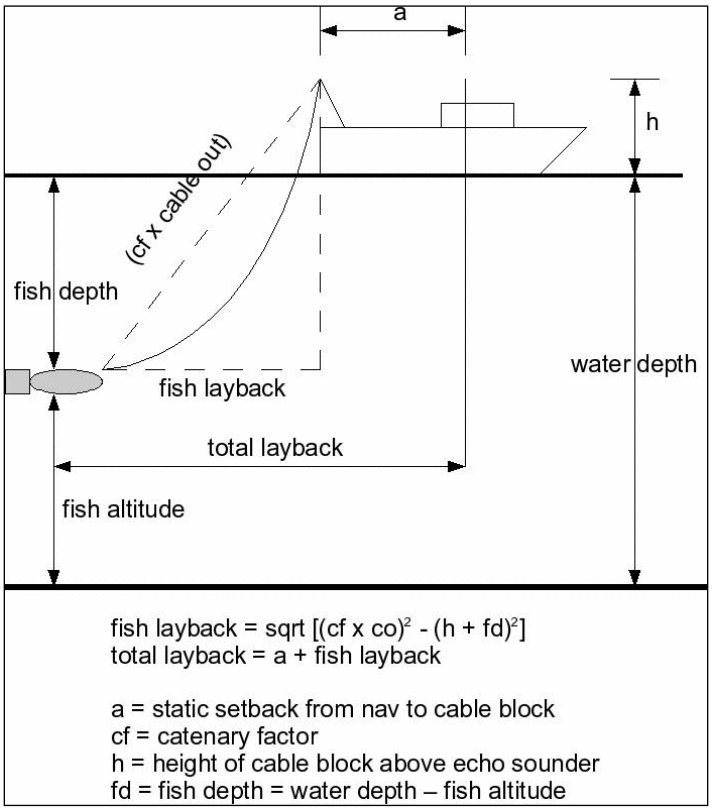


Figure 1. Hydromap layback correction diagram.

The catenary factor (cf) was set at 1.0 for all lines. This was done because the use of a depressor wing, combined with very little cable out, made it very unlikely that there was enough catenary to factor into the equation.

The height of the cable block above the waterline (h) was a constant value. A measurement of 6.9 meters from the waterline to the sheave was used for this value (Figure 2). Figure 3 shows the R/V Sea Scout in retrieval operations of the side scan sonar; image also shows the general layback configuration.

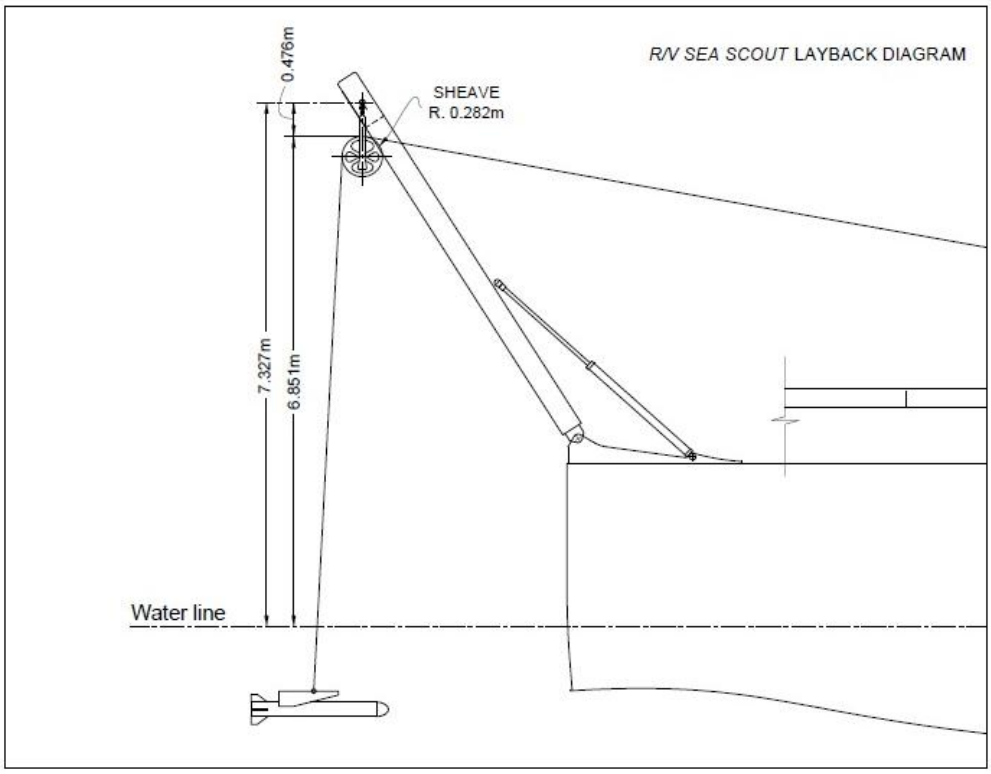


Figure 2. R/V *Sea Scout* layback diagram.

Figure 3. R/V *Sea Scout* towfish operations.

The static setback from the navigation source to the A-frame cable block (a in Figure 1) is the along track distance from the primary positioning system to the side scan sonar sheave on the A-frame fully extended. Both C-Nav and the F180 were used as primary positioning systems during different portions of survey operations; the primary position source used for each survey is detailed in the respective Descriptive Reports.

Layback with F180 as primary positioning system

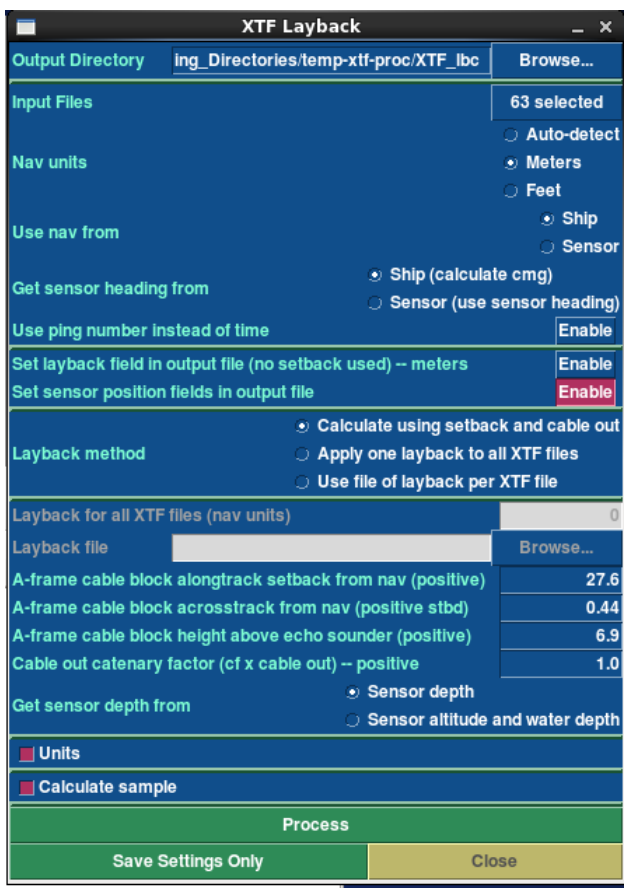
The static setback is a value of 27.6 m for data using the F180 as the navigation source (Tables 10 and 11).

Table 10. F180 IMU and sheave offsets from CRP.

	Acrosstrack (positive starboard)	Alongtrack (positive bow)	Z (positive up)
IMU (F180)	-0.30 m	-0.32 m	0.12 m
Sheave (C/L)	0.14 m	-27.92 m	1.87 m

Table 11. Offsets between F180 IMU and sheave.

	Acrosstrack (positive starboard)	Alongtrack (positive bow)	Z (positive up)
IMU (F180)	0.44 m	-27.6 m	1.75 m



Layback with C-NAV as the primary positioning system

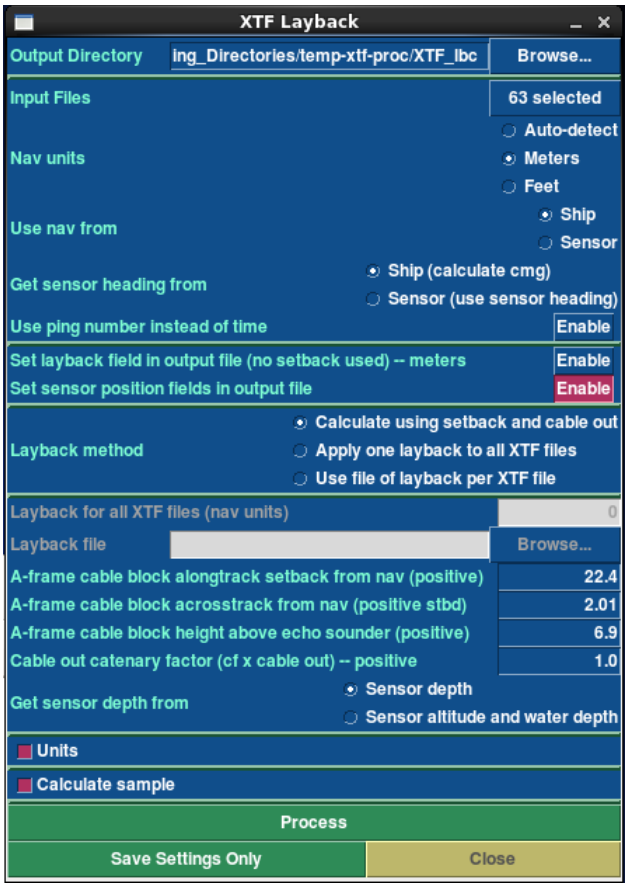
The static setback is 22.4 m for data that used C-Nav as the primary navigation source; this value is the distance from the primary C-Nav antenna to the sheave (Tables 12 and 13)

Table 12. Primary C-NAV antenna and sheave offsets from CRP.

	Acrosstrack (positive starboard)	Alongtrack (positive bow)	Z (positive up)
Primary GPS Antenna	-1.87 m	-5.52 m	4.71 m
Sheave (C/L)	0.14 m	-27.92 m	1.87 m

Table 13. Offsets between primary C-NAV antenna and sheave

	Acrosstrack (positive starboard)	Alongtrack (positive bow)	Z (positive up)
Primary GPS Antenna	2.01 m	-22.4 m	2.84 m



Fish depth, water depth, and fish altitude are values that are recorded into the raw .xtf file. The fish depth was obtained from either the pressure sensor on the side scan sonar, or the fish altitude (bottom track) subtracted from the water depth. If the pressure sensor in the fish was not working properly, fish altitude and water depth was used for this calculation.

Dynamic Draft Report

General:

The draft of a vessel can change with carrying speeds and cause the vessel to settle down in the water. The stern will squat, which causes the relationship of the transducers to the water surface to change. In order to correct for the dynamic draft of the R/V *Sea Scout*, a squat and settlement test was performed south of Cameron, LA on October 5 – 6, 2012.

The resultant corrections are added to the soundings to refer them to a static state. Squat corrections are therefore considered positive quantities as the transducer depresses (squats) deeper into the water at increased speeds. In this case, a positive squat is added to the raw observed/recorded depth. A negative squat may occur with high-speed planning, surface effect, or hovering type vessels.

Definitions:

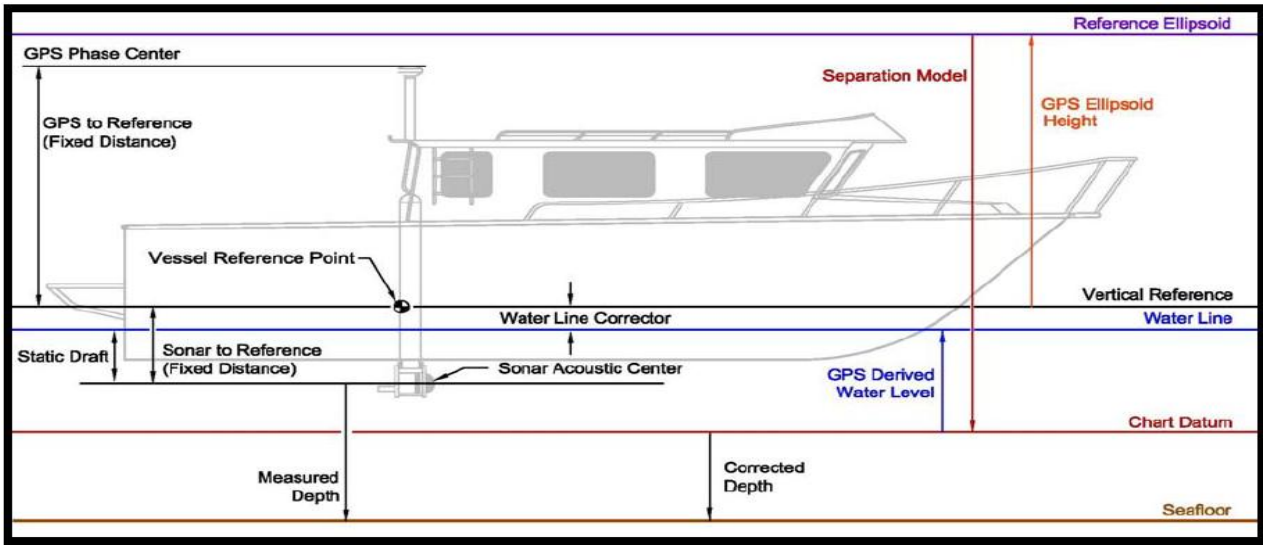


Figure 4

Procedure:

An RTK base station was set up as close to the test area as possible and a static self-survey of at least one hour over a temporary point was conducted. The vessel communicates with the base station via radio connection. Because the radio connection between the boat and the base station has a limited range, a test survey line was run to determine the approximate range. The survey line started near the base station and the ship transited west until the connection was lost; this was repeated in the eastern direction.

The survey crew documented the limits of the radio's range on the navigation screen. The C-Navigator displays "RTK-I" when there is a connection; when the radio connection is lost this will change. In addition, the Rx light on the radio should continue to blink once per second until the connection is lost. Fixes were taken as soon as the radio connection dropped. There were two fix locations, one at each end of the test area. The coordinates from

the fixes were used to create waypoints in the Hydromap display window and a line plotted for the vessel to follow.

Secondly, rpm values associated with specific vessel speeds were established. Although the R/V *Sea Scout* is equipped with four engines, only the smaller two (C18 engines) are used during NOAA survey operations and this will be the focus of this procedure. Another two (2) test lines were run, starting at the one of the limits of the radio range and running along the coast, then turning around and repeating the procedure. The engine rpm at each of the following speeds was recorded in each direction:

Table 14. Survey speed and associated RPMs.

Direction (EAST)	Survey Speed			Max Speed
Speed (kts)	6	7.5	9	10.3
RPM	930	1140	1400	1620

Table 15. Survey speed and associated RPMs.

Direction (WEST)	Survey Speed			Max Speed
Speed	6	7.5	9	10.3
RPM	700	910	1140	1440

The rpm of the two (2) test lines were averaged together, and a rounded rpm value chosen close to the average for operations:

Table 16. Average RPMs at each speed and final RPMs used for the test.

FINAL VALUES	Survey Speed			Max Speed
Speed (kts)	6	7.5	9	10.3
Average of RPMs	815	1025	1270	1490
Final rpm used	800	1000	1300	1500

For the squat and settlement test, a total of 7 (seven) lines were completed. Starting at the far end of the radio range the vessel transited along the pre-plotted survey line while the survey crew recorded data for approximately 2 minutes at each of six (6) rpm:

Table 17. RPM values used in the test.

	Clutch	Neutral	Survey Speeds			Maximum
RPM value	0000	0600	0800	1000	1300	1500

Processing:

An Excel spreadsheet was used for calculation purposes. The RTK GPS data from each run in conjunction with NOAA verified water level data is used. The GGA strings were extracted from each of the GPS files and all records without a ‘4’ in the GPS code, which indicates a fixed RTK solution, removed. The average Ellipsoid Height was then calculated for each run. The data was normalized for ellipsoid height and tide. Verified tidal data from the NOAA tide station 8768094 (Calcasieu Pass, LA) for the time period of the squat test was used.

Results:

The result of this normalization process is the average elevation differences of the vessel at different speeds (rpm). Although seven (7) runs were conducted, only runs three (3) through seven (7) were used in the final calculations because the first line was run on a different day and the second line was the first trial run of the second day.

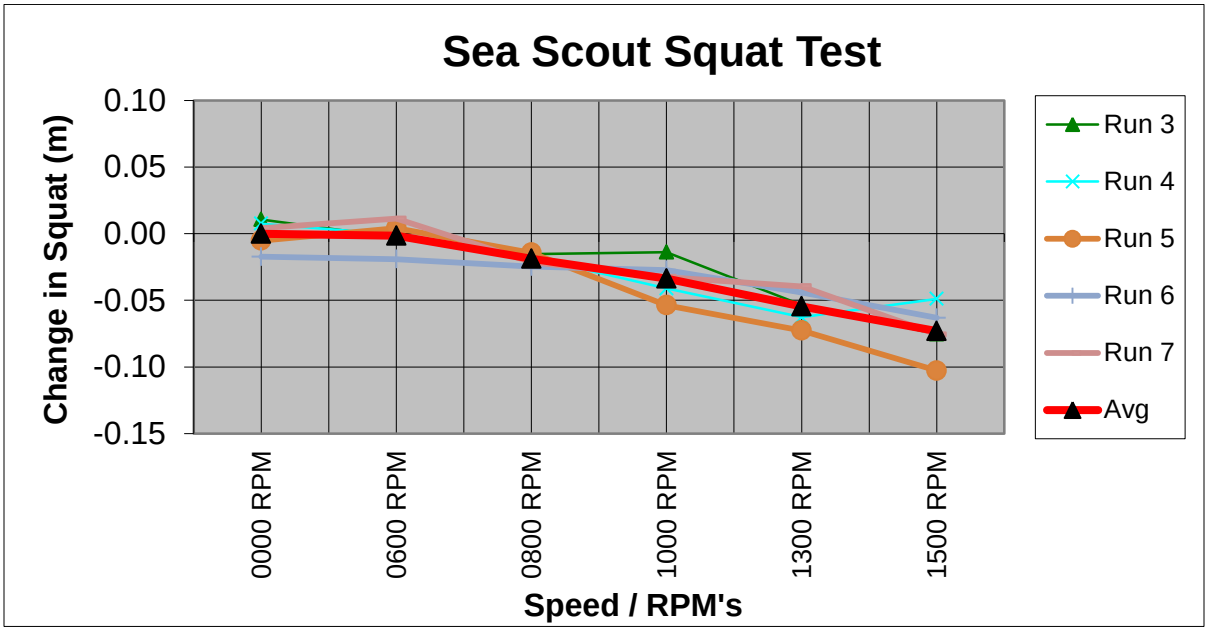


Figure 5. Sea Scout squat test results.

Table 18. Squat and Settlement test results for the R/V *Sea Scout* South of Cameron, LA in the Gulf of Mexico (October 5 and 6, 2012)

Vertical Correction (m)	Speed (m/s)
0.00	0.17
0.00	2.23
-0.02	2.94
-0.03	3.66
-0.05	4.67
-0.07	5.19

Squat and Settlement Test Log

Project Number:	OPR-K354-KR-12	Page #:	001
Vessel Name:	Sea Scout	Date (YY/MM/DD):	12/10/05
General Locality:	South of Cameron, LA	Julian Day:	279

Time (UTC)	Line Name	RPMs	HDG	Speed	HDOP	RTK-I?	Comments
1345							Crew/Equipment arrive at dock
1615							Equipment setup and tested
							J. Parker departs vessel w/
							RTK Base Station
1750							Depart dock for Squat Test
1900							Arrived on site for squat test
1924							Reached easterly limit
2035							Reached westerly limit
2040							Testing speed
2100							Troubleshooting Base
							Station
2202							Base Station running
2203							Transit back into range
2247	Run1_Neutral	0	89	0	0.8	√	SOL
2253	Run1_Neutral	0	89	0	0.8	√	EOL
2255	Run1_Clutch	600	089	3.7	0.9	√	SOL
2258	Run1_Clutch	600	089	3.7	0.9	√	EOL
2300	Run1_800RPM	800	089	5.1	0.9	√	SOL
2303	Run1_800RPM	800	089	5.2	0.9	√	EOL
2304	Run1_1000RPM	1000	089	6.9	0.9	√	SOL
2307	Run1_1000RPM	1000	089	6.7	0.9	√	EOL
2308	Run1_1300RPM	1300	089	8.6	0.9	√	SOL
2311	Run1_1300RPM	1300	089	8.7	0.9	√	EOL
2314	Run1_1500RPM	1500	089	10	0.9	√	SOL
2317	Run1_1500RPM	1500	089	10	0.9	√	EOL
2322	Run2_neutral	0	269	0	0.9	√	SOL
2327	Run2_neutral	0	269	0	0.9	X	Abort line – no differential
							Troubleshooting
0340							Arrive at dock – Squat &
							Settlement test incomplete

Squat and Settlement Test Log

Project Number:	OPR-K354-KR-12	Page #:	002
Vessel Name:	Sea Scout	Date (YY/MM/DD):	12/10/06
General Locality:	South of Cameron, LA	Julian Day:	280

Time (UTC)	Line Name	RPMs	HDG	Speed	HDOP	RTK-I?	Comments
1750							Depart dock for squat
							settlement test
1820	Run2_neutral_2	0	89	0.9	0.9	√	SOL
1823	Run2_neutral_2	0	89	0.9	0.9	√	EOL
1825	Run2_Clutch	600	089	4.4	0.9	√	SOL
1829	Run2_Clutch	600	089	4.3	0.9	√	EOL
1832	Run2_800RPM	800	089	5.6	0.9	√	SOL
1835	Run2_800RPM	800	089	5.6	0.9	√	EOL
1837	Run2_1000RPM	1000	089	6.8	0.9	√	SOL – Boat wake 18:39:58
1840	Run2_1000RPM	1000	089	6.9	0.9	√	EOL
1841	Run2_1300RPM	1300	089	8.9	0.9	√	SOL
1844	Run2_1300RPM	1300	089	8.8	0.9	√	EOL
1845	Run2_1500RPM	1500	089	10.1	0.9	√	SOL
1846	Run2_1500RPM	1500	089	10.1	0.9	√	Abort line – operator error
1846	Run2_1500RPM_2	1500	089	10.1	0.9	√	SOL
1849	Run2_1500RPM_2	1500	089	10.1	0.9	√	EOL
1856	Run3_neutral	0	269	0.2	1.0	√	SOL
1859	Run3_neutral	0	269	0.1	1.0	√	EOL
1901	Run3_Clutch	600	269	4.1	1.0	√	SOL
1904	Run3_Clutch	600	269	4.3	1.0	√	EOL
1906	Run3_800RPM	800	269	5.8	1.0	√	SOL
1909	Run3_800RPM	800	269	5.8	1.0	√	EOL
1910	Run3_1000RPM	1000	269	7.2	1.0	√	SOL
1913	Run3_1000RPM	1000	269	7.3	1.0	√	EOL
1914	Run3_1300RPM	1300	269	9.3	0.9	√	SOL
1917	Run3_1300RPM	1300	269	9.0	0.9	√	EOL
1918	Run3_1500RPM	1500	269	10.1	0.9	√	SOL
1921	Run3_1500RPM	1500	269	10.0	0.9	√	EOL
1926	Run4_neutral	0	089	0.4	0.9	√	SOL
1929	Run4_neutral	0	089	0.2	0.9	√	EOL
1930	Run4_Clutch	600	089	4.4	0.9	√	SOL
1933	Run4_Clutch	600	089	4.3	0.9	√	EOL – loss of lock during run
1935	Run4_800RPM	800	089	5.5	0.9	√	SOL
1938	Run4_800RPM	800	089	5.4	0.9	√	EOL

Squat and Settlement Test Log

Project Number:	OPR-K354-KR-12	Page #:	003
Vessel Name:	Sea Scout	Date (YY/MM/DD):	12/10/06
General Locality:	South of Cameron, LA	Julian Day:	280

Time (UTC)	Line Name	RPMs	HDG	Speed	HDOP	RTK-I?	Comments
1939	Run4_1000RPM	1000	089	6.9	1.0	√	SOL
1942	Run4_1000RPM	1000	089	6.8	1.0	√	EOL
1943	Run4_1300RPM	1300	089	9.0	1.0	√	SOL
1946	Run4_1300RPM	1300	089	9.0	1.0	√	EOL
1948	Run4_1500RPM	1500	089	10	1.0	√	SOL
1951	Run4_1500RPM	1500	089	10.1	1.1	√	EOL
1955	Run5_neutral	0	269	0.2	0.9	√	SOL
1958	Run5_neutral	0	269	0.1	0.9	√	EOL
1959	Run5_Clutch	600	269	4.2	0.9	√	SOL
2002	Run5_Clutch	600	269	4.3	0.9	√	EOL
2004	Run5_800RPM	800	269	5.8	0.9	√	SOL
2007	Run5_800RPM	800	269	5.9	0.9	√	EOL
2008	Run5_1000RPM	1000	269	7.2	0.9	√	SOL
2011	Run5_1000RPM	1000	269	7.3	0.9	√	EOL
2013	Run5_1300RPM	1300	269	9.2	0.9	√	SOL
2016	Run5_1300RPM	1300	269	9.2	0.9	√	EOL
2017	Run5_1500RPM	1500	269	10.2	0.9	√	SOL
2020	Run5_1500RPM	1500	269	10.2	0.9	√	EOL
2024	Run6_neutral	0	089	0.5	0.9	√	SOL
2027	Run6_neutral	0	089	0.5	0.9	√	EOL
2029	Run6_Clutch	600	089	4.6	0.9	√	SOL – loss of RTK lock
2032	Run6_Clutch	600	089	4.3	1.0	√	EOL
2033	Run6_800RPM	800	089	5.7	1.0	√	SOL
2036	Run6_800RPM	800	089	5.6	1.0	√	EOL
2037	Run6_1000RPM	1000	089	7.0	1.0	√	SOL
2040	Run6_1000RPM	1000	089	7.0	1.0	√	EOL
2043	Run6_1300RPM	1300	089	8.9	1.0	√	SOL
2046	Run6_1300RPM	1300	089	9.0	1.0	√	EOL
2047	Run6_1500RPM	1500	089	10	1.1	√	SOL
2050	Run6_1500RPM	1500	089	10	1.1	√	EOL
2055	Run7_neutral	600	269	0.7	1.1	√	SOL
2058	Run7_neutral	600	269	0.4	1.1	√	EOL
2100	Run7_Clutch	800	269	4.3	1.1	√	SOL
2103	Run7_ Clutch	800	269	4.3	1.1	√	EOL

Squat and Settlement Test Log

Project Number:	OPR-K354-KR-12	Page #:	004
Vessel Name:	Sea Scout	Date (YY/MM/DD):	12/10/06
General Locality:	South of Cameron, LA	Julian Day:	280

Time (UTC)	Line Name	RPMs	HDG	Speed	HDOP	RTK-I?	Comments
2105	Run7_800RPM	800	269	5.8	1.1	√	SOL
2108	Run7_800RPM	800	269	5.9	1.3	√	EOL
2110	Run7_1000RPM	1000	269	7.3	1.3	√	SOL
2113	Run7_1000RPM	1000	269	7.2	1.0	√	EOL
2113	Run7_1300RPM	1300	269	9.0	1.0	√	SOL
2117	Run7_1300RPM	1300	269	9.1	1.0	√	EOL
2118	Run7_1500RPM	1500	269	10.3	1.0	√	SOL
2121	Run7_1500RPM	1500	269	9.9	1.0	√	EOL
2140	All_eng_rpm_test	---	89	10.3	1.0	√	SOL
2153	All_eng_rpm_test	---	89	9.8	0.8	√	EOL
2217	All_eng_rpm_test_2	---	269	8.0	0.8	√	SOL – EOL missed
2245	All_Run1_1000RPM	1000	089	8.9	0.9	√	SOL
2245	All_Run1_1000RPM	1000	089	8.9	0.9	√	EOL
2249	All_Run1_1600RPM	1600	089	13.8	0.9	√	SOL
2251	All_Run1_1600RPM	1600	089	13.7	0.9	√	EOL
2253	All_Run1_2000RPM	2000	089	19	0.9	√	SOL
2255	All_Run1_2000RPM	2000	089	18.1	0.9	√	EOL
2256	All_Run1_Max	Max	089	24.1	0.9	√	SOL
2259	All_Run1_Max	Max	089	24.0	0.9	√	EOL
2306	All_Run2_1000RPM	1000	269	10.0	0.9	√	SOL
2308	All_Run2_1000RPM	1000	269	9.8	0.9	√	EOL
2309	All_Run2_1600RPM	1600	269	14.7	0.9	√	SOL
2311	All_Run2_1600RPM	1600	269	15.1	0.9	√	EOL
2314	All_Run2_2000RPM	2000	269	21.0	0.9	√	SOL
2316	All_Run2_2000RPM	2000	269	20.6	0.9	√	EOL
2317	All_Run2_Max	Max	269	24.1	0.9	√	SOL
2319	All_Run2_Max	Max	269	24.7	0.9	√	EOL
2322	All_Run3_1000RPM	1000	089	9.2	0.9	√	SOL
2324	All_Run3_1000RPM	1000	089	9.4	0.9	√	EOL
2326	All_Run3_1600RPM	1600	089	14.4	0.9	√	SOL
2328	All_Run3_1600RPM	1600	089	14.5	0.9	√	EOL
2329	All_Run3_2000RPM	2000	089	20.4	0.9	√	SOL
2331	All_Run3_2000RPM	2000	089		0.9	√	EOL

Squat and Settlement Test Log

Project Number:	OPR-K354-KR-12	Page #:	005
Vessel Name:	Sea Scout	Date (YY/MM/DD):	12/10/06
General Locality:	South of Cameron, LA	Julian Day:	280

Time (UTC)	Line Name	RPMs	HDG	Speed	HDOP	RTK-I?	Comments
2332	All_Run3_Max	Max	089	24	0.9	√	SOL
2334	All_Run3_Max	Max	089	24.0	0.9	√	EOL
2337	All_Run4_1000RPM	1000	269	9.9	0.9	√	SOL
2339	All_Run4_1000RPM	1000	269	9.8	1.0	√	EOL
2340	All_Run4_1600RPM	1600	269	15.0	1.0	√	SOL
2342	All_Run4_1600RPM	1600	269	14.9	1.0	√	EOL
2344	All_Run4_2000RPM	2000	269	20.8	1.1	√	SOL
2346	All_Run4_2000RPM	2000	269	21.0	1.1	√	EOL
2347	All_Run4_Max	Max	269	24.0	1.1	√	SOL
2349	All_Run4_Max	Max	269	24.7	1.1	√	EOL
2350							Transit to dock
0000							New day 12/10/07 JD 281
0040							Arrive at dock
0059							Survey crew depart
							for Lafayette J. Parker,
							A. Robertson

APPENDIX II

Echosounder Reports

System Accuracy Check (Confidence Check) Report

Lead line comparisons were conducted throughout survey operations as an independent check on the multibeam bottom-detect. Lead lines were not taken in larger sea conditions and water depths greater than 15 – 20 meters in order to avoid increased error in the lead line measurement due to factors including wave heights and currents.

In addition, an Odom Echotrac MKIII was used to collect single beam data. This data was continuously recorded and monitored in real-time as an independent check of the nadir beam (bottom-detect) of the multibeam sonar system.

These confidence checks were analyzed for each Sheet. Differences between the multibeam and single beam and multibeam and lead line depths were calculated and statistics computed. These are shown in respective tables below (Tables 19 and 24). The data used to calculate the statistics are shown in Tables 21 - 24.

In general, there is good agreement between the multibeam (MB), single beam (SB) and lead line (LL) depth values. However, the largest differences between the multibeam and lead line readings are those conducted in H12435 (Sheet 3), where depths approach the maximum extent of which reliable lead lines are performed.

Table 19. Averages of the depth difference values between MB and SB and MB and LL.

	Average of difference of MB and SB Depth (m)	**Average of difference of MB and LL Depth (m)**
H12433	-0.0546	-0.0458
H12434	-0.0907	-0.0569
H12435	-0.12	-0.30
H12436	-0.05	-0.08

Table 20. Standard deviation of the depth difference values between the MB and SB and MB and LL.

	Standard deviation of difference of MB and SB Depth (m)	**Standard deviation of difference of MB and LL Depth (m)**
H12433	0.0891	0.1205
H12434	0.1367	0.0887
H12435	0.0428	0.1566
H12436	0.0623	0.1032

Table 21. Lead line, MB and Single Beam depth information and associated statistics for survey H12433.

Lead Line Log									
LL H12433									
Date (mm/dd/yyyy)	**Time**	**X**	**Y**	**Lead Line Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**Difference of MB and SB Depth**	**Difference of MB and LL Depth**
06/09/2012	0158	664304.89	3199908.62	LL_120609a	8.35	8.38	8.4	-0.03	-0.05
06/13/2012	2308	667827.16	3203852.61	LL_120613b	6.1	5.9	6.0	0.20	0.10
06/15/2012	0121	667866.99	3202745.33	LL_120615a	6.92	7.06	7.0	-0.14	-0.08
06/16/2012	0410	666229.64	3200205.38	LL_120616a	7.48	7.70	7.89	-0.22	-0.41
06/27/2012	2359	666972.11	3200113.44	LL_120627a	7.53	7.6	7.6	-0.07	-0.07
06/29/2012	1622	668177.42	3200547.13	LL_120629a	8.8	8.8	8.8	0.00	0.00
06/30/2012	1310	671727.79	3201430.91	LL_120630a	7.1	7.2	7.1	-0.10	0.00
07/02/2012	1410	663979.24	3201596.96	LL_120702a	8.5	8.6	8.5	-0.10	0.00
07/03/2012	1356	664369.77	3202226.01	LL_120703a	8.3	8.3	8.3	0.00	0.00
07/04/2012	1314	664157.76	3203251.26	LL_120704a	7.8	7.9	7.8	-0.10	0.00
07/05/2012	2201	670159.99	3203060.03	LL_120705a	6.46	6.57	6.5	-0.11	-0.04
07/07/2012	1843	671818.01	3198978.69	LL_120707b	7.53	7.57	7.45	-0.04	0.08
07/08/2012	1954	670774.38	3199541.68	LL_120708b	7.44	7.4	7.4	0.04	0.04
07/10/2012	0036	671219.31	3200386.61	LL_120710a	7.38	7.42	7.45	-0.04	-0.07
07/11/2012	0148	671804.24	3200272.51	LL_120711a	7.13	7.20	7.25	-0.07	-0.12
07/15/2012	0124	670652.74	3201535.29	LL_120715a	6.51	6.5	6.4	0.01	0.11
07/16/2012	0227	671135.09	3202511.01	LL_120716a	6.37	6.55	6.5	-0.18	-0.13
07/17/2012	1226	678565.49	3203592.31	LL_120717	8.3	8.29	8.3	0.01	0.00
07/18/2012	0038	671044.63	3203876.91	LL_120718a	5.89	6.0	6.0	-0.11	-0.11
07/18/2012	1304	678274.53	3204322.91	LL_120718a	8.1	8.08	8.0	0.02	0.10
07/19/2012	1509	678270.45	3204891.86	LL_120719a	7.8	7.83	7.8	-0.03	0.00
07/22/2012	0348	671658.08	3205054.93	LL_120722a	5.75	5.8	5.9	-0.05	-0.15
07/23/2012	0445	675250.27	3203668.99	LL_120723a	7.2	7.4	7.5	-0.20	-0.30
10/22/1012	1806	676868.21	3202461.57	LL_121022a	7.8	7.8	7.8	0.00	0.00
								Average of Difference	
								-0.0546	-0.0458
								Standard Deviation of Difference	
								0.0891	0.1205

Table 22, Lead line, MB and Single Beam depth information and associated statistics for survey H12434.

Lead Line Log									
LL H12434									
Date (mm/dd/yyyy)	**Time**	**X**	**Y**	**Lead Line Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**Difference of MB and SB Depth**	**Difference of MB and LL Depth**
05/15/2012	2152	663117.22	3205155.84	LL_120515b	7.03	7.4	7.1	-0.37	-0.07
05/16/2012	1959	667849.00	3207721.34	LL_120516b	4.99	4.8	5.0	0.19	-0.01
05/18/2012	0053	662624.08	3211083.11	LL_120518a	5.47	5.6	5.5	-0.13	-0.03
05/19/2012	0058	662521.28	3210042.35	LL120519a	5.43	5.64	5.5	-0.21	-0.07
05/20/2012	1142	667725.07	3209077.41	LL_120520a	4.77	5.3	4.95	-0.53	-0.18
05/20/2012	1921	666096.28	3208976.45	LL_120520b	5.37	5.55	5.40	-0.18	-0.03
05/23/2012	0428	662837.31	3208678.89	LL_120523a	5.67	5.8	5.70	-0.13	-0.03
07/26/2012	1345	678317.49	3206202.00	LL_120726a	7.2	7.2	7.4	0.00	-0.20
07/27/2012	1457	678411.61	3206321.31	LL_120727a	7.3	7.3	7.3	0.00	0.00
07/29/2012	0136	678433.17	3206666.71	LL_120729a	6.72	6.78	6.85	-0.06	-0.13
07/29/2012	1430	675721.56	3206940.39	LL_120729b	6.39	6.55	6.4	-0.16	-0.01
07/29/2012	2240	664530.33	3205570.58	LL_120729c	6.39	6.38	6.4	0.01	-0.01
08/01/2012	1910	672184.88	3204763.64	LL_120730a	6.0	6.2	6.0	-0.20	0.00
08/01/2012	0120	678535.84	3208336.50	LL_120801a	5.9	6.0	6.0	-0.10	-0.10
08/02/2012	0213	678572.45	3209410.95	LL_120802a	5.38	5.5	5.5	-0.12	-0.12
08/02/2012	2030	674415.95	3207081.39	LL_120802b	5.8	5.89	5.95	-0.09	-0.15
08/04/2012	0033	678347.64	3209625.52	LL_120804a	5.45	5.52	5.5	-0.07	-0.05
08/23/2012	1627	677461.60	3210287.01	LL_120823a	4.7	4.87	4.75	-0.17	-0.05
08/24/2012	1412	666098.88	3206645.82	LL_120824a	5.7	5.8	5.7	-0.10	0.00
08/25/2012	1502	672493.48	3206955.14	LL_120825a	5.3	5.4	5.4	-0.10	-0.10
09/03/2012	1707	664117.95	3208778.30	LL_120903a	5.7	5.7	5.7	0.00	0.00
09/04/2012	1546	664305.60	3207783.97	LL_120904a	5.8	5.88	5.7	-0.08	0.10
09/12/2012	0525	660393.66	3207822.33	LL_120912a	5.6	5.6	5.8	0.00	-0.20
09/13/2012	0740	663885.07	3206740.22	LL_120913a	6.6	6.5	6.7	0.10	-0.10
09/16/2012	0021	667982.30	3205932.03	LL_120916a	6.5	6.41	6.7	0.09	-0.20
09/16/2012	2317	671508.55	3210347.77	LL_120916b	4.99	5.05	5.0	-0.06	-0.01
09/21/2012	0409	671765.47	3209538.81	LL_120921a	4.8	4.86	4.8	-0.06	0.00
11/04/2012	1130	678187.63	3205750.82	LL_121104a	7.3	7.3	7.1	0.00	0.20
11/09/2012	0832	677434.25	3206947.74	LL_121109a	6.3	6.4	6.4	-0.10	-0.10
								Average of Difference	
								-0.0907	-0.0569
								Standard Deviation of Difference	
								0.1367	0.0887

Table 23. Lead line, MB and Single Beam depth information and associated statistics for survey H12435.

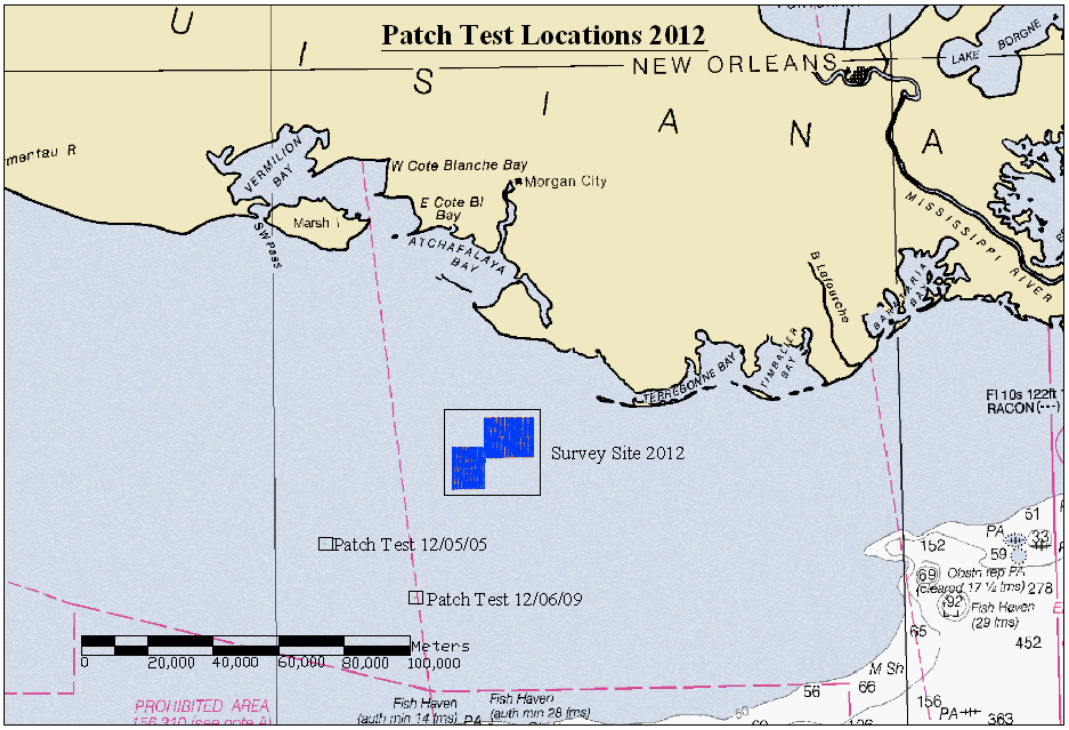
Lead Line Log									
LL H12435									
Date (mm/dd/yyyy)	**Time**	**X**	**Y**	**Lead Line Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**Difference of MB and SB Depth**	**Difference of MB and LL Depth**
05/26/2012	0037	653933.70	3192011.25	LL_120526a	16.5	16.7	17.0	-0.20	-0.50
05/27/2012	0036	653659.41	3194762.20	LL_120527a	15.39	15.5	15.7	-0.11	-0.31
05/27/2012	2013	654785.03	3189853.38	LL_120527c	17.29	17.4	17.5	-0.11	-0.21
05/28/2012	1656	659133.20	3190993.20	LL_120528b	15.1	15.2	15.2	-0.10	-0.10
05/29/2012	1942	663312.99	3189448.61	LL_120529c	13.9	14.0	14.3	-0.10	-0.40
								Average of Difference	
								-0.12	-0.30
								Standard Deviation of Difference	
								0.0428	0.1566

Table 24. Lead line, MB and Single Beam depth information and associated statistics for survey H12436.

Lead Line Log									
LL H12436									
Date (mm/dd/yyyy)	**Time**	**X**	**Y**	**Lead Line Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**Difference of MB and SB Depth**	**Difference of MB and LL Depth**
06/01/2012	0630	662449.47	3195779.99	LL_120601a	11.6	11.6	11.8	0.00	-0.20
06/03/2012	0043	654350.42	3196623.89	LL_120603a	13.87	14.0	13.9	-0.13	-0.03
06/04/2012	0006	654289.79	3198916.69	LL_120604a	12.92	12.9	12.89	0.02	0.03
06/06/2012	0320	659041.55	3197466.94	LL_120606a	11.72	11.8	11.9	-0.08	-0.18
06/07/2012	1632	658550.80	3200607.41	LL_120607a	11.38	11.46	11.4	-0.08	-0.02
07/13/2012	2239	661601.2	3201499.83	LL_120713a	9.06	9.06	9.0	**Average of Difference**	
								-0.05	-0.08
								Standard Deviation of Difference	
								0.0623	0.1032

System Alignment Test (Patch Test) Report

Patch tests were conducted on May 5, 2012 and June 9, 2012. Below is a map showing the locations of the patch tests and the survey area for 2012.



	May 05, 2012		June 9, 2012	
Position	(X) 613351.72	(Y) 3172185.17	(X) 641465.98	(Y) 3155769.43
Water Depth	36.35m		46.8m	
Waterline to CRP			4.92m	
Draft			(Port) 1.48m	(Stbd) 1.50m
SVP Harmonic Mean			1537m/s	
YSI (surface velocity)			1536m/s	

Patch test data for C & C Technologies' surveys have been historically processed using the proprietary software Hydromap. For the 2012 survey, the patch test data were also processed using the calibration tool in CARIS 7.1.

Purpose:

The patch tests are performed in order to calculate the mounting angles of the multibeam transducers in the vessel reference frame. The angular offsets are applied in the topside transducer control software to ensure accurate depth calculations. The first patch took place prior to survey operations and the second patch test took place as a verification of the first patch test.

Patch Test Processing: Hydromap

Procedure:

The R/V *Sea Scout* has a dual head EM3002 configuration. The port head (SH1) has serial number 211 and starboard head (SH2) has serial number 369. Patch tests were conducted separately for each head. The sample calculations shown below are from the patch test conducted on June 9, 2012. The procedure is essentially the same for the May 05, 2012 patch test, the only difference was the first set of yaw lines, which were run in the same direction as opposed to opposite directions. The results for the May and June patch tests are shown in Tables 25 and 26, respectively.

Pitch: Two reciprocal lines over a significant bottom feature at the slowest practical speed.

$$\Delta P = \tan^{-1}\left(\frac{\Delta H}{D \cdot 2}\right)$$

ΔP = Pitch Correction
ΔH = Change in Horizontal Position
D = Water Depth
Results:

Sonar Head 1: ΔH=0.0	D=46.8*2=93.6	**ΔP = 0.0**
Sonar Head 2: ΔH=0.0	D=46.6*2=93.2	**ΔP = 0.0**

Roll: Two reciprocal lines over a flat surface.

$$\Delta R = \tan^{-1}\left(\frac{\Delta D}{2 \cdot \Delta O}\right)$$

ΔR = Roll Correction
ΔD = Depth Difference (between two points on both lines)
ΔO = Distance to ΔD from Nadir
Results:

Sonar Head 1: ΔD=0.30	ΔO=49.83*2=99.66	**ΔR = 0.1724**
Sonar Head 2: ΔD=0.26	ΔO=49.83*2=99.66	**ΔR = 0.1494**

Yaw: Two parallel lines over a feature with the feature in the outer portion of the swath and 10% to 20% overlap.

$$\Delta Y = \tan^{-1}\left(\frac{\Delta A}{\Delta O \cdot 2}\right)$$

ΔY = Yaw Correction
ΔA = Measured Along-Track Distance
ΔO = Distance from Nadir
Results:

Sonar Head 1: ΔA=0.40	ΔO=60.49*2=120.98	**ΔY = 0.189**
Sonar Head 2: ΔA=20.82	ΔO=60.49*2=120.98	**ΔY = 9.770**

Note: The values obtained are neither positive nor negative in Hydromap. The sign of the values is determined after.

Table 25. May 05, 2012 Patch Test results.

	Sonar Head 211	Sonar Head 369
Pitch	0.0°	0.0°
Roll	-0.17°	-0.19°
Yaw	0.0°	-8.61°

Table 26. June 09, 2012 Patch Test results.

	Sonar Head 211	Sonar Head 369
Pitch	0.0°	0.0°
Roll	-0.1724°	-0.15°
Yaw	-0.189°	-9.77°

Patch Test Processing: CARIS

The data from the patch tests were processed in CARIS 7.1 using the calibration tool and the procedures outlined in the CARIS Technical Note: MBES Calibration Procedure using CARIS HIPS, except that the offsets were solved for in the order: pitch, roll, yaw.

Patch Test 120505

The data used for SH1 were lines Patch1 through Patch4.
The data used for SH2 were lines Patch5 through Patch9.
Both heads were run to verify the results of the patch test with lines Patch10 through Patch13.

Table 27. Lines used in calibration for each sonar head for patch test conducted on 120505.

	Lines used for SH1	Lines used for SH2
Pitch	Patch1 & Patch2	Patch5 & Patch6
Roll	Patch 1 & Patch 2	Patch6 & Patch7
Yaw	Patch3 & Patch4	Patch7 & Patch 9

Patch Test 120609

Table 28. Lines used in calibration for each sonar head for patch test conducted on 120609.

	Lines used for SH1	Lines used for SH2
Pitch	Pitch1 & Pitch2	Pitch5 & Pitch6
Roll	Roll1 & Roll2	Pitch3 & Pitch4
Yaw	Yaw1 & Yaw2	Yaw4 & Yaw5

*SH1: Before calibrating Yaw the Vessel Config file was edited to have a Roll offset of 0.17° in order to reset the offsets to 0. The Yaw lines were then merged again and calibrated.

*SH2: Before calibrating Yaw the Vessel Config file was edited to have a Roll offset of 0.15° because the Installation parameters/SIS had the Transducer2 Roll set as -0.15. Yaw lines were remerged to cancel the effect of roll offset used in the collection software (SIS).
Final Results and Comparisons

Below are the results from several people that resolved the patch test biases several times in CARIS for the May 05, 2012 patch test.

Table 29. Results of patch test on May 05, 2012.

120505-SH1-211	Pitch	Roll	Yaw	12505-SH2-369	Pitch	Roll	Yaw
Processor 1	0.19	-0.21	1.10	Processor 1	0.46	-0.17	-9.00
	0.18	-0.16	0.90		0.23	-0.16	-9.30
	0.22	-0.16	1.00		0.40	-0.13	-9.00
	0.19	-0.17	1.00		0.40	-0.14	-9.20
Average	**0.20**	**-0.18**	**1.00**	**Average**	**0.37**	**-0.15**	**-9.13**
STD DEV	**0.02**	**0.02**	**0.08**	**STD DEV**	**0.10**	**0.02**	**0.15**
120505-SH1-211	Pitch	Roll	Yaw	12505-SH2-369	Pitch	Roll	Yaw
Processor 2	0.18	-0.21	1.30	Processor 2	0.40	-0.15	-9.30
	0.20	-0.22	1.10		0.50	-0.15	-9.30
	0.28	-0.21	1.20		0.70	-0.19	-9.40
	0.15	-0.23	1.10		0.54	-0.21	-9.60
Average	**0.20**	**-0.22**	**1.18**	**Average**	**0.54**	**-0.18**	**-9.40**
STD DEV	**0.06**	**0.01**	**0.10**	**STD DEV**	**0.12**	**0.03**	**0.14**
120505-SH1-211	Pitch	Roll	Yaw	12505-SH2-369	Pitch	Roll	Yaw
Processor 3	0.15	-0.20	1.00	Processor 3	0.30	-0.15	-9.00
	0.08	-0.22	1.40		1.00	-0.15	-9.10
	0.10	-0.15	0.80		0.60	0.22	-9.80
	0.20	-0.19	1.10		0.60	-0.24	-9.10
Average	**0.13**	**-0.19**	**1.08**	**Average**	**0.63**	**-0.08**	**-9.25**
STD DEV	**0.05**	**0.03**	**0.25**	**STD DEV**	**0.29**	**0.20**	**0.37**
Average of Average	**0.18**	**-0.19**	**1.08**	**Average of Average**	**0.51**	**-0.14**	**-9.26**

Below are the comparisons between the values from Hydromap and the values from CARIS.

Table 30. Comparisons between Hydromap and CARIS patch test values.

120505-SH1-211	Pitch	Roll	Yaw	120605-SH2-369	Pitch	Roll	Yaw
Hydromap	0.00	-0.17	0.00	Hydromap	0.00	-0.19	8.61
CARIS	0.18	-0.19	1.08	CARIS	0.51	-0.14	-9.26
Difference				Difference			

Below are the results from several people that resolved the patch test biases several times in CARIS for the June 09, 2012 patch test.

Table 31. Results of patch test on June 06, 2012.

120609-SH1-211	Pitch	Roll	Yaw	120609-SH2-369	Pitch	Roll	Yaw
Processor 1	-0.71	-0.11	-0.91	Processor 1	0.12	-0.09	-9.30
	-0.72	-0.16	-0.95		0.10	-0.07	-9.82
	-0.80	-0.16	-0.88		0.04	-0.05	-9.56
	-0.74	-0.14	-0.87		0.08	-0.07	-9.32
Average	**-0.74**	**-0.14**	**-0.90**	**Average**	**0.09**	**-0.07**	**-9.50**
STD DEV	**0.04**	**0.02**	**0.04**	**STD DEV**	**0.03**	**0.02**	**0.24**
120609-SH1-211	Pitch	Roll	Yaw	120609-SH2-369	Pitch	Roll	Yaw
Processor 2	-0.93	-0.09	-0.62	Processor 2	0.10	-0.05	-9.97
	-0.87	-0.14	-0.42		0.33	-0.06	-9.91
	-0.91	-0.13	-0.40		0.23	-0.06	-9.20
	-0.88	-0.12	-0.30		0.27	-0.07	-8.30
Averge	**-0.90**	**-0.12**	**-0.44**	**Average**	**0.23**	**-0.06**	**-9.35**
STD DEV	**0.03**	**0.02**	**0.13**	**STD DEV**	**0.10**	**0.01**	**0.78**
120609-SH1-211	Pitch	Roll	Yaw	120609-SH2-369	Pitch	Roll	Yaw
Processor 3	-0.80	-0.10	-0.65	Processor 3	0.08	-0.10	-9.41
	-0.95	-0.11	-0.52		0.09	-0.08	-9.55
	-0.75	-0.09	-0.55		0.07	-0.07	-9.46
	-0.93	-0.11	-0.45		0.12	-0.12	-9.25
Average	**-0.86**	**-0.10**	**-0.54**	**Average**	**0.09**	**-0.09**	**-9.42**
STD DEV	**0.10**	**0.01**	**0.08**	**STD DEV**	**0.02**	**0.02**	**0.13**
Average of Average	**-0.82**	**-0.13**	**-0.61**	**Average of Average**	**0.11**	**-0.06**	**-9.41**

Below are the comparisons between the values from Hydromap and the values from CARIS.

Table 32. Comparisons between Hydromap and CARIS patch test values.

120609-SH1-211				120609-SH2-369			
	Pitch	Roll	Yaw		Pitch	Roll	Yaw
Hydromap	0.00	-0.17	-0.189	Hydromap	0.00	-0.15	-9.77
CARIS	-0.82	-0.13	-0.61	CARIS	0.11	-0.06	-9.41
Difference				Difference			

Conclusions

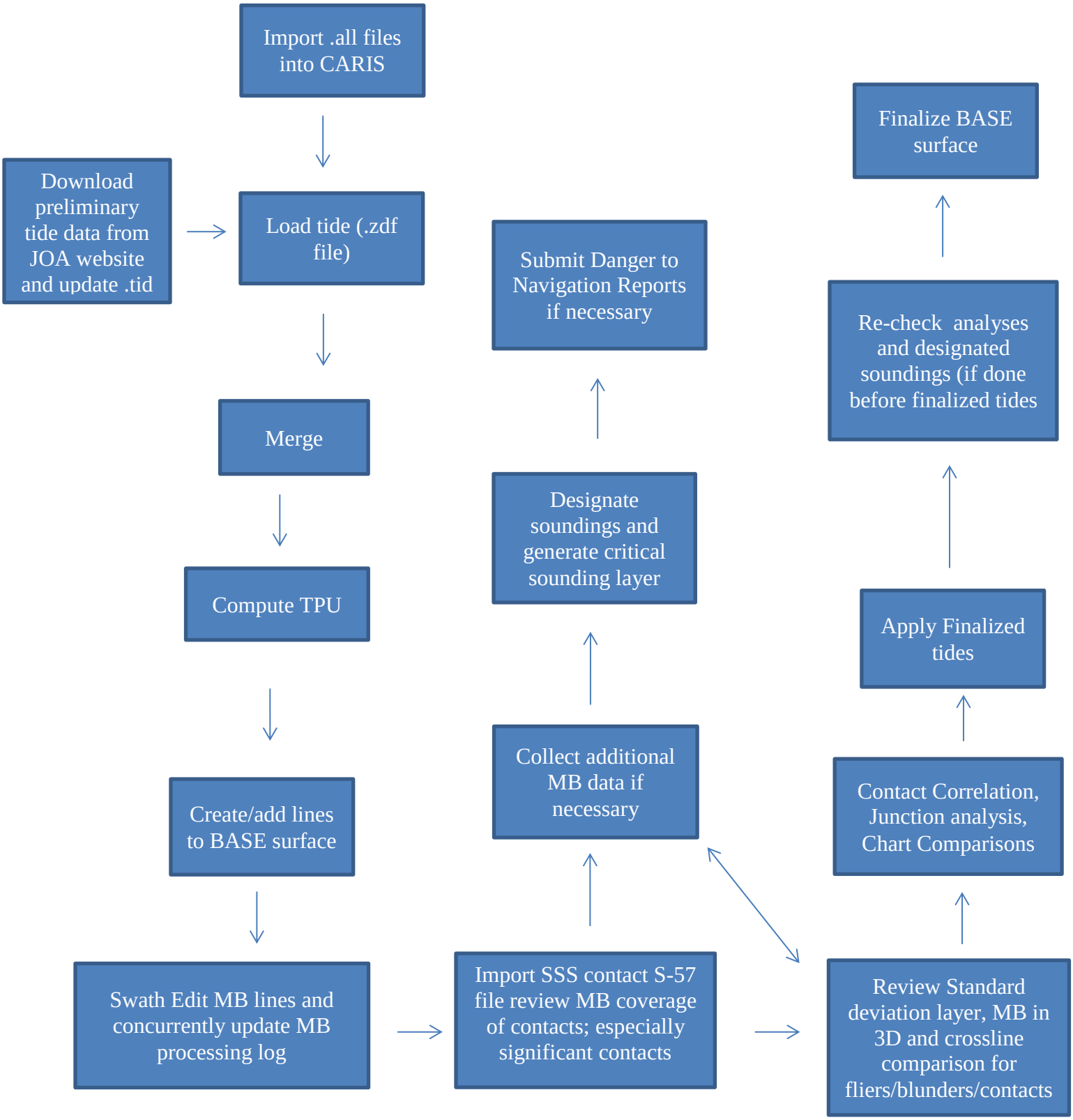
Historically, and in this survey, the offset values are obtained from Hydromap and immediately input into the SIS control software. The CARIS processing took place during post-processing of the data. Although it is evident that there are some differences between the offset values obtained from Hydromap and the values obtained through CARIS, the differences are generally less than a degree, and in some cases less than 0.1 degrees.

During processing of the data for this survey, no significant offsets were observed within the data and for this reason the original patch test values obtained from Hydromap are retained and no additional post-processing occurred other than what is already specified the Data Acquisition and Processing Report and in respective Descriptive Reports.

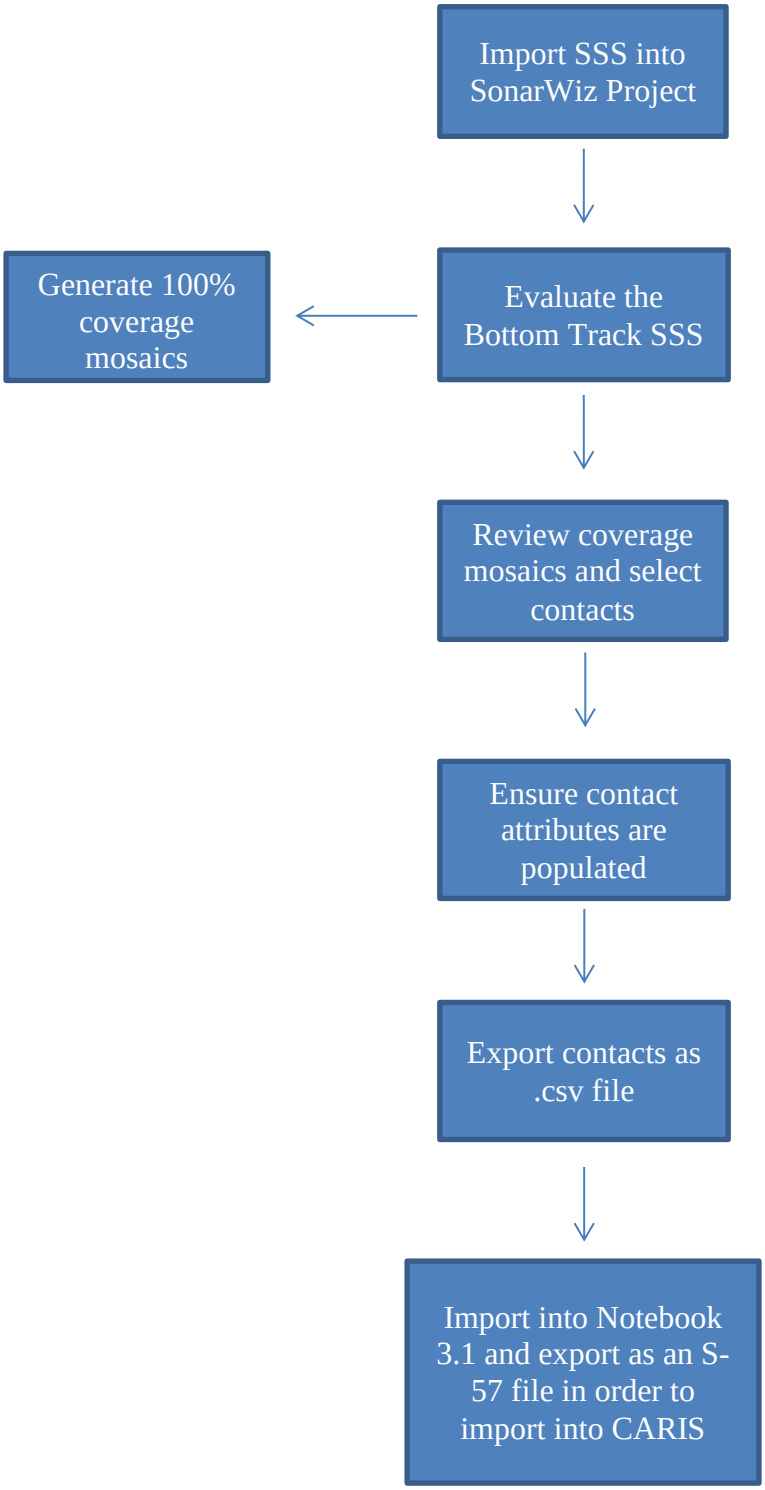
Patch Test data and logs are located in a separate folder on each submitted hard drive.

Data Processing Flow Diagrams

MB Processing Workflow



SSS Processing Workflow



APPENDIX III

Positioning and Attitude Sensor Reports

Calibration and Configuration Reports

Calibration settings for F180 Series.

Calibration status is: Complete

Attitude Accuracy: 0.039 degrees.
Heading Accuracy: 0.054 degrees.

Calibration Configuration Parameters

X GPS Offset: -5.797 metres.
X GPS Accuracy: 0.008 metres.
Y GPS Offset: -0.431 metres.
Y GPS Accuracy: 0.005 metres.
Z GPS Offset: -4.690 metres.
Z GPS Accuracy: 0.023 metres.
GPS Rotation: 88.68 degrees.
GPS Rotation Accuracy: 0.01 degrees.
GPS Elevation: -0.59 degrees.
GPS Elevation Accuracy: 0.01 degrees.

Other Configuration Parameters

GPS Antenna Separation: 2.160 metres.
GPS Correction Type: DGPS.
Heading Offset: 0.00 degrees.
Pitch Offset: 0.00 degrees.
Roll Offset: 0.00 degrees.
X Remote Lever Arm: 0.000 metres.
Y Remote Lever Arm: 0.000 metres.
Z Remote Lever Arm: 0.000 metres.
Heave coupling: AC.
Altitude compensation to mean sea level datum: No.

Serial 1 Output Parameters

Serial 1 string: NMEA / PASHR / PRDID.
Serial 1 baud: 19200.
Serial 1 data bits: 8.
Serial 1 stop bits: 1.
Serial 1 parity: None.
Serial 1 HDT update rate: 5 Hz.
Serial 1 GGA update rate: 5 Hz.
Serial 1 VTG update rate: 5 Hz.
Serial 1 ZDA update rate: 1 Hz.
Serial 1 GST update rate: 1 Hz.
Serial 1 PASHR update rate: OFF Hz.
Serial 1 PRDID update rate: OFF Hz.

Serial 2 Output Parameters

Serial 2 string: EM3000 (Tate-Bryant).
Serial 2 baud: 19200.
Serial 2 data bits: 8.
Serial 2 stop bits: 1.
Serial 2 parity: None.
Serial 2 update rate: 50 Hz.

APPENDIX IV

Sound Speed Sensor Reports

Calibration Reports

1174

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1174
CALIBRATION DATE: 04-Jan-12

SBE19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

```
g =  4.15451545e-003
h =  5.85577535e-004
i =  1.07859856e-006
j = -2.51511097e-006
f0 = 1000.0
```

IPTS-68 COEFFICIENTS

```
a =  3.64764037e-003
b =  5.78130283e-004
c =  7.66544274e-006
d = -2.51489902e-006
f0 = 2386.465
```

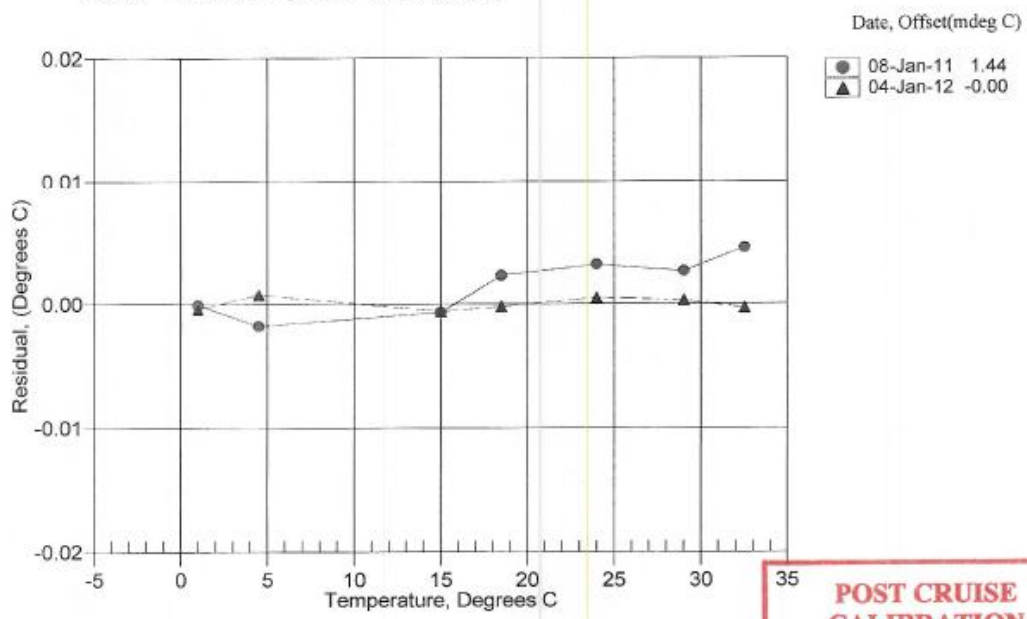
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2386.465	0.9996	-0.00041
4.5000	2584.363	4.5007	0.00075
14.9999	3247.249	14.9993	-0.00060
18.5000	3492.613	18.4998	-0.00021
24.0000	3904.106	24.0005	0.00051
29.0000	4306.624	29.0003	0.00028
32.5000	4605.071	32.4997	-0.00032

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



POST CRUISE CALIBRATION

C&C Technologies
SURVEY SERVICES
730 E. KALISTE SALOOM ROAD, LAFAYETTE, LA (337) 261-0660

2645

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2645
CALIBRATION DATE: 19-Nov-11

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

GHIJ COEFFICIENTS

```
g = -4.06099346e+000
h =  4.86294267e-001
i =  5.20819597e-004
j =  2.39080638e-006
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  5.65968191e-004
b =  4.86041169e-001
c = -4.05811059e+000
d = -8.24391289e-005
m =  3.0
CPcor = -9.5700e-008 (nominal)
```

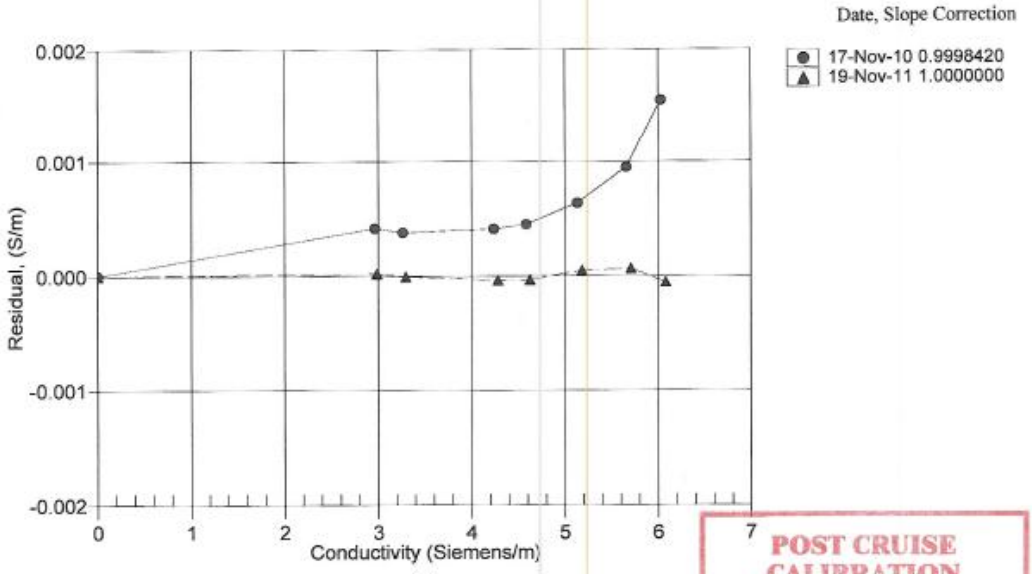
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88528	0.00000	0.00000
1.0000	34.9334	2.98502	8.31239	2.98504	0.00002
4.5000	34.9127	3.29292	8.67975	3.29292	-0.00000
15.0000	34.8689	4.27738	9.76076	4.27734	-0.00004
18.5000	34.8594	4.62347	10.11298	4.62344	-0.00003
24.0000	34.8489	5.18294	10.65742	5.18298	0.00005
29.0000	34.8424	5.70611	11.14202	5.70617	0.00006
32.5000	34.8382	6.07938	11.47492	6.07932	-0.00005

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



POST CRUISE CALIBRATION

C&C Technologies
SURVEY SERVICES
730 E. KALISTE SALOOM ROAD, LAFAYETTE, LA (337) 261-0660

SEA-BIRD ELECTRONICS, INC.

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2791
CALIBRATION DATE: 07-Jun-11

SBE19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

```
g =  4.19605691e-003
h =  6.09414069e-004
i =  4.23873314e-006
j = -1.75704804e-006
f0 = 1000.0
```

IPTS-68 COEFFICIENTS

```
a =  3.64763815e-003
b =  5.97516689e-004
c =  9.04945916e-006
d = -1.75660120e-006
f0 = 2478.851
```

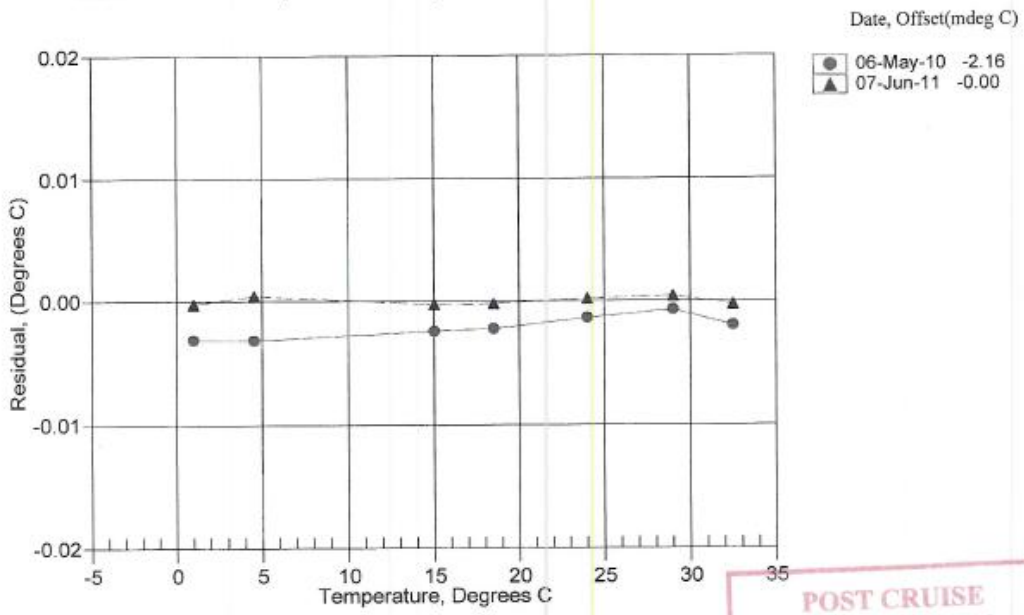
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2478.851	0.9998	-0.00024
4.5000	2677.473	4.5004	0.00043
14.9999	3339.710	14.9996	-0.00026
18.4999	3583.651	18.4997	-0.00020
24.0000	3991.534	24.0002	0.00018
29.0000	4389.152	29.0004	0.00038
32.5000	4683.083	32.4997	-0.00029

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



POST CRUISE CALIBRATION

5221

Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 08-Jun-12

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 1.231077e-003
a1 = 2.556504e-004
a2 = 4.392866e-007
a3 = 1.204727e-007

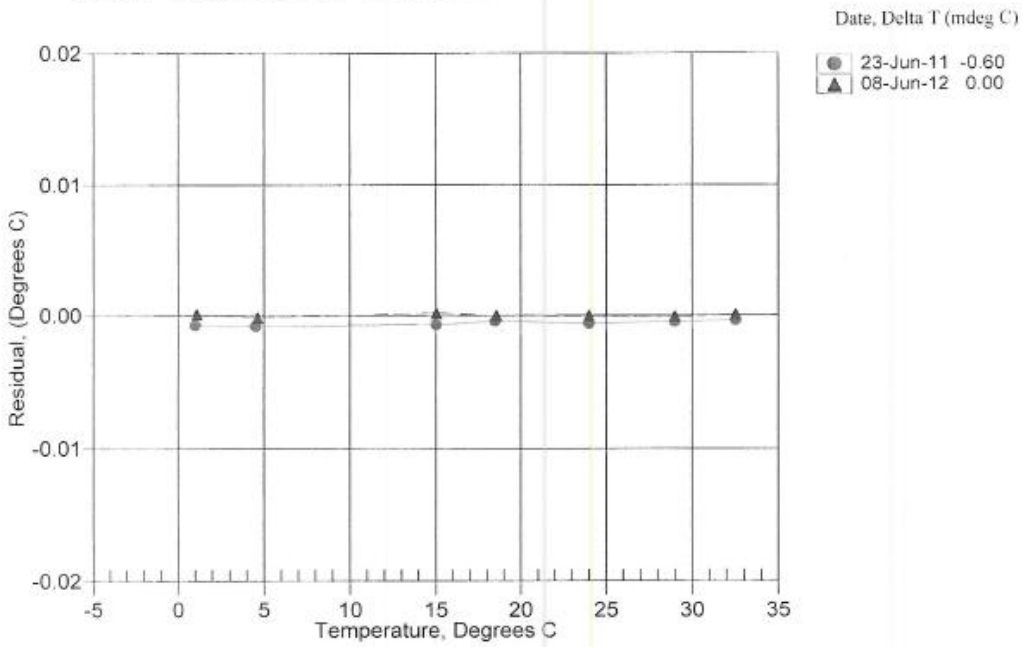
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0720	734292.475	1.0721	0.0001
4.6098	656393.458	4.6096	-0.0002
15.0433	461464.864	15.0435	0.0002
18.5416	407613.610	18.5416	-0.0000
24.0000	334211.831	24.0000	-0.0000
29.0000	277300.576	28.9999	-0.0001
32.5000	242692.610	32.5001	0.0001

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



5222

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 5222
CALIBRATION DATE: 19-May-12

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

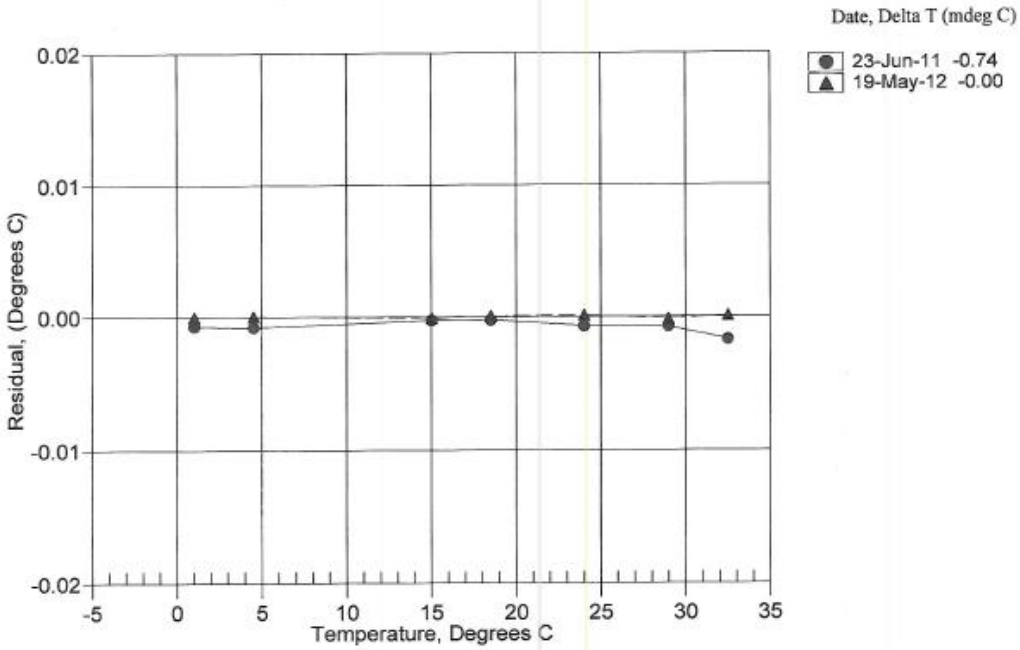
ITS-90 COEFFICIENTS

```
a0 =  1.284740e-003
a1 =  2.556854e-004
a2 =  6.681988e-007
a3 =  1.190013e-007
```

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	619242.797	1.0000	-0.0000
4.5000	549276.712	4.5000	0.0000
15.0000	375967.525	14.9999	-0.0001
18.5000	329535.288	18.5001	0.0001
23.9999	266593.881	24.0000	0.0001
29.0000	218767.542	28.9998	-0.0002
32.5001	189917.102	32.5002	0.0001

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