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NATIONAL OCEAN SERVICE

Data Acquisition & Processing Report

Type of Survey Navigable Area

Project Number OPR-K339-KR-14

Time Frame June 2014 to May 2015

LOCALITY

State Louisiana

General Locality Lousiana Coast, LA

2015

CHIEFS OF PARTY
Tara Levy

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A. EQUIPMENT

A.1. MAJOR OPERATIONAL SYSTEMS

The major operational systems used to acquire hydrographic data were Kongsberg EM 2040C and EM3002 multibeam echo sounders (MBES) and Klein 5000 V2 and EdgeTech 4200 side scan sonars (SSS). Lists of the survey equipment are shown in Tables 1, 2 and 3 for each vessel used in operations.

Table 1. Survey equipment aboard the R/V *Sea Scout*

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM2040C	Transducer: 0131 Topside: 528
Multibeam Echo Sounder (Starboard)	Kongsberg	EM2040C	Transducer: 0133 Topside: 529
Side Scan Sonar (Primary)	Klein	5000 V2	Side Scan: 377 Topside: 792
Side Scan Sonar (Back –up)	Klein	5000 V2	Side Scan: 376 Topside: 790
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	F0407061
Attitude and Positioning System	CodaOctopus	F180	F0907069
Attitude and Positioning System (spare)	Coda Octopus	F180	F0104012
Positioning System	CNAV	3050	CNAV Receiver: 13769
Positioning System	CNAV	3050	CNAV Receiver: 13752
Positioning System (replaced 13752)	CNAV	3050	CNAV Receiver: 15006
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, 7515,7516
Cable Payout Indicator	Subsea Systems	PI-5600	234, 235

Table 2. Survey equipment aboard the R/V *C-Wolf*

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM3002	Transducer: 561 Topside: 1009
Side Scan Sonar (Primary)	EdgeTech 4200	300/600 kHz Portable	Side Scan: 38216 Topside: 38213
Single Beam Echo Sounder	ODOM	Hydrotrac	Transducer: Topside: 11062
Attitude and Positioning System	CodaOctopus	F180	F0803009
Positioning System	CNAV	2050	CNAV Receiver: 5329
Positioning System	CNAV	2050	CNAV Receiver: 5399
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	12H100794
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221, 5221

Table 3. Survey equipment aboard the R/V *C-Ghost.*

System	Manufacturer	Model	Serial Number
Multibeam Echo Sounder (Port)	Kongsberg	EM3002	Transducer: 561 Topside: 1010
Side Scan Sonar (Primary)	EdgeTech 4200	30/600kHz Portable	Side Scan: 38168 Topside: 38162
Single Beam Echo Sounder	ODOM	CV100	Topside: 26034
Attitude and Positioning System	CodaOctopus	F180	F0104012
Attitude and Positioning System	CodaOctopus	F180	F0907076
Positioning System	CNAV	2050	CNAV Receiver: 5334
Positioning System	CNAV	2050	CNAV Receiver: 5332
Sound Speed at Transducer	YSI Electronics	600R-BCR-C-T	13H101931 13L100270
CTD	Sea-Bird Electronics, Inc	SBE 19 Plus	5221, 5222

A.2. SURVEY VESSELS

The majority of survey operations were conducted aboard the R/V *Sea Scout*, owned and operated by C & C Technologies. The R/V *Sea Scout* is a 134 foot (40.842 meter) catamaran survey vessel based out of New Iberia, Louisiana. Vessel profile and vessel specification information is shown in Table 4. Portions of survey operations were also conducted with the R/V *C-Wolf* and R/V *C-Ghost*, two 30 foot (9.144 meter) aluminum vessels owned and operated by C & C Technologies. Vessel profile and vessel specification information is shown in Tables 5 and 6. Vessel diagrams with all measured offsets from the central reference point (CRP) of each vessel are shown in Appendix 1: Vessel Reports – Vessel Offset Reports.

Table 4. R/V *Sea Scout* 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’
Beam	37’ 4”
Draft	6’ 6”
Freeboard	7’ 7.5”

Table 5. R/V *C-Wolf* Vessel Profile and Specifications

Owner/Operator	C & C Technologies, Inc.
Home Port / Flag	Lafayette, Louisiana / USA
Hull ID	JQN00027J708
LA Registration Number	LA-2935-FS
Year Built	2008
Builder	Razerhead Boats Inc.
Intended Service	Oceanographic Research
Operational Area	Shallow Water, USA
Length	30’
Beam	8.5’
Draft	2.5’
Freeboard	2.5’

Table 6. R/V *C-Ghost* Vessel Profile Specifications

Owner/Operator	C & C Technologies, Inc.
Home Port / Flag	Lafayette, Louisiana / USA
Hull ID	JQN00023E707
LA Registration Number	LA-4402-FR
Year Built	2007
Builder	Razerhead Boats Inc.
Intended Service	Oceanographic Research
Operational Area	Shallow Water, USA
Length	30’
Beam	8.5’
Draft	2.5’
Freeboard	2.5’

A.3. SURVEY COVERAGE METHODS

Two hundred percent (200%) side scan sonar coverage with concurrent set line spacing MBES coverage was acquired in H12635. Object Detection MBES with backscatter was acquired in H12634 and H12636. Fill-in lines were collected to ensure that the requirements for Object Detection MBES were met; all lines are included in the MBES processing logs. Full bathymetric coverage was also obtained within the radii of all AWOIS (Automated Wreck and Obstruction Information System) items assigned for full investigation. In H12634 and H12636, side scan sonar data was collected only for feature investigations; a mosaic was not generated but all side scan data (raw and processed) are included with survey deliverables.

Multibeam crossline data was acquired along transects perpendicular to the main scheme lines. Crossline mileage consisted of at least 8% of the main scheme line mileage in H12635, and at least 4% of the main scheme line mileage in H12634 and H12636, in accordance with Section 5.2.4.3 of the HSSD (2014). Refer to section B.1.3.1 for details on crossline comparisons.

Multibeam and side scan sonar operations specific to each vessel are outlined in the following sections.

A.3.1. **Multibeam Operations**

A.3.1.1. R/V *Sea Scout*

Multibeam survey operations aboard the R/V *Sea Scout* were conducted using both single head and dual head configurations comprised of Kongsberg EM2040C multibeam echo sounders. Each transducer is mounted on a retractable ram, one transducer in the port hull and one transducer in the starboard hull. The 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. When a single head configuration was used, it was always done so using the port transducer. The port transducer (serial number 0131) was operated at a frequency of 300 kHz. The multibeam sonar was operated in normal detection mode and equidistant beam spacing. Pertinent operational specifications of the EM2040C multibeam system are shown in Table 7. These specifications were obtained from the EM2040C product specification documentation.

Table 7. EM2040C Operational Specifications

Frequencies	200-400 kHz in steps of 10 kHz
No. of soundings per ping Single Head, Single Swath	400
No. of soundings per ping Single Head, Dual Swath	800
No. of soundings per ping Dual Head, Dual Swath	1600
Maximum Ping Rate	50 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	25 µs to 12 µs

A.3.1.2. R/V *C-Wolf* and R/V *C-Ghost*

Multibeam survey operations aboard the R/V *C-Wolf* and R/V *C-Ghost* were conducted with single Kongsberg EM3002 multibeam echo sounder configurations. The transducers aboard each vessel are mounted on a ram that extends through a moon pool in the center of the vessel that can be raised and lowered as needed for transit and survey operations.

The transducer aboard the R/V *C-Wolf* (serial number 561) was operated at a frequency of 300 kHz and the angular coverage of the sonar was typically set at 64 degrees from nadir. The transducer aboard the R/V *C-Ghost* (serial number 605) was also operated at a frequency of 300 kHz but with the angular coverage of the sonar typically set at 60 degrees from nadir. The multibeam sonar was operated in high-density equidistant beam spacing mode. The high density mode increased the number of soundings to 254 per ping. Pertinent operational specifications of the EM3002 multibeam system are shown in Table 8.

Table 8. EM3002 Operational Specifications

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

A.3.2. Side Scan Sonar Operations

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 the line spacing of 40, 60, and 90 meters, respectively. 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 (2014). 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 generally created using an even/odd numbering system to ensure that 200% coverage was obtained.

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 the required range scale. Confidence checks were observed and recorded in the logs.

Refer to the following sections, section C.2: Vessel Offset Measurements and Configuration and Appendix I: Vessel Reports – Vessel Layback Reports for additional side scan sonar layback information and vessel-specific operations.

A.3.2.1. R/V *Sea Scout*

A Klein 5000 V2 side scan sonar was operated in a towed configuration aboard the R/V *Sea Scout*. A hanging sheave mounted to a retractable A-frame at the stern of the vessel was used as the tow point. 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 acquisition logs and also digitally in the side scan .xtf files, and later used for layback calculations. The side scan sonar range scale did not exceed 100 m, in accordance with Section 6.1.2.4 of the HSSD (2014). 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 9), 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 quality and coverage.

Table 9. Klein 5000 V2 Product Specifications

Number of Beams	5 port and 5 starboard
Frequency	455 kHz
Resolution (along track)	10 cm at 50 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, 200 m and 250 m reconnaissance mode

A.3.2.2. R/V *C-Wolf* and R/V *C-Ghost*

An EdgeTech 4200 side scan sonar was operated in a towed configuration and a hanging sheave mounted to a fixed A-frame at the stern of the vessel was used as the tow point. The cable out values were recorded in the acquisition logs and later used for layback calculations. The side scan sonar range scale did not exceed 100 m, in accordance with Section 6.1.2.4 of the HSSD (2014). In general, the survey speed of the towed side scan sonar would be limited by the range scale. However, according to the EdgeTech 4200 product specifications, the sonar fish can be towed at higher speeds with no loss of bottom coverage when operating in the High Speed Mode. The survey speed did not reach the limits as stated in the product specifications (Table 10) 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 quality and coverage.

Table 10. EdgeTech 4200 Product Specifications

Number of Beams	2 port and 2 starboard
Frequency	300/600 kHz
Resolution (along track)	600 kHz: 0.6m @ 100m
Resolution (across track)	1.5 cm at 600 kHz
Operating Speed Envelope	4 to 12kts @ 150m

A.4. ADDITIONAL SURVEY OPERATIONS

A.4.1. **Singlebeam Operations**

An Odom Echotrac MK III was used to collect single beam data aboard the R/V *Sea Scout*; an Odom CV100 used aboard the R/V *C-Ghost;* and a Hydrotrac was used aboard the R/V *C-Wolf*. 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.

A.4.2. **Sound Speed Operations**

Sea Bird Electronics SBE19 and SBE19 Plus CTDs were used to calculate the speed of sound through the water column. Casts were performed at least twice daily aboard the R/V *Sea Scout* and more often as needed. In general, two CTDs were simultaneously lowered within a cage structure during each cast. Casts were performed at least once daily aboard the R/V *C-Wolf* and R/V *C-Ghost* and more often as needed. Endeco YSI 600R sondes were used to calculate the sound speed at the transducer. Refer to Section C.7 for additional information.

A.4.3. **Bottom Samples**

Bottom samples were acquired with a Wildco® Standard Ponar® grab sampler deployed from a winch aboard the R/V *Sea Scout*; no grab sample operations were conducted from the R/V *C-Wolf* or the R/V *C-Ghost*. The samples were described and photographed in the field; the bottom samples are fully attributed in the S-57 Final Feature File.

A.4.4. **Backscatter**

Backscatter was acquired and logged within each raw EM2040C and EM3002 file. The backscatter data was imported during CARIS conversion and reviewed when necessary. For areas where Object Detection with Backscatter coverage was acquired (H12634 and H12636), a backscatter mosaic was created using C & C Technologies' proprietary Hydromap software. This mosaic was then imported into the CARIS project for review and comparison with the BASE surface of the survey area. The backscatter mosaics are included in the respective Field Sheets directory of the survey deliverables.

A.5. ACQUISITION AND PROCESSING SOFTWARE

A list of data acquisition and processing software and systems are shown in Tables 11, 12, and 13. All systems on the network are synced using 1PPS strings from GPS. Updates to processing software are shown in Table 14.

Table 11. Data Acquisition and Processing Software – R/V *Sea Scout*

Purpose	Software	Version	Date of Installation
Multibeam Data Recording and Monitoring	Hydromap	n/a	11-20-2013
Multibeam Control Software	Seafloor Information System (SIS)	4.1.5	07-01-2014
Side Scan Collection	SonarWiz5	V.5.06.0039	07-01-2014
Side Scan Processing	SonarWiz5	V.5.06.0039	07-01-2014
Multibeam Processing	CARIS HIPS/SIPS	8.1.7	07-01-2014
Multibeam Processing	Notebook	3.1.1 with SP1	07-01-2014
CTD Conversion Tool	Seabird Electronics Sea Term	1.5.0.9	07-01-2014
CTD Conversion Tool	Seabird Electronics Data Conversion	7.22.0.2	07-01-2014
CTD Conversion Tool	SVTool	1.2	07-01-2014
IMU control software	F180 Series	3.04.0004	07-01-2014

Table 12. Data Acquisition and Processing Software – R/V *C-Wolf*

Purpose	Software	Version	Date of Installation
Multibeam Data Recording and Monitoring	Hydromap	n/a	05-25-2014
Multibeam Control Software	Seafloor Information System (SIS)	3.4.3	05-25-2014
Side Scan Collection	SonarWiz5	V.5.06.0024	05-25-2014
Side Scan Processing	SonarWiz5	V.5.06.0039	07-01-2014
Multibeam Processing	CARIS HIPS/SIPS	8.1.7	07-01-2014
Multibeam Processing	Notebook	3.1.1	07-01-2014
CTD Conversion Tool	Seabird Electronics Sea Term	1.59	05-25-2014
CTD Conversion Tool	Seabird Electronics Data Conversion	7.23.1	05-25-2014
CTD Conversion Tool	SVTool	1.2	05-25-2014
IMU control software	F180 Series	3.04.0002	05-25-2014

Table 13. Data Acquisition and Processing Software - R/V *C-Ghost*

Purpose	Software	Version	Date of Installation
Multibeam Data Recording and Monitoring	Hydromap	n/a	05-25-2014
Multibeam control Software	Seafloor Information System (SIS)	3.4.3	05-25-2014
Side Scan Collection	SonarWiz5	V.5.06.0024	05-25-2014
Side Scan Processing	SonarWiz5	V.5.06.0039	07-01-2014
Multibeam Processing	CARIS HIPS/SIPS	8.1.7	07-01-2014
Multibeam Processing	Notebook	3.1.1	07-01-2014
CTD Conversion Tool	Seabird Electronics Sea Term	1.59	05-25-2014
CTD Conversion Tool	Seabird Electronics Data Conversion	7.23.1	05-25-2014
CTD Conversion Tool	SVTool	1.2	05-25-2014
IMU control software	F180 Series	3.04.0002	05-25-2014

Table 14. Data Processing Software Updates

Purpose	Software	Version	Date of Installation
Side Scan Processing (Office)	SonarWiz5	V.5.06.0049	03/25/2014
Side Scan Processing (Office)	SonarWiz5	V.5.07.0007	09/15/2014
Side Scan Processing (Office)	SonarWiz5	V.5.07.0009	09/26/2015
Side Scan Processing (Office)	SonarWiz5	V.5.07.0011	10/20/2014
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.4	01/13/2014
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.7	03/10/2014
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.8	07/09/2014
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.9	10/01/2014
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.12	03/20/2015
Multibeam Processing (Office)	CARIS HIPS/SIPS	8.1.13	06/01/2015

Kongsberg's Seafloor Information System (SIS) software was used as the control software for the multibeam echo sounders. 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 allow the operator to monitor coverage, compare between single beam and multibeam depths, monitor the various 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 re-runs were necessary due to degraded quality of data during acquisition or due to lack of coverage, the aforementioned difficulties were logged in the field. Additional data was collected for quality assurance. Hydromap software was used to monitor the survey line plan and also allow the boat operator(s) to maintain on-line control for all vessels in the field.

Multibeam data processing was conducted using CARIS HIPS and SIPS 8.1. 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 in the Final Feature File. The NOAA Extended Attribute File V5_3_2 was used. The multibeam processing workflow is detailed in Section B.1.3.

The side scan sonar data was collected, processed, evaluated, and additionally utilized in the identification of contacts via Chesapeake Technologies' SonarWiz software. 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-K339-KR-14 was processed using CARIS HIPS and SIPS 8.1. 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 to data collection. Uncertainty estimates assigned are further described in the following sections. The vessel files used for this project are included in the Data\Processed\HDCS\VesselConfig folder for each sheet.

CARIS HIPS was used to apply tides, merge, compute TPU, apply SVC if necessary, 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.

B.1.1. **CARIS Vessel Files**

B.1.1.1. R/V *Sea Scout*

Several vessel files were created for the R/V *Sea Scout*. At commencement of survey operations in H12635, only one vessel file was generated, regardless of whether data was collected with one or two transducers. CARIS correspondence indicates that this should not be an issue for the type of MBES system in use. However, CARIS indicated that it is generally best practice to keep data collected with one transducer associated with one .hvf vessel file and data collected with dual transducers associated with a separate .hvf vessel file. This was the method employed for H12634 and H12636.

The vessel file used for H12635 is called SS_140720. The vessel files used for H12634 and H12636 are SeaScout_OneTransducer and SeaScout_Two_Transducers, each noting the distinction between the working parameter(s). It was observed and confirmed in the acquisition logs that when data was collected with one transducer, it was SH1; SH1 is recognized as the port head on the vessel.

The R/V *Sea Scout* vessel files contain the following active sensors: Transducer 1, Navigation, Gyro, Heave, Pitch, Roll, Draft, and TPU. The SS_140720 and dual transducer vessel file (SeaScout_Two_Transducers) additionally contain Transducer 2 as per their working specification parameters.

Transducer 1: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) because the location of the transducer is 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) because the data is corrected for these during data acquisition using the SIS control software.

Transducer 2: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) because the location of the transducer is 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) 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 Gyro fields are edited because no offset was applied and the F180 IMU is aligned to the ship's 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 in real-time during data acquisition.

Draft: A squat and settlement test was performed in order to correct for the dynamic draft of the vessel (Table 15). All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 15. Vertical displacement of R/V *Sea Scout* with speed

Vertical Correction (m)	Speed (m/s)
0.00	0.00
-0.01	1.91
-0.01	2.49
-0.01	2.88
-0.03	3.40
-0.04	3.88
-0.05	4.36

TPU Offsets: The offsets (Tables 16 and 17) were calculated from known locations of the equipment from the CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

Table 16. R/V *Sea Scout* MRU to Transducer offsets

Transducer	MRU to Trans X (m)	MRU to Trans Y (m)	MRU to Trans Z (m)
Transducer 1	-2.925	-1.540	7.184
Transducer 2	3.514	-1.545	7.243

Table 17. R/V *Sea Scout* NAV to Transducer offsets

Transducer	NAV to Trans X (m)	NAV to Trans Y (m)	NAV to Trans Z (m)
Transducer 1	-3.070	3.665	12.510
Transducer 2	3.369	3.660	12.569

According to CARIS 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; therefore, the Transducer Roll (deg) is equal to the offset angle entered in the SIS control software (Table 18).

Table 18. Values entered in the Transducer Roll fields of the TPU Offsets section for the R/V *Sea Scout*.

Date	Transducer 1 Roll (deg)	Transducer 2 Roll (deg)
June 17, 2014	0.388	0.540

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 19. Explanation and reasoning are further explained in the following text.

Table 19. Values entered for the TPU Standard Deviation section of the HVF for the R/V *Sea Scout.*

Field	Value
Motion Gyro:	0.05°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.05 m
Timing Trans:	0.01 s
Nav Timing:	0.01 s
Gyro Timing:	0.01 s
Heave Timing:	0.01 s
Pitch Timing:	0.01 s
Roll Timing:	0.01 s
Offset X:	0.0017 m
Offset Y:	0.0037 m
Offset Z:	0.0009 m
Vessel Speed:	0.73 m/s
Loading:	0.0165 m
Draft:	0.056 m
Delta Draft:	0.02 m
MRU Align StdDev Gyro:	0.029°
MRU Align StdDev Roll/Pitch:	0.04°

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, which 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.

The Timing Trans and Nav, Gyro, Heave, Pitch and Roll Timing values were set to 0.01 s as they are serial connections, and 0.01 s is an appropriate value according to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual.

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 20).

Table 20. Errors of measured R/V *Sea Scout* 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 the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.36 knots (0.7 m/s) was used for the average current (Johnson, 2008).

Loading: Historically, the loading uncertainty has been calculated as the difference between the maximum and minimum draft measured for the duration of the survey. Correspondence with CARIS (refer to Project_Reports\Project_Correspondence) indicates that this is high when the draft is measured every day and an updated method was established. First, the difference between the minimum and maximum draft measured during each day was calculated. CARIS correspondence indicated that this value could be halved, but was not in order to provide a more conservative estimate. The differences for all the days were then averaged together for an estimate of the loading uncertainty.

Draft: The standard deviation of the draft measurements taken for the duration of survey operations.

Delta Draft: The dynamic draft data consists of 6 sets of lines run at varying speeds and the squat of the vessel at each speed. The standard deviation was calculated for each set of squat values for a specified speed setting and then averaged together for a final value.

According to the 2014 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. Several processors resolved the patch test several times in CARIS to calculate the standard deviations. Refer to Appendix II: System Alignment Reports for additional information.

B.1.1.2. R/V *C-Wolf*

The R/V *C-Wolf* vessel file contains the following active sensors: Transducer 1, Navigation, Gyro, Heave, Pitch, Roll, Draft and TPU. Note that the SVP section may still show up in the vessel file as it was unable to be removed although no lines were sound velocity corrected.

Transducer 1: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) for Transducer 1 because the location of the transducer is 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) 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 Gyro fields are edited because no offset was applied and the F180 IMU is aligned to the ship's 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 in real-time during data acquisition.

Draft: A squat and settlement test was performed in order to correct for the dynamic draft of the vessel (Table 21). All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 21. Vertical displacement of the R/V *C-Wolf* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.00
-0.01	1.55
-0.02	2.15
-0.07	3.32
-0.10	3.70

TPU Offsets: The offsets (Tables 22 and 23) were calculated from known locations of the equipment from CRP (refer to Appendix I: Vessel Reports – Vessel Offsets Report for additional information).

Table 22. MRU to Transducer offsets for the R/V *C-Wolf*.

MRU to Trans X (m)	MRU to Trans Y (m)	MRU to Trans Z (m)
0	-4.275	0.64

Table 23. NAV to Transducer offsets for the R/V *C-Wolf*

NAV to Trans X (m)	NAV to Trans Y (m)	NAV to Trans Z (m)
0.435	-1.158	3.11

According to CARIS correspondence, the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducer aboard the R/V *C-Wolf* is mounted flat; therefore the value entered in the Transducer Roll is equal to the offset angle entered in the SIS control software (Table 24).

Table 24. Transducer Roll for the R/V *C-Wolf*

Date	Trans Roll (deg)
Jun 2, 2014	-0.15

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 25. Explanation and reasoning are further detailed in the following text.

Table 25. Values entered for the TPU Standard Deviation section of the HVF for the R/V *C-Wolf*.

Field	Value
Motion Gyro:	0.1°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.1 m
Timing Trans:	0.01 s
Nav Timing:	0.01 s
Gyro Timing:	0.01 s
Heave Timing:	0.01 s
Pitch Timing:	0.01 s
Roll Timing:	0.01 s
Offset X:	0.02 m
Offset Y:	0.02 m
Offset Z:	0.02 m
Vessel Speed:	0.73 m/s
Loading:	0.070 m
Draft:	0.016 m
Delta Draft:	0.012 m
MRU Align StdDev Gyro:	0.05°
MRU Align StdDev Roll/Pitch:	0.05°

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, which match the specifications in the F180 user's manual.

The Position NAV (m) was 0.1 m for survey operations conducted using the C-Nav 2050 as the primary navigation.

The Timing Trans and Nav, Gyro, Heave, Pitch and Roll Timing values were set to 0.01 s as they are serial connections, and 0.01 s is an appropriate value according to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual.

The X/Y/Z Offset values: The survey of the equipment offsets on the R/V *C-Wolf* was carried out using a total station. Typical accuracies are between 2 and 3 cm.

Vessel Speed: According to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.36 knots (0.7 m/s) was used for the average current (Johnson, 2008).

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

Draft: The standard deviation of the draft measurements taken for the duration of survey operations.

Delta Draft: The dynamic draft data consists of 4 sets of lines run at varying speeds and the squat of the vessel at each speed. The standard deviation of each set of squat values for a specific speed setting was calculated and then averaged together for a final value.

According to the 2014 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. Several processors resolved the patch test several times in CARIS to calculate the standard deviations. Refer to Appendix II: System Alignment Reports for additional information.

B.1.1.3. R/V *C-Ghost*

The R/V *C-Ghost* vessel file contains the following active sensors: Transducer 1, Navigation, Gyro, Heave, Pitch, Roll, Draft, TPU. Note that the SVP section may still show up in the vessel file as it was unable to be removed although no lines were sound velocity corrected.

Transducer 1: The X/Y/Z fields (the location of the transducer from the reference point) are zero (0) for Transducer 1 because the location of the transducer is 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 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 Gyro fields are edited because no offset was applied and the F180 IMU is aligned to the ship's 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 (Table 26). All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file. Refer to Section C.3: Static and Dynamic Draft Corrections for additional information.

Table 26. Vertical displacement of the R/V *C-Ghost* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.00
-0.01	1.54
-0.02	2.06
-0.03	2.83
-0.05	3.34
-0.08	4.12
-0.08	5.14

<u>TPU Offsets</u>: The offsets (Tables 27 and 28) were calculated from known locations of the equipment from CRP (refer to Appendix 1: Vessel Reports – Vessel Offsets Report for additional information).

Table 27. MRU to Transducer offsets for the R/V *C-Ghost*.

MRU to Trans X (m)	MRU to Trans Y (m)	MRU to Trans Z (m)
0.000	-4.676	0.930

Table 28. NAV to Transducer offsets for the R/V *C-Ghost*.

NAV to Trans X (m)	NAV to Trans Y (m)	NAV to Trans Z (m)
0.387	-1.302	3.214

According to CARIS correspondence, the Transducer Roll is the mounting angle of the Receive Array + Roll Calibration. The transducer aboard the R/V *C-Ghost* is mounted flat; therefore the value entered in the Transducer Roll is equal to the offset angle entered in the SIS control software (Table 29). Several separate patch tests were performed for the R/V *C-Ghost*. Only data collected after the July 16, 2014 patch test was used in the final CARIS projects for 2014 data. A supplementary calibration was conducted on March 21, 2015 prior to collecting additional data.

Table 29. Values entered in the Transducer Roll field of the TPU Offsets section for the R/V *C-Ghost*.

Date	Trans Roll (deg)
July 16, 2014	1.42
March 21, 2015	1.17

TPU Standard Deviation:

The values entered for the Standard Deviation are shown in Table 30. Explanation and reasoning are further detailed in the following text.

Table 30. Values entered for the TPU Standard Deviation section of the HVF for the R/V *C-Ghost*.

Field	Value
Motion Gyro:	0.1°
Heave % Amplitude:	5%
Heave (m):	0.05 m
Roll:	0.025°
Pitch:	0.025°
Position Nav:	0.1 m
Timing Trans:	0.01 s
Nav Timing:	0.01 s
Gyro Timing:	0.01 s
Heave Timing:	0.01 s
Pitch Timing:	0.01 s
Roll Timing:	0.01 s
Offset X:	0.02 m
Offset Y:	0.02 m
Offset Z:	0.02 m
Vessel Speed:	0.73 m/s
Loading:	0.143m
Draft:	0.030m
Delta Draft:	0.007 m
MRU Align StdDev Gyro:	0.08°
MRU Align StdDev Roll/Pitch:	0.085°

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, which match the specifications in the F180 user's manual.

The Position NAV (m) was 0.1 m for survey operations conducted using the C-Nav 2050 as the primary navigation.

The Timing Trans and Nav, Gyro, Heave, Pitch and Roll Timing values were set to 0.01 s as they are serial connections, and 0.01 s is an appropriate value according to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual.

The X/Y/Z Offset values: The survey of the equipment offsets on the R/V *C-Ghost* was carried out using a total station. Typical accuracies are between 2 and 3 cm.

Vessel Speed: According to the Chapter 4 Appendix – CARIS HVF Uncertainty Values of the 2014 NOAA Field Procedures Manual, this value is 0.03 plus the average current in the area; a value of 1.36 knots (0.7 m/s) was used for the average current (Johnson, 2008).

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

Draft: The standard deviation of the draft measurements taken for the duration of survey operations.

Delta Draft: The dynamic draft data consists of 5 sets of lines run at varying speeds and the squat of the vessel at each speed. The standard deviation of each set of squat values for a specific speed setting was calculated and then averaged together for a final value.

According to the 2014 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. Several processors resolved the patch test several times in CARIS to calculate the standard deviations. Refer to Appendix II: System Alignment Reports for additional information.

B.1.2. **Total Propagated Uncertainty (TPU)**

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

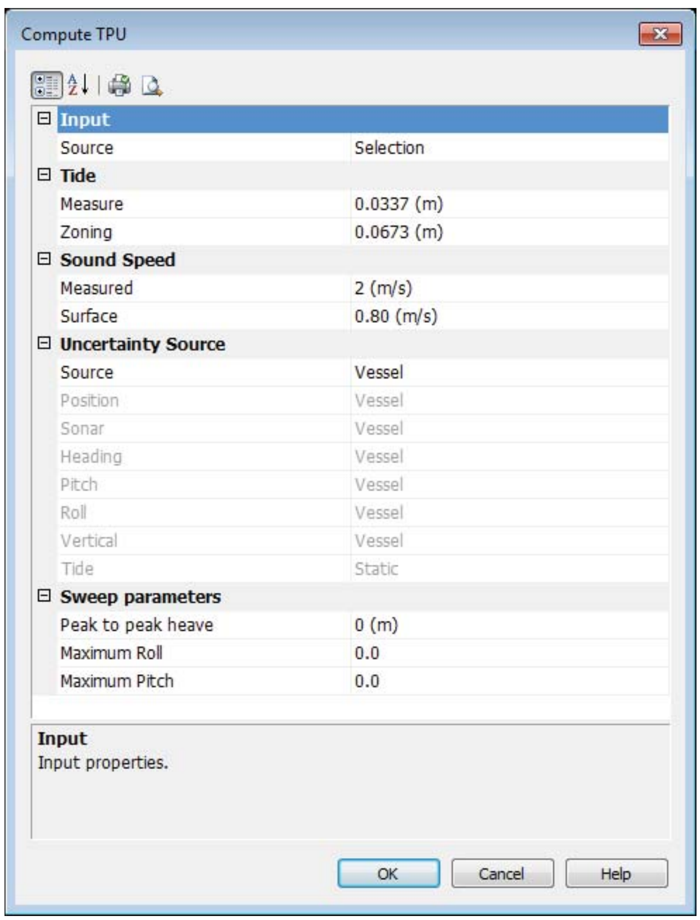


Figure 1. Total Propagated Uncertainty (TPU) values.

B.1.2.1. Tide Component

According to section 1.3.3 of the Tides and Water Levels Statement of Work for this project (OPR-K339-KR-14), the estimated tidal error contribution to the survey area is 0.198 meters at the 95% confidence level. This estimate includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error.

According to section 4.1.6 of the HSSD (2014) the typical measurement error is 0.10 m at the 95% confidence level and the tidal zoning error is 0.20 m at the 95% confidence level. This indicates that the typical tidal zoning error is twice that of the typical measurement error. Although the provided estimate of 0.198 m is less than the tidal and measurement errors suggested in the HSSD (2014), the estimate was divided into a zoning component and a measurement component, keeping the proportions as close to that of the values of the HSSD (2014) as possible.

A value of 0.132 m of the 0.198 m was attributed to the zoning error and 0.066 m was attributed to the measurement error. All error values entered in CARIS for the TPU calculation are assumed to be at the 1 sigma level, according to the Field Procedures Manual Section 4.2.3.8 and both the zoning and measurement errors were further divided by 1.96. Therefore, a final value of 0.0673 m was entered as the zoning tide value and 0.0337 m was entered as the measurement error.

Although the estimated tidal error contribution includes the datum error, which is typically 0.11 m for the Gulf coast at the 95% confidence level, according to section 4.1.6 of the HSSD (2014), no datum error was subtracted out of the provided estimated tidal error to provide more conservative values for the measurement and zoning errors.

B.1.2.2. Sound Speed Component

The measured sound speed 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) are known. The specifications for the 600R (http://www.ysi.com/productsdetail.php?600R-9) are shown in Table No. 31 and the known amount by which a certain change in salinity and temperature affect sound speed are shown in Table No. 32.

Table 31. 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 32. 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 31) 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. 31) 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.

B.1.2.3. Horizontal and Vertical Uncertainty Components

The CARIS TPU command computes both a horizontal TPU (HzTPU) and depth TPU (DpTPU). According to section 3.1.1 of the HSSD (2014), 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 (2013) 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 sample values are shown in Table 33.

Table 33. Maximum IHO Order 1 TVU values for water depths of 1 – 25 m in increments of 5 m.

a	b	Water Depth (m)	Maximum (TVU)
0.5	0.013	1	0.500
		5	0.504
		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. The TVU was specifically examined by generating two additional QC BASE surface layers for the non-finalized surfaces. The first (TVU_Maximum) calculates the maximum TVU at each node with the below formula and was used in determination of designating versus examining soundings on features:

$$\sqrt{(0.5^2) + (0.013 * Depth)^2}$$

The second layer generated was defined as the difference between the TVU_Maximum and Uncertainty layers. Positive values indicate that the Uncertainty < TVU_Maximum, which is ideal, while negative values indicate that the Uncertainty > TVU_Maximum. These areas were further reviewed if necessary.

In accordance with section 5.1.2 of the HSSD (2014), all depths reported in the deliverables are accompanied by the estimate of TPU.

B.1.3. **Multibeam Processing**

Upon commencement of data acquisition for a Sheet, a CARIS project was created for the Sheet and multibeam lines converted by the processor on shift. All lines converted were assigned a project, vessel, and day. Preliminary tidal data from the 8760922 (Pilot Station East, SW Pass, LA) water level station was downloaded from the CO-OPS website: http://opendap.co-ops.nos.noaa.gov/axis//text.html or the NOAA Tides and Currents website and applied to all data in CARIS using the tidal zoning file supplied by CO-OPS (Refer to Section C.8 for detailed tide correction information). The lines were merged, TPU was computed and an uncertainty BASE surface created; resolution varied depending on the coverage type for each Sheet.

Multibeam data were reviewed using the CARIS HIPS swath editor with the BASE surface and pertinent background data open. Background data included the chart(s) and the line files, as well as the PRF and CSF provided by NOAA. For areas where both multibeam and side scan sonar data were collected, the preferred multibeam review method involves the ability to simultaneously review the side scan sonar data. When this was not possible, potential contacts were designated in the CARIS project and noted in multibeam processing log for future review with the side scan sonar data. In swath editor, erroneous and noisy data was rejected from the project.

In addition, if applicable, a 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 main scheme 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 were incorporated into BASE surfaces and then cleaned in swath editor and subset editor. 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 were reviewed with respect to main scheme multibeam lines, charted data, and, if available, 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 and swath editor, as wells as comparison to charts, side scan sonar, backscatter data and side scan sonar contacts imported from SonarWiz. If data were found to misrepresent the seafloor, it was rejected. In addition, the BASE surface was evaluated using the CARIS 3D window with increased vertical exaggeration that can highlight outliers as well as potential contacts.

All examined soundings on the surface were reviewed and were either changed to designated or retained as examined using the criteria outlined in section 5.2.1.2 of the HSSD (2014). A designated sounding was selected when the difference between the closest grid node depth and shallower sounding on a feature is more than one-half the maximum allowable TVU at that depth (< 20 m depth) or when the difference is more than the maximum allowable TVU at that depth (> 20 m depth). A TVU_Maximum layer, addressed in section B.1.2.3, was generated for each surface that would be finalized and used during this review.

BASE surfaces were named as <Survey registry number>_<Sounding Type>_<units of resolution>_<Vertical Datum>, as specified in section 8.4.2 of the HSSD (2014). If more than one BASE surface of the same resolution exists, a suffix of <#of#> (e.g. 1of2, 2of2) was added to the BASE surface name. All BASE surfaces were created as uncertainty surfaces based upon IHO Order 1a standards. BASE surface resolution varied depending on depth and acquisition method, and is detailed in each descriptive report.

Crossline comparisons were generated on a regular basis as a quality control tool, which is explained further in the following section.

B.1.3.1. Crossline Comparisons

Crosslines were run perpendicular to mainscheme survey lines and comprised at least 8% of mainscheme line mileage for Set Line Spacing coverage and 4% for Object Detection/Full MBES Coverage, in accordance with Section 5.2.4.3 of the HSSD (2014). Crossline comparisons were performed as a quality control tool to identify systematic errors and blunders in the survey data.

B.1.3.1.1 Hydromap Statistical Comparisons

C & C Technologies' proprietary Hydromap software 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 from nadir, 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 are used for analysis. Processing parameters are set to use all beams with no filtering, and tidal effects 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. Data is provided in graphical form in a separate PDF document for each main line. A selection of these PDF's is found in Separates II of the deliverables.

B.1.3.1.2 CARIS Comparisons

Crossline comparisons were performed in CARIS HIPS 8.1 using the surface difference tool. Separate 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 Vertical Uncertainty (TVU), as outlined in Section 5.2.4.3 of the HSSD (2014). 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 BASE surface of the mainscheme lines (the reference surface). The crossline sounding data were grouped by beam number. Survey statistic outputs include 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 Order 2), 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 Field Sheet directory.

B.1.3.2. Reporting, Products and Finalization

Junction analysis was performed between adjoining contemporary and historical surveys 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 using cleaned BASE surfaces of main scheme and investigation lines, colored depth ranges, and sounding layers. The data were compared to the largest scale charts in this area. Data was compared to the most recent nautical charts, and updates to the charts are specified in each Descriptive Report.

The sounding layer to which charted soundings were compared was generated from the 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 meters). A single-defined radius was chosen that generated a sufficient amount of soundings, which 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. The designated soundings were applied in order to maintain the shallowest soundings within the final BASE surface (Figure 2). Any depth threshold applied is detailed in the Descriptive Reports.

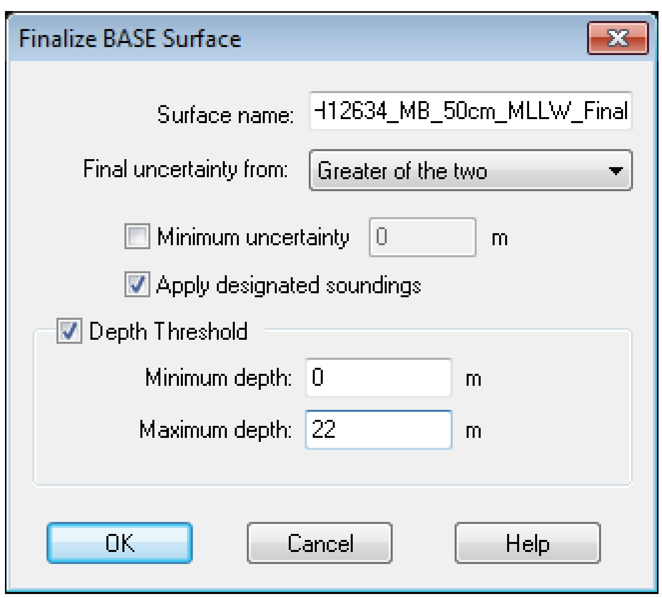


Figure 2. Sample BASE surface finalization parameters.

B.2. SIDE SCAN SONAR

B.2.1. **Image Processing**

Side scan sonar data were processed using Chesapeake Technologies' SonarWiz5. The water column was auto tracked in the field and the data slant range corrected after the data was imported into SonarWiz5. The bottom track was also reviewed during post-processing. The side scan sonar files were either layback corrected in Sonarwiz or Hydromap and gains applied when necessary. The side scan sonar data were evaluated and contacts identified, always selected from slant-range corrected data. Bottom tracked and layback corrected files were exported from SonarWiz in included with the final deliverables.

B.2.2. **Data Review 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 were also reviewed at least twice during post processing. 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; gaps were filled when possible.

When applicable (e.g. when 200% side scan sonar data was acquired), a mosaic for each 100% side scan sonar coverage of the Sheet was created and submitted for the requirement of the final deliverables. The coverage mosaics were generated from lines that were identified by an even/odd numbering system. These mosaics served as an additional quality control tool and were not only used for coverage but were used to correlate contacts seen on adjacent lines. The mosaics can be found in the Data\Processed\Field Sheets directory.

B.2.3. **Contact Selection**

Sonar contacts were identified and selected as each line was reviewed. All contacts with shadows were selected when possible. In areas where a high density of contacts exist in close proximity, the hydrographer retained the ability to select the area as a region, ensuring that the contact with the greatest height off bottom was selected and/or the least depth examined in the bathymetry. All existing infrastructure, such as pipelines, wells, platforms, and buoys were also documented.

In addition to measuring the dimensions of each contact in SonarWiz, contacts were assigned two attributes to aid in the processing workflow. The first attribute is related to the nature of the contact and one of several descriptors was chosen for each contact. These included, but may not be limited to: insignificant contact (INSCON), significant contact (SIGCON), linear contact not clearly a pipeline (LINEAR), offshore platform (OFSPLF), submerged pipeline (PIPSOL), jetty or groin (JETTY), submerged cable (CBLSUB), fish contact (FSHGRD), seabed area (SBAREA), unknown contacts (UNKCON), buoys (BUOY) and WRECKS. Most of these descriptors fulfill the requirement of updating the NINFOM for the customized attributes for the side scan sonar list as outlined in 8.2 of the HSSD (2014). However, the hydrographer may elect to retain LINEAR, INSCON and SIGCON if unsure of the exact nature of the feature. The second attribute is related to the significance of the contact and might include descriptors such as INSCON, SIGCON, OBSTRN and DTON.

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 6.1.3.2 of the HSSD (2014). These contacts were always given the attribute 'SIGCON' during processing. Other contacts may have been deemed significant based on their characteristics (dimensions, strength of return, location etc.).

Large schools of fish were identified by shape, detached shadows and observations recorded in the acquisition logs. If selected, these contacts were noted as FSHGRD; however, fish were not generally picked as contacts. The label seabed area (SBAREA) was used to include seabed change and features such drag scars. The unknown (UNKCON) label was used only if no shadow could be measured and no other descriptor could be used to identify the feature. The majority of the UNKCON contacts are picked generally because of possible correlation to either a significant or insignificant feature found on an adjacent line based on 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 exported from SonarWiz as a Comma Delimited File (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 opened in CARIS.

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 further investigated. Danger to Navigation (DtoN) reports were submitted for uncharted significant contacts and structures, if necessary.

After 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 Description field updated in SonarWiz, which would become the 'Remarks' field in the final S-57 deliverable. This final S-57 file of all the contacts was generated in accordance with section 8.2 of the HSSD (2014).

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 J of the 2014 HSSD (Figure 3).

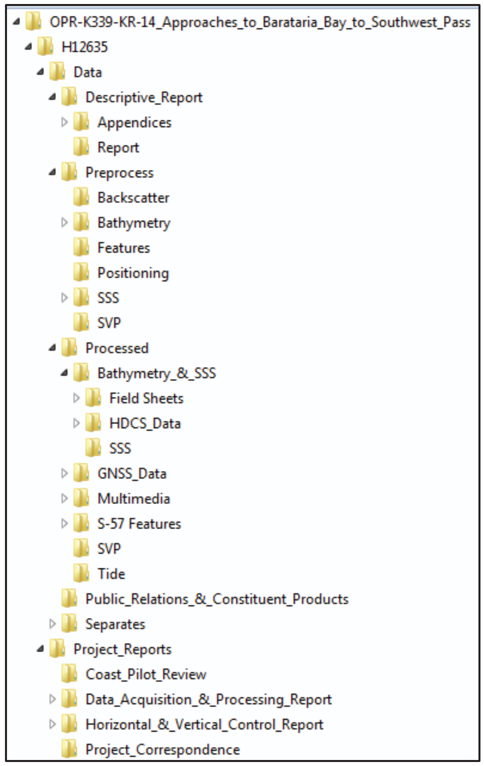


Figure 3. Overview of data directory structure.

Within the Processed\Bathymetry_&_SSS folder a <Field Sheets> folder and an <HDCS Data> folder were added to the directory structure to remain consistent with the CARIS processing directories. An additional SSS folder was also added and populated with fully corrected SSS files exported from SonarWiz. No folders were removed from the directory structure as listed in Appendix J; if no data exists for that particular folder, a text file explanation is included.

C. CORRECTIONS TO ECHO SOUNDINGS

C.1. INSTRUMENT CORRECTIONS

In order to ensure that the multibeam system was functioning properly, the single beam 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**

C.2.1.1. R/V *Sea Scout*

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. Figure 4 shows a picture of the R/V *Sea Scout* and a vessel diagram with all measured offsets from the central reference point is shown in Appendix I: Vessel Reports – Vessel Offset Reports.

Figure 4. R/V *Sea Scout*.

C.2.1.2. R/V *C-Wolf*

The offsets for the R/V *C-Wolf* were measured with a total station while the vessel was trailered. Figure 5 shows a picture of the R/V *C-Wolf* and a vessel diagram with all measured offsets from the central reference point is shown in Appendix I: Vessel Reports – Vessel Offset Reports.

Figure 5. R/V *C-Wolf*

C.2.1.3. R/V C-*Ghost*

The offsets for the R/V *C-Ghost* were measured with a total station while the vessel was trailered. Figure 6 shows a picture of the R/V *C-Ghost* and a vessel diagram with all measured offsets from the central reference point is shown in Appendix I: Vessel Reports – Vessel Offset Reports.

Figure 6. R/V *C-Ghost*

C.2.2. Layback

Layback was either applied to the side scan sonar XTF files during post-processing using SonarWiz 5, or during post-processing using C & C Technologies' Hydromap software. Refer to Appendix I: Vessel Reports – Vessel Layback Report for additional information.

C.3. STATIC AND DYNAMIC DRAFT

C.3.1. R/V *Sea Scout*

Static draft measurements were generally read twice daily during survey operations. The R/V *Sea Scout* is equipped with two draft tubes, one on the port side and one on the starboard side, 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 5.136 and 5.198 m on the port and starboard sides, respectively. Therefore, an addition of 1.2 m to each of these values (6.336 m and 6.398 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 6.336 m and 6.398 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; if only one head is in use, the one relevant draft measurement is used.

In order to correct for the dynamic draft of the vessel, a squat and settlement test was performed in Calcasieu Pass, LA on March 25, 2014. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

C.3.2. R/V *C-Wolf*

Static draft aboard the RV *C-Wolf* is measured using a rod that is placed down through a hole in the top of the multibeam ram. The rod measures the distance from the waterline to the top of the EM3002 mounting plate. This value is then put into the draft formula to obtain the waterline to CRP measurement, which is entered into SIS.

In order to correct for the dynamic draft of the R/V *C-Wolf*, a squat and settlement test was performed in at Cypremort Point, LA on April 22, 2014. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

C.3.3. R/V *C-Ghost*

Static draft aboard the RV *C-Ghost* is measured using a rod that is placed down through a hole in the top of the multibeam ram. The rod measures the distance from the waterline to the top of the EM3002 mounting plate. This value is put into the draft formula to obtain the waterline to CRP measurement, which is entered into SIS.

In order to correct for the dynamic draft of the R/V *C-Ghost*, a squat and settlement test was performed in Lake Duplechin, LA on March 18, 2015. Refer to Appendix I: Vessel Reports – Dynamic Draft Report for additional information.

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 R/V *C-Wolf* and R/V *C-Ghost* have similar configurations, except that the vessels are equipped with C-Nav 2050 receivers.

The C-Nav 3050 receivers use the C-Nav Subscription Services, which can achieve 5 cm horizontal accuracy and 10 cm vertical accuracy. The C-Nav 2050 receivers also use the C-Nav Subscription Services and can achieve 10 cm position accuracy. These systems are controlled and monitored with either a C-Navigator system or the C-Setup control software.

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. The antenna baseline for the F180 is 2.151 m on the R/V *Sea Scout*, 1.485 m on the R/V *C-Wolf,* and 1.560 m on the R/V *G-Ghost*. Manufacturer accuracies are shown in Table 34.

Table 34. Manufacturer accuracies for the CodaOctopus F180 attitude and positioning system.

Baseline	Heading	Roll	Pitch	Heave
2 meter	0.05º	0.025º	0.025º	The greater of 5% of heave amplitude or 5 cm
1 meter	0.1º	0.025º	0.025º	The greater of 5% of heave amplitude or 5 cm

C.5. EQUIPMENT OFFSETS

Equipment offsets from the CRP were entered directly into the Kongsberg SIS software. The Primary C-Nav 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, if applicable. The F180 offsets were entered in POS, COM4, Attitude 1, COM2 and Attitude 2, COM3.

C.6. MULTIBEAM CALIBRATIONS

Prior to commencement of survey operations, a standard patch test was performed for each vessel to quantify the error biases for navigation timing, pitch, roll and heading. CARIS HIPS and SIPS 8.1 was used to calculate these error biases, and C & C Technologies' proprietary software Hydromap was used to verify the results. 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. Refer to the patch test report for additional information. Refer to Tables 35 – 37 for vessel specific values.

A supplementary patch test was conducted for the R/V *Sea* Scout on April 29, 2015 (Table 38). Patch tests were also performed on June 7th, June 11th, and June, 26th 2014 for the R/V *C-Ghost*. Data collected using the values from these patch tests was not used for any sheet. A supplementary calibration was conducted on March 21, 2015 prior to collecting additional data with the R/V *C-Ghost* (Table 39).

Table 35. Patch Test Results (R/V *Sea Scout* –July 17, 2014)

	Roll	Pitch	Heading
Port Transducer	0.388°	0.000°	0.050°
Starboard Transducer	0.540°	0.429°	1.250°

Table 36. Patch Test Results (R/V *C-Wolf* – June 2 and 3, 2014)

	Roll	Pitch	Heading
Multibeam Transducer	-0.150°	-2.120°	-1.000

Table 37. Patch Test Results (R/V *C-Ghost* – July 16, 2014)

	Roll	Pitch	Heading
Multibeam Transducer	1.420°	1.960°	1.260°

Table 38. Patch Test Results (R/V *Sea Scout* –April 29, 2015)

	Roll	Pitch	Heading
Port Transducer	-1.05°	-0.47°	1.79°
Starboard Transducer	-0.90°	-0.22°	2.40°

Table 39. Patch Test Results (R/V *C-Ghost* – March 21, 2015)

	Roll	Pitch	Heading
Multibeam Transducer	1.17°	1.85°	0.77°

C.7. SOUND SPEED CORRECTIONS

Seabird Electronics SBE19 and SBE19 Plus CTDs were used to collect sound speed data through the water column. Simultaneous sound speed profiles were acquired aboard the R/V *Sea Scout* (Figure 7) and reviewed together as a quality control check; only one cast was typically conducted aboard the R/V *C-Wolf and* R/V *C-Ghost.* The profile would be entered into the SIS control software and the multibeam data corrected for the water column sound speed in real-time. Prior to importation into SIS, 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 mean water column sound speed generated from the chosen sound speed profile was applied to the single beam echo sounder data.

Figure 7. CTD set-up on the R/V *Sea Scout*.

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

The digital sound speed data and confidence checks can be found in: \Separates \II_Digital_Data\Sound_Speed_Data_Summary. In addition, a summary (.csv file) of the sound speed data acquired can be found in the Sound_Speed_List folder. This file was imported into Notebook 3.1 and exported as an S-57 file to be easily brought into CARIS. The .hob and .000 files along with a ReadMe.txt file of the attribute mapping used are also located in the Sound_Speed_List folder.

C.8. TIDES AND WATER LEVEL CORRECTIONS

The operating National Water Level Observation Network (NWLON) station 8760922 (Pilot Station East, SW Pass, LA) provided water level reducers for this project.

During survey operations, preliminary 6-minute tidal data from the 8760922 water level station was downloaded from the NOAA Tides and Currents 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 tidal zoning definition file supplied by NOAA/CO-OPS; Table 40 shows the tide zones and correctors.

Table 40. Pilot Station East, SW Pass, LA (8760922) Tide Zones and Correctors.

Tide Zone	Reference Station	Time Corrector	Range Ratio
CGM368	8760922	12	x1.09
CGM371	8760922	6	x1.09
CGM375	8760922	6	x1.13
CGM376	8760922	0	x1.09
CGM392	8760922	12	x1.13
CGM393	8760922	18	x1.13
CGM697	8760922	0	x1.05
CGM698	8760922	-6	x1.05
CGM699	8760922	0	x0.92

Tidal zoning correctors were applied to verified data from the 8760922 (Pilot Station East, SW Pass, LA) water level station for final processing, as outlined in section 1.5 of the Tides and Water Levels Statement of Work. The verified tidal data was downloaded from the NOAA Tides and Currents website.

D. LETTER OF APPROVAL

Data Acquisition and Processing Report

OPR-K339-KR-14

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
Digitally signed by Tara Levy
Date: 2015.08.11 09:35:11 -05'00'

Tara Levy
Chief of Party
C & C Technologies
Aug 2015

Nicole Galloway
Geoscientist
C & C Technologies
Aug 2015

C&C Technologies
An Oceaneering International Company

Appendices to Accompany Data Acquisition and Processing Report

OPR-K339-KR-14

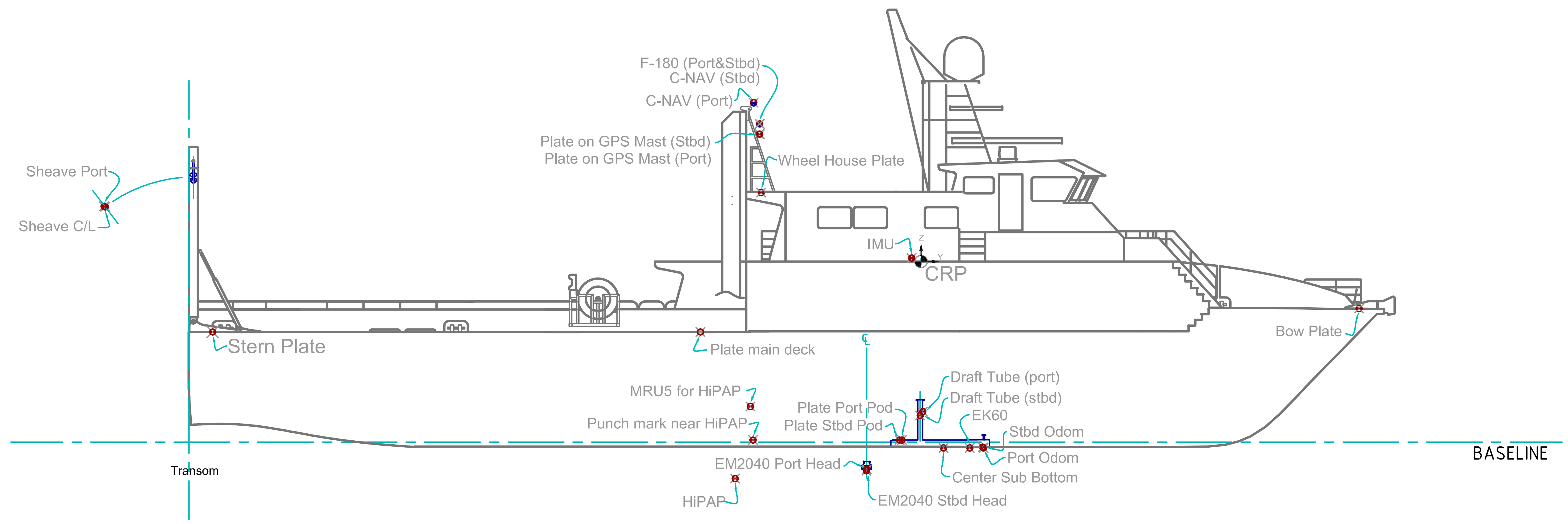
APPENDIX I

Vessel Reports

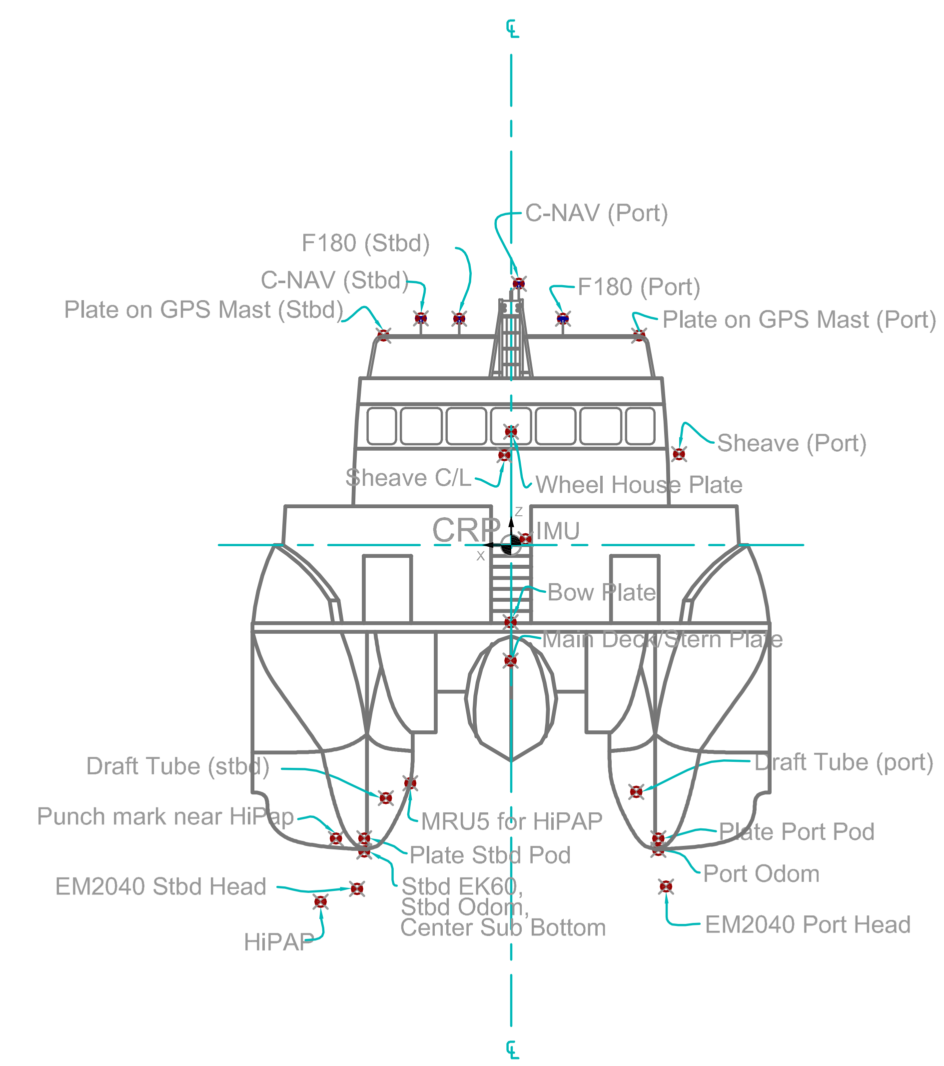
APPENDIX I

Vessel Reports

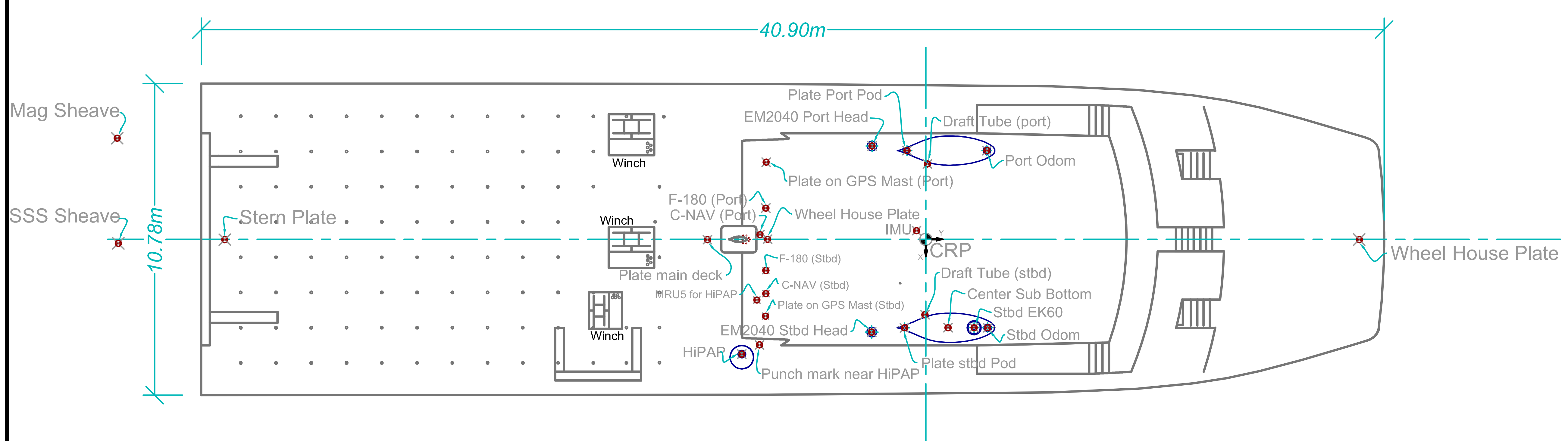
Vessel Offset Reports



SECTION



FRONT VIEW



PLAN VIEW

Locations From CRP	X(Starboard)	Y (Forward)	Z(Vertical)
Plate main deck	0.009	-7.548	-2.413
Stern Plate	0.009	-24.241	-2.413
Bow Plate	0.009	14.990	-1.607
WheelHouse Plate	0.001	-5.468	-2.363
IMU (F180)	-0.300	-0.321	0.116
F180 (Port)	-1.075	-5.526	4.723
C-NAV (Port)	-0.155	-5.526	5.442
F180 (Stbd)	1.076	-5.534	4.713
C-NAV (Stbd)	1.881	-5.534	4.721
Plate on GPS Mast (Port)	-2.670	-5.522	4.359
Plate on GPS Mast (Stbd)	2.660	-5.536	4.359
Sheave C/L	0.138	-27.922	1.865
Sheave Port Side	-3.501	-27.964	1.893
HiPAP	3.971	-6.359	-7.430
Punch mark near HiPap	3.654	-5.754	-6.113
MRU5 for HiPAP	2.103	-5.838	-4.965
EM2040 Stbd Head	3.214	-1.866	-7.127
Draft Tube (stbd)	2.609	-0.031	-5.200
Stbd Odom	3.057	2.143	-6.379
Stbd EK60	3.059	1.673	-6.379
Plate stbd Pod	3.059	-0.728	-6.113
Center Sub Bottom	3.059	0.773	-6.379
EM2040 Port Head	-3.225	-1.861	-7.068
Draft Tube (port)	-2.611	0.056	-5.136
Port Odom	-3.071	2.112	-6.352
Plate Port Pod	-3.071	-0.647	-6.110

R/V SEA SCOUT OFFSET DIAGRAM

C&C Technologies
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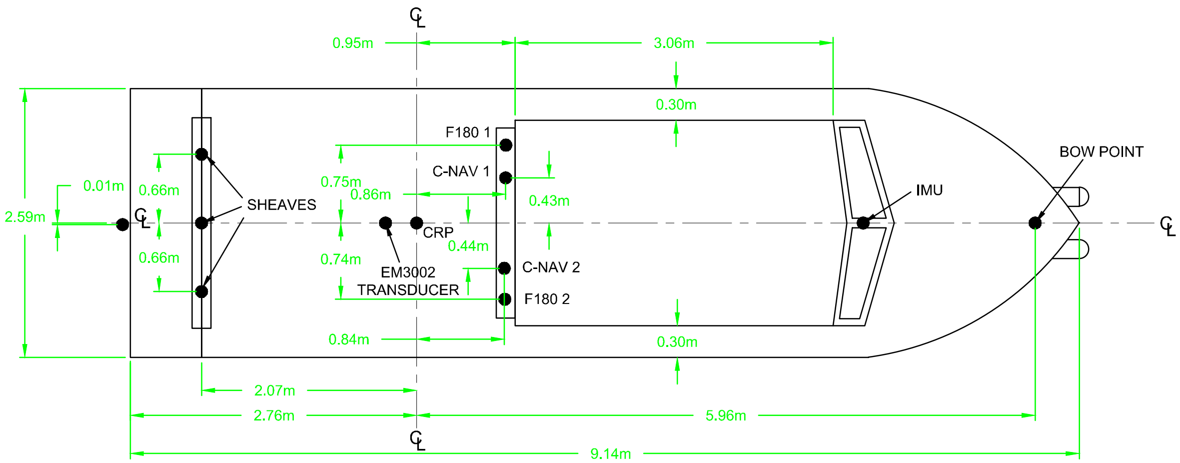
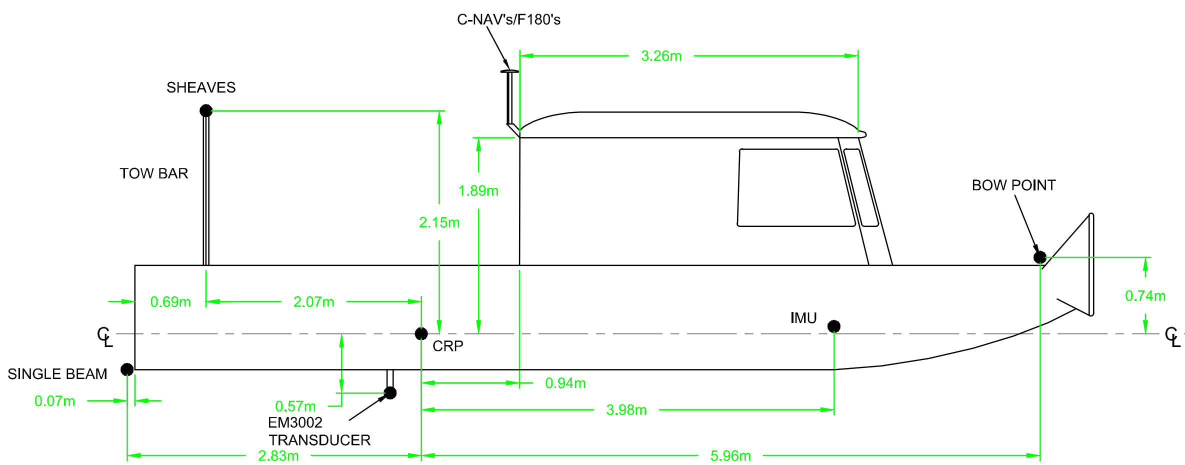
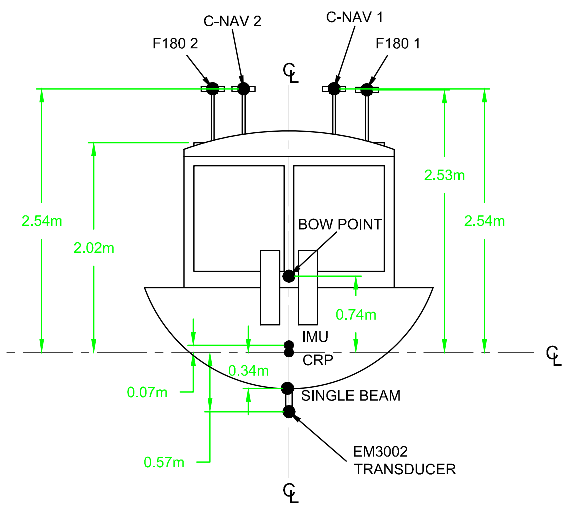
National Oceanic and Atmospheric Administration
U.S. DEPARTMENT OF COMMERCE



LOCATIONS FROM CRP	Y (FORWARD)	X (STARBOARD)	Z (VERTICAL)
C-NAV 1	0.858m	-0.435m	2.540m
C-NAV 2	0.845m	0.437m	2.530m
F180 1	0.860m	-0.750m	2.530m
F180 2	0.850m	0.735m	2.540m
IMU	3.975m	ON ℄	0.070m
EM3002 TRANSDUCER	-0.300m	ON ℄	-0.570m
SHEAVE	-2.073m	-0.661m	2.149m
SHEAVE	-2.073m	ON ℄	2.149m
SHEAVE	-2.073m	0.661m	2.149m
SINGLE BEAM	-2.834m	0.015m	-0.345m
BOW POINT	5.960m	0.000m	.735m





R/V C-WOLF

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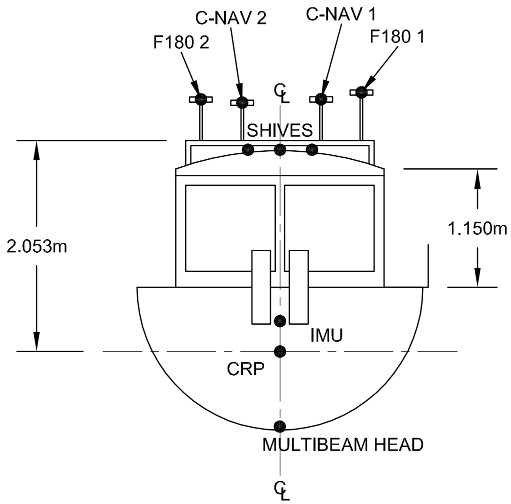
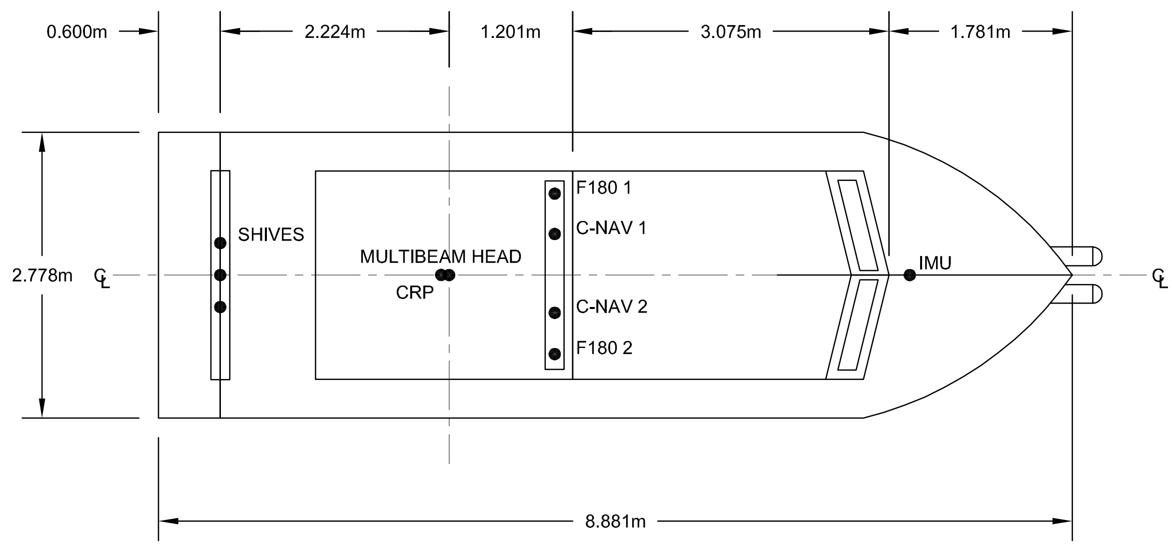
DATE: 07/08/2014 TIME: 08:26 FILENAME: O:\ADMIN\VESSEL-INFO\C-WOLF\C-WOLF_OFFSETS\C-WOLF-NOAA_07-08-2014.DWG



LOCATIONS FORM CRP	X (Forward)	Y (Starboard)	Z (Downward)
C-NAV 1 (primary)	1.120m	-0.387m	-2.484m
C-NAV 2 (secondary)	1.120m	0.380m	-2.484m
F180 1 (primary)	1.120m	-0.792m	-2.519m
F180 2 (secondary)	1.120m	0.768m	-2.451m
MULTIBEAM HEAD	-0.182m	ON ℄	0.730m
F180 - IMU	4.494m	0.000m	-0.205m
SHIVE	-2.224m	-0.311m	-1.963m
SHIVE	-2.224m	ON ℄	-1.963m
SHIVE	-2.224m	0.311m	-1.963m



R/V C-GHOST

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APPENDIX I

Vessel Reports

Vessel Layback Reports

Vessel Layback Report – R/V *Sea Scout*

Side scan sonar data was collected with a Klein 5000 V2 series side scan sonar, 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 (Figure 1).

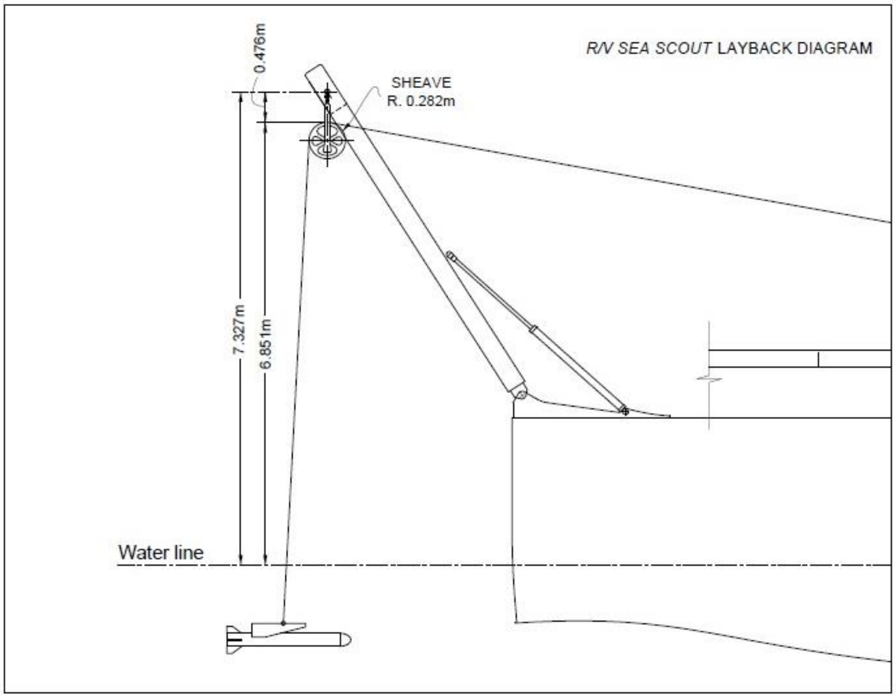


Figure 1. R/V *Sea Scout* layback diagram.

The side scan sonar data was layback corrected in post-processing using SonarWiz5 (Chesapeake Technology, Inc.).

SonarWiz Processing:

Cable out was generally logged within the XTF file via a cable counter during data collection but can be added in SonarWiz if needed. The sheave offsets are applied to the side scan sonar files to correct for the offset from the primary C-Nav GPS antenna to the towpoint (Table 1), and an offset is applied to correct for the distance from the waterline to the sheave (Table 2). Positive X indicates that the sheave is starboard of the GPS, negative Y indicates that the sheave is aft of the GPS antenna and SonarWiz requires the sheave height to be positive.

Table 1. Sheave offsets from GPS

Sheave Offset from GPS (meters)	X	Y
	0.295	-22.22

Table 2. Sheave Height

Sheave Height Above Waterline (meters)	Z
	6.9

Applying layback to side scan sonar XTF files using SonarWiz allows the user to choose one of two layback algorithms, either Cable – Percent, which is used when only cable out was recorded, or Cable – Sensor Depth, which is used if the towfish has a depth sensor. The user also chooses the percentage of cable out to apply as an along-track offset. Bottom tracked and layback corrected files were exported from SonarWiz for the final deliverables.

Hydromap Processing:

Layback correcting the side scan sonar files using Hydromap uses the variables and calculations shown in Figure 2.

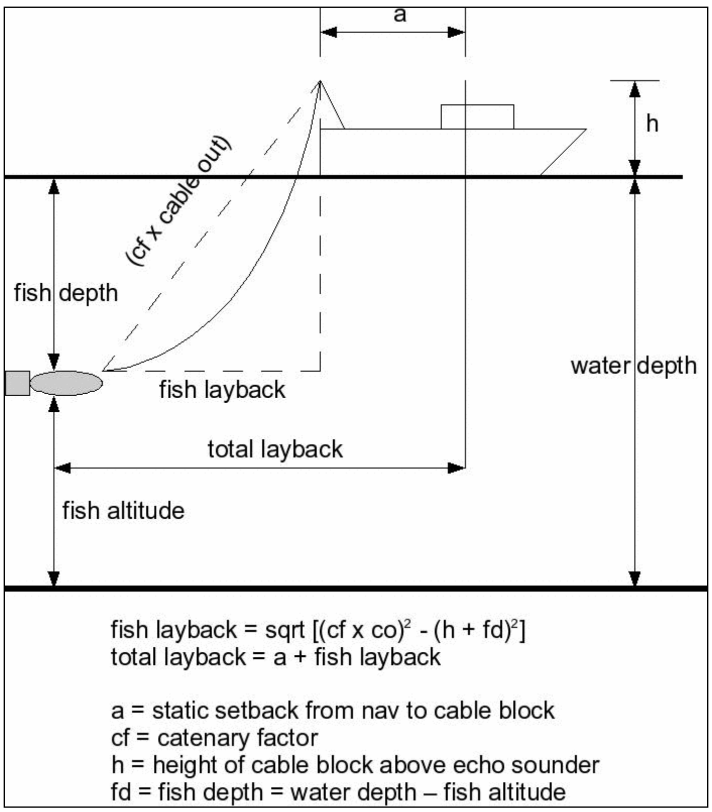


Figure 2. Hydromap layback correction diagram.

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 static setback from the navigation source to the A-frame cable block (a in Figure 2) is the along track distance from the primary positioning system to the side scan sonar sheave on the A-frame fully extended (refer to Table 1). 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.

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 (Table 2, Figure 1). Figure 3 shows the R/V *Sea Scout* in retrieval operations of the side scan sonar; image also shows the general layback configuration.

Figure 3. Configuration of towed side scan sonar on the R/V *Sea Scout*.

Vessel Layback Report – R/V *C-Wolf*

Side scan sonar data was collected with an Edgetech 4200 series side scan sonar system, operated in a towed configuration. A hanging sheave mounted to a fixed A-frame at the stern of the vessel was used as the tow point for the side scan sonar (refer to the R/V *C-Wolf* offset diagram for additional information).

SonarWiz5 (Chesapeake Technology, Inc.) was used to collect the side scan data and C&C Technologies' proprietary Hydromap software was used for layback corrections. No real-time layback correction was done during data collection. Cable out was set to zero with no sheave offsets, and the side scan sonar was given primary C-Nav GPS position.

Before the data could be layback corrected in Hydromap, the XTF files had to be imported into Sonarwiz5. Once imported, the cable out was updated using the Set Cable Out tool (Figure 1), and the bottom tracking was reviewed and fixed as necessary using the Bottom Track tool (Figure 2). The Update XTF Parameters tool (Figure 3) was then used to update the XTF files with the new bottom tracking (altitude) and the new cable out values.

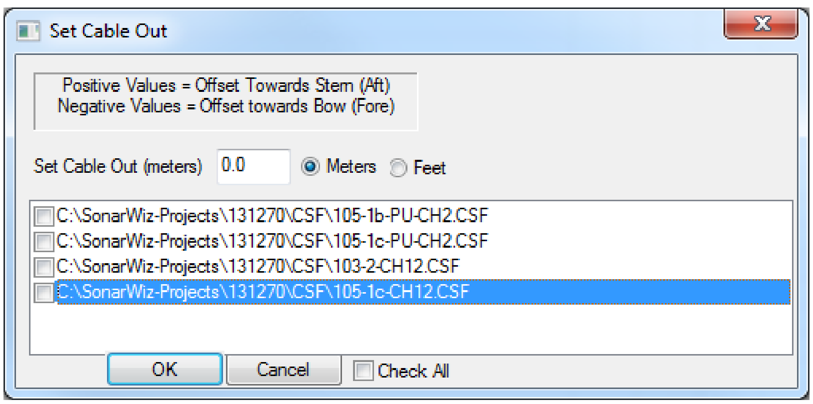


Figure 1. Sonarwiz5 Set Cable Out tool

Figure 2. Sonarwiz5 Bottom Track tool

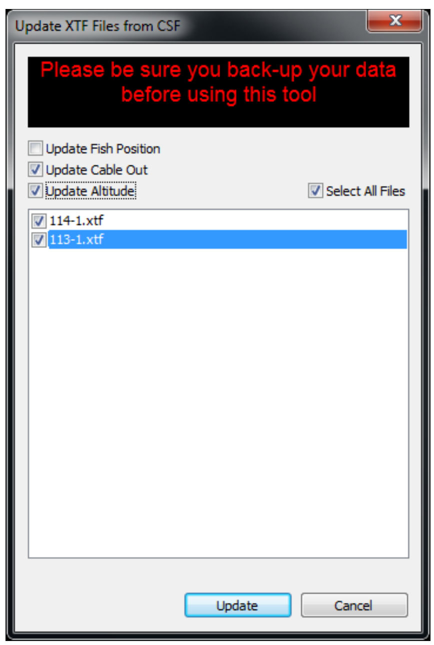


Figure 3. Sonarwiz 5; Update XTF Parameters tool

Layback correcting the side scan sonar files using Hydromap uses the variables and calculations shown in Figure 4.

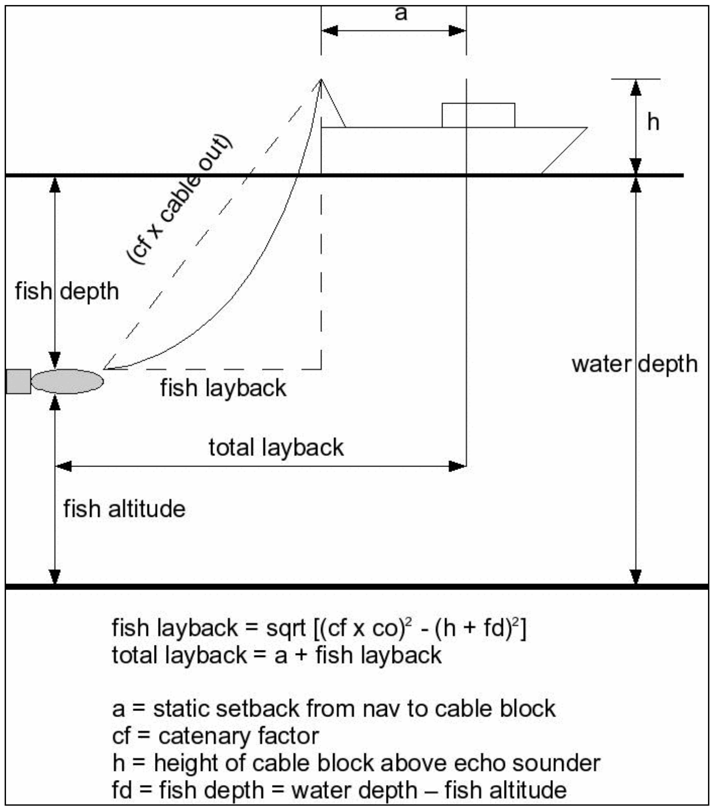


Figure 4. Hydromap layback correction diagram

The static setback from the navigation source to the A-frame cable block (a in Figure 4) is the along track distance from the primary positioning system to the side scan sonar sheave (refer to Table 1). Water depth and fish altitude are values that are recorded into the raw XTF file. The fish depth was obtained from the fish altitude (bottom track) subtracted from the water depth.

The height of the cable block above the waterline (h) was a constant value. A measurement of 1.9 meters from the waterline to the sheave was used for this value (Table 2, Figure 4). Figure 5 below shows all the layback settings as they appear in the Hydromap XTF layback tool.

Table 1. Sheave offsets from Primary C-Nav GPS

Sheave Offset from Primary C-Nav GPS (meters)	X	Y
	0.435	-2.931

Table 2. Sheave Height

Sheave Height Above Waterline (meters)	Z
	1.9

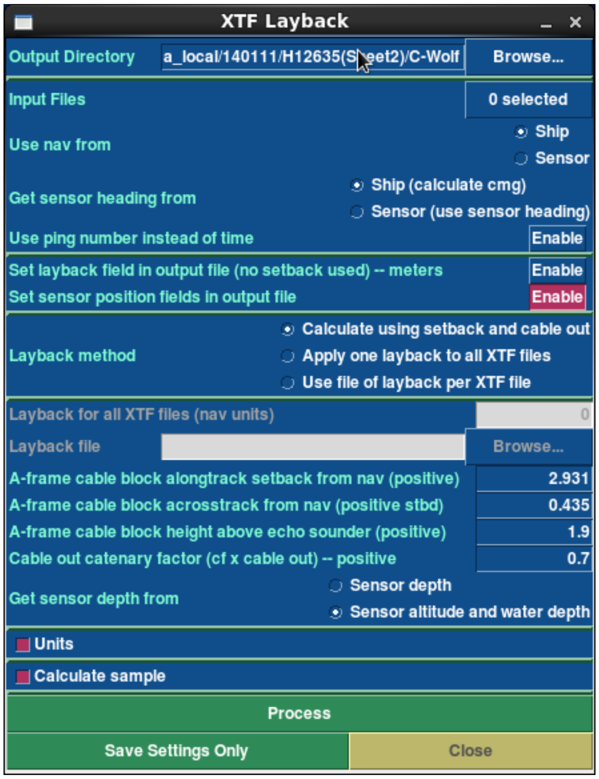


Figure 5. Hydromap XTF Layback tool

Vessel Layback Report – R/V *C-Ghost*

Side scan sonar data was collected with an Edgetech 4200 series side scan sonar system, operated in a towed configuration. A hanging sheave mounted to a fixed A-frame at the stern of the vessel was used as the tow point for the side scan sonar (refer to the R/V *C-Ghost* offset diagram for additional information).

SonarWiz5 (Chesapeake Technology, Inc.) was used to collect the side scan data. No real-time layback correction was done during data collection. Cable out was set to zero with no sheave offsets, and the side scan sonar was given primary C-Nav GPS position. Either C & C Technologies' proprietary Hydromap software or SonarWiz used for layback corrections. Layback corrected files were exported from SonarWiz for the final deliverables.

Layback Correction: Hydromap

Before the data could be layback corrected in Hydromap, the XTF files had to be imported into Sonarwiz5. Once imported, the cable out was updated using the Set Cable Out tool (Figure 1), and the bottom tracking was reviewed and fixed as necessary using the Bottom Track tool (Figure 2). The Update XTF Parameters tool (Figure 3) was then used to update the XTF files with the new bottom tracking (altitude) and the new cable out values.

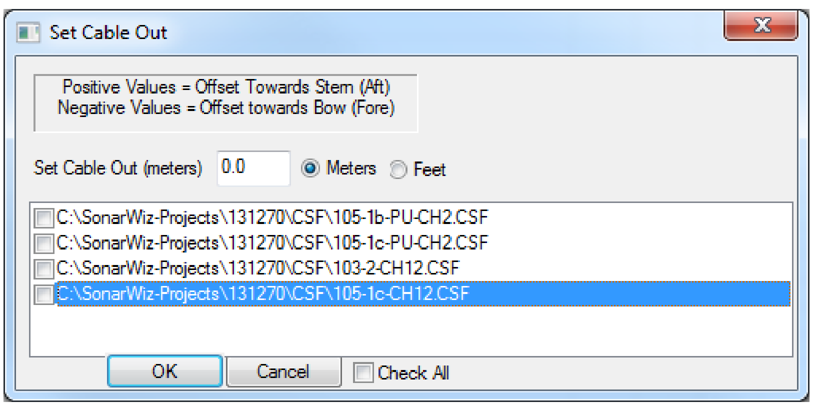


Figure 1. Sonarwiz5 Set Cable Out tool

Figure 2. Sonarwiz5 Bottom Track tool

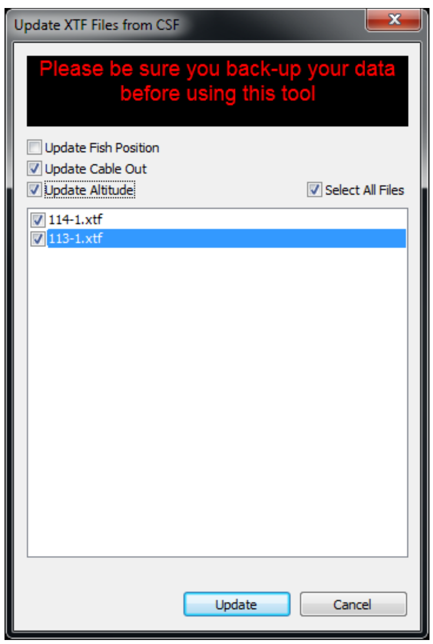


Figure 3. Sonarwiz 5; Update XTF Parameters tool

Layback correcting the side scan sonar files using Hydromap uses the variables and calculations shown in Figure 4.

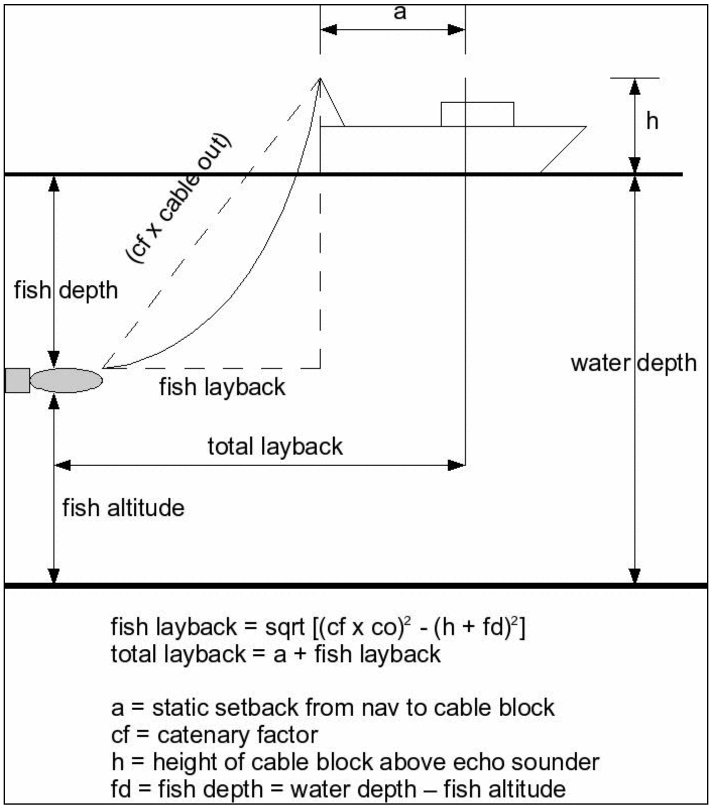


Figure 4. Hydromap layback correction diagram

The static setback from the navigation source to the A-frame cable block (a in Figure 4) is the along track distance from the primary positioning system to the side scan sonar sheave (refer to Table 1). Water depth and fish altitude are values that are recorded into the raw XTF file. The fish depth was obtained from the fish altitude (bottom track) subtracted from the water depth.

The height of the cable block above the waterline (h) was a constant value. A measurement of 1.9 meters from the waterline to the sheave was used for this value (Table 2, Figure 4). Figure 5 shows all the layback settings as they appear in the Hydromap XTF layback tool.

Table 1. Sheave offsets from Primary C-Nav GPS

Sheave Offset from Primary C-Nav GPS (meters)	X	Y
	0.387	-3.344

Table 2. Sheave Height

Sheave Height Above Waterline (meters)	Z
	1.9

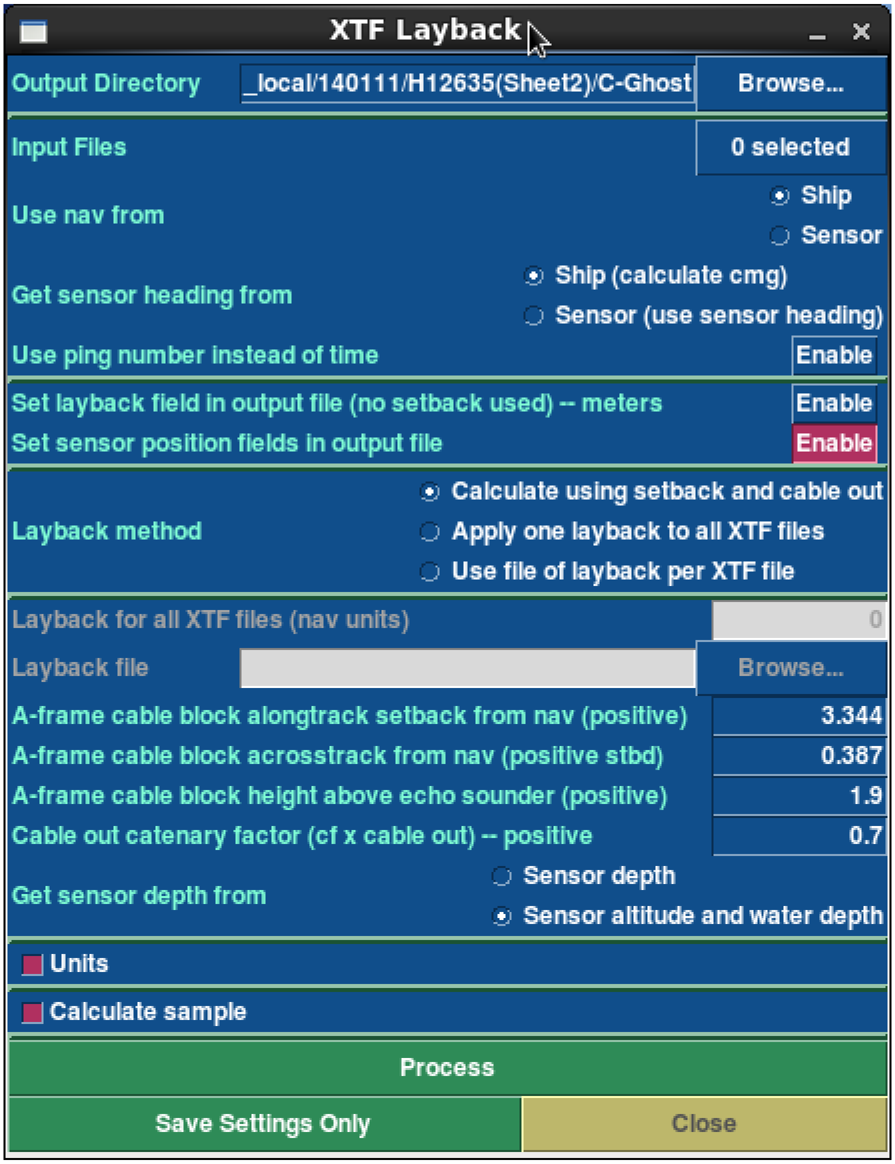


Figure 5. Hydromap XTF Layback tool

Layback Correction: SonarWiz

Raw side scan sonar XTF files are imported into SonarWiz. Sheave offsets are applied to the side scan sonar files to correct for the offset from the primary C-Nav GPS antenna to the towpoint (Table 1), and an offset is applied to correct for the distance from the waterline to the sheave (Table 2). Positive X indicates that the sheave is starboard of the GPS, negative Y indicates that the sheave is aft of the GPS antenna and SonarWiz requires the sheave height to be positive. Cable out values recorded in the field are also applied.

Applying layback to side scan sonar XTF files using SonarWiz allows the user to choose one of two layback algorithms, either Cable – Percent, which is used when only cable out was recorded, or Cable – Sensor Depth, which is used if the towfish has a depth sensor. The user also chooses the percentage of cable out to apply as an along-track offset.

APPENDIX I

Vessel Reports

Dynamic Draft Reports

Dynamic Draft Report – R/V *Sea Scout*

General:

The draft of a vessel can change with varying speeds and cause the vessel to settle down in the water. The stern will squat, causing 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 in Calcasieu Pass, LA on March 25, 2014.

The resultant corrections are added to the raw soundings to refer them back to a static state, as though the boat is stationary. 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:

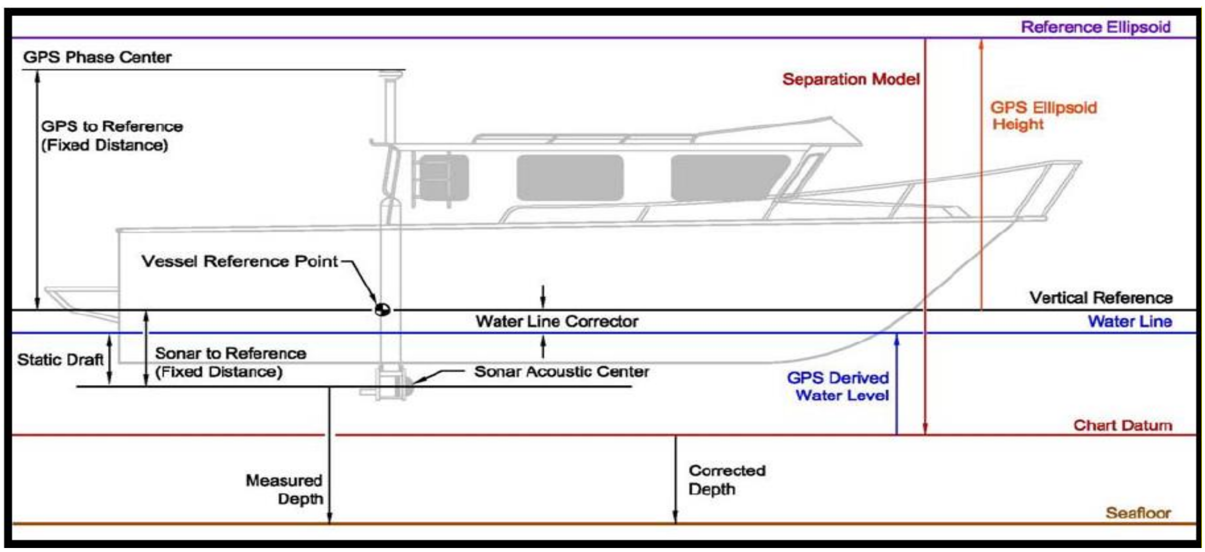


Figure 1. General definitions

Procedure:

An RTK base station was set up on land 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. The C-Navigator displays “RTK-I” denoting a RTK fixed position (highest accuracy) when there is a connection with the base station; when the radio connection is lost this will change to “RTK-F” (a lower accuracy for position). In addition, the Rx light on the radio should continue to blink once per second until the connection is lost. The survey crew is responsible to observe this connection carefully and only record when "RTK-I" is displayed.

A number of vessel speeds were determined for the squat test. General surveying speeds start at approximately 3.0 kts and generally do not exceed 6.0 kts. Additionally, a baseline must be set with which to compare all subsequent speeds. The final values that were determined for this squat and settlement test were idle (0 kts), 0600 RPM (3.5 kts), 0750 RPM (4.5 kts), 0850 RPM (5.5 kts), 1000 RPM (6.5 kts), 1150 RPM (7.5 kts) and 1300 RPM (8.5 kts).

An arbitrary line was created in the navigational software (Hydromap) that was within the radio limits for the vessel to follow. Starting at one end of the survey line the vessel ran at each predetermined speed sequentially and the survey crew recorded each speed separately for a minimum of one minute. Survey crew also closely monitored the radio connection to ensure good data is being recorded (RTK-I). This procedure was repeated six (6) times.

Processing:

The GGA strings were extracted from each of the GPS files and all records without the 'RTK-I' level of accuracy (denoted by a '4' in the raw data) were removed. Each recording, once properly formatted, were brought into Microsoft Excel where the majority of the processing took place. The average Ellipsoid Height was calculated for each run. The data was normalized for ellipsoid height by subtracting the average of the ellipsoid heights at idle. The normalized ellipsoid heights were also normalized for tide, using tidal values from Calcasieu Pass, LA station 8768094. The average ellipsoid height was then calculated for each speed.

Results:

The result of this normalization process is the average elevation difference of the vessel at different speeds. The final vertical displacement of the R/V *Sea Scout* with speed is shown in Table 1 and Figure 2. Runs 1 and 2 were removed from final processing due to some anomalous values. All final 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.

Table 1. Vertical displacement of the R/V *Sea Scout* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.00
-0.01	1.91
-0.01	2.49
-0.01	2.88
-0.03	3.40
-0.04	3.88
-0.05	4.36

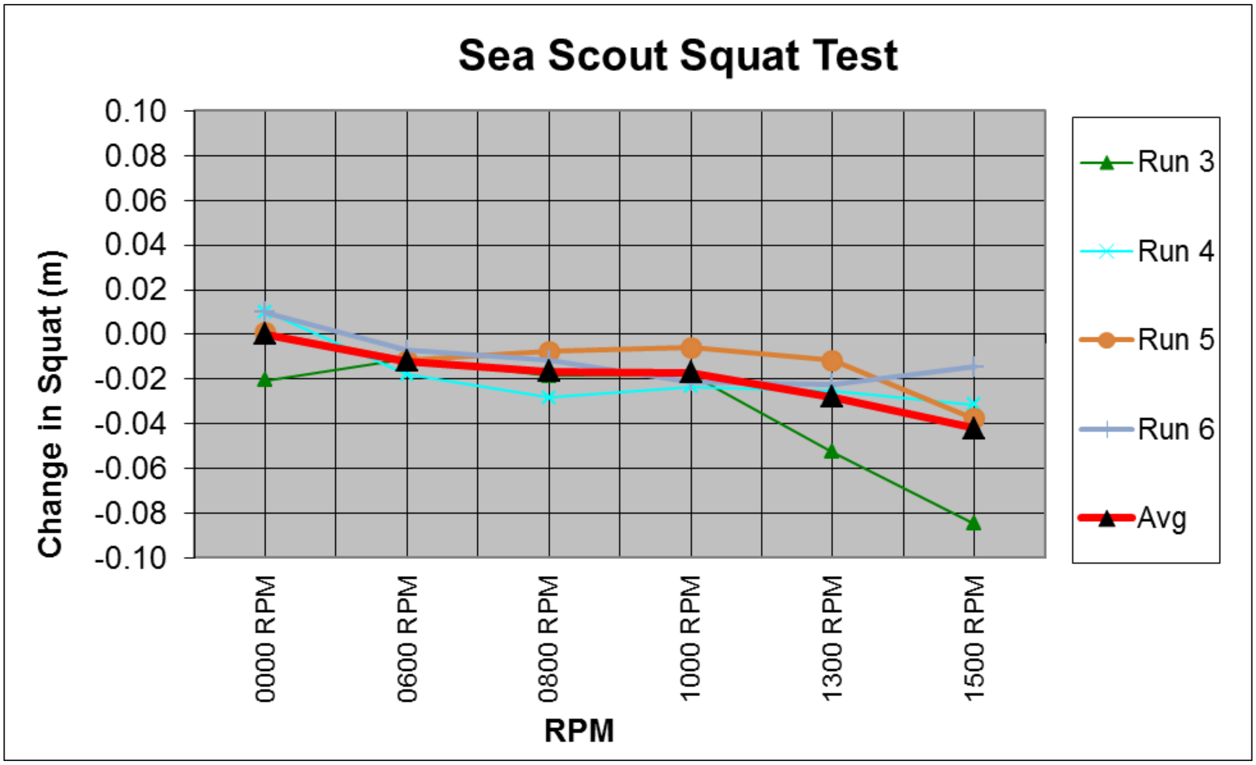


Figure 2. R/V *Sea Scout* squat test results.

Project Log

C&C Technologies SURVEY SERVICES	Squat Test			
	Job Number:	**121028**	**Page #:**	**01**
	Vessel Name:	**SEA SCOUT**	**Date** (YY/MM/DD):	**14/03/25**
	General Locality:	**Outside Cameron Jetties**	**Julian Day:**	**84**

Time (UTC)	Line Name	Fix	HDG	Speed	HDOP	Depth	
1800							At the dock in Cameron, LA
							Testing RTK equipment
							For squat test
2000							Depart dock
2215							RTL receiving corrections
2221	Squat1-0000		260	0	0.7		SOL 0kts 0000RPM
2222	Squat1-0000		260	0	0.7		EOL
2225	Squat1-0600		260	3.9	0.7		SOL 3.5kts 0600 RPM
2226	Squat1-0600		260	3.7	0.7		EOL-turn at EOL may have skewed data
2228	Squat1-0750		260	4.8	0.7		SOL 4.5kts 0750 RPM
2230	Squat1-0750		260	4.9	0.7		EOL
2231	Squat1-0850		260	5.6	0.7		SOL 5.5 KTS 0850RPM
2232	Squat1-0850		260	5.7	0.7		EOL
2233	Squat1-1000		260	6.5	0.7		SOL 6.5kts 1000RPM
2235	Squat1-1000		260	6.6	0.7		EOL
2236	Squat1-1150		260	7.5	0.6		SOL 7.5kts 1150RPM
2238	Squat1-1150		260	7.5	0.6		EOL
2239	Squat1-1300		260	8.4	0.6		SOL 8.5 kts 1300 RPM
2241	Squat1-1300		260	8.4	0.6		EOL
							Run #1 complete
							May have to cut 0600 RPM
							Off at end due to turn
2245	Squat2-0000		080	0	0.6		SOL 0kts 0000RPM
2246	Squat2-0000		080	0	0.6		EOL
2248	Squat2-0600		080	3.5	0.6		SOL 3.5kts 0600 RPM
2250	Squat2-0600		080	3.5	0.6		EOL
2252	Squat2-0750		080	4.8	0.6		SOL 4.5kts 0750 RPM
2253	Squat2-0750		080	4.7	0.6		EOL
2255	Squat2-0850		080	5.3	0.6		SOL 5.5 KTS 0850RPM
2257	Squat2-0850		080	5.5	0.6		EOL vessel turned a bit at SOL
2258	Squat2-1000		080	6.4	0.6		SOL 6.5kts 1000RPM
2259	Squat2-1000		080	6.4	0.6		EOL
2301	Squat2-1150		080	7.5	0.6		SOL 7.5kts 1150RPM

Project Log

C&C Technologies SURVEY SERVICES	Squat Test			
	Job Number:	**121028**	**Page #:**	**02**
	Vessel Name:	**SEA SCOUT**	**Date** (YY/MM/DD):	**14/03/25**
	General Locality:	**Outside Cameron Jetties**	**Julian Day:**	**84**

Time (UTC)	Line Name	Fix	HDG	Speed	HDOP	Depth	
2302	Squat2-1150		080	7.5	0.6		EOL
2303	Squat2-1300		080	8.4	0.6		SOL 8.5 kts 1300 RPM
2305	Squat2-1150		080	8.5	0.6		EOL
							Run #2 complete
							0850 RPM run might have
							To be cut at SOL due to turn
							Recorded extra data in case
2308	Squat3-0000		260	0	0.6		SOL 0kts 0000RPM
2309	Squat3-0000		260	0	0.6		EOL
2312	Squat3-0600		260	3.9	0.7		SOL 3.5kts 0600 RPM
2313	Squat3-0600		260	3.9	0.7		EOL
2316	Squat3-0750		260	5.0	0.7		SOL 4.5kts 0750 RPM
2318	Squat3-0750		260	5.0	0.7		EOL
2319	Squat3-0850		260	5.7	0.7		SOL 5.5 KTS 0850RPM
2321	Squat3-0850		260	5.7	0.7		EOL
2322	Squat3-1000		260	6.8	0.7		SOL 6.5kts 1000RPM
2323	Squat3-1000		260	6.8	0.7		EOL
2324	Squat3-1150		260	7.7	0.7		SOL 7.5kts 1150RPM
2325	Squat3-1150		260	7.7	0.7		EOL
2327	Squat3-1300		260	8.5	0.7		SOL 8.5 kts 1300 RPM
2328	Squat3-1300		260	8.5	0.7		EOL
							Run #3 complete
							0000 RPM may have been
							Accidentally written over
2335	Squat4-0000		080	0	0.7		SOL 0kts 0000RPM
2336	Squat4-0000		080	0	0.7		EOL
2338	Squat4-0600		080	3.6	0.7		SOL 3.5kts 0600 RPM
2340	Squat4-0600		080	3.6	0.7		EOL
2341	Squat4-0750		080	4.7	0.7		SOL 4.5kts 0750 RPM
2342	Squat4-0750		080	4.7	0.7		EOL
2344	Squat4-0850		080	5.3	0.7		SOL 5.5 KTS 0850RPM
2345	Squat4-0850		080	5.4	0.7		EOL
2347	Squat4-1000		080	6.5	0.7		SOL 6.5kts 1000RPM

Project Log

C&C Technologies SURVEY SERVICES	Squat Test		
Job Number:	**121028**	**Page #:**	**03**
Vessel Name:	**SEA SCOUT**	**Date (YY/MM/DD):**	**14/03/25**
General Locality:	**Outside Cameron Jetties**	**Julian Day:**	**84**

Time (UTC)	Line Name	Fix	HDG	Speed	HDOP	Depth	
2348	Squat4-1000		080	6.5	0.7		EOL
2350	Squat4-1150		080	7.4	0.7		SOL 7.5kts 1150RPM
2351	Squat4-1150		080	7.4	0.7		EOL
2352	Squat4-1300		080	8.4	0.7		SOL 8.5 kts 1300 RPM
2353	Squat4-1300		080	8.4	0.7		EOL
							Run #4 complete
2358	Squat5-0000		260	0	0.7		SOL 0kts 0000RPM
2359	Squat5-0000		260	0	0.6		EOL
0001	Squat5-0600		260	3.8	0.7		SOL 3.5kts 0600 RPM
0003	Squat5-0600		260	3.9	0.7		EOL
0004	Squat5-0750		260	5.0	0.7		SOL 4.5kts 0750 RPM
0005	Squat5-0750		260	5.0	0.7		EOL
0006	Squat5-0850		260	5.8	0.7		SOL 5.5 KTS 0850RPM
0007	Squat5-0850		260	5.8	0.8		EOL
0008	Squat5-1000		260	6.8	0.7		SOL 6.5kts 1000RPM
0010	Squat5-1000		260	6.9	0.6		EOL
0010	Squat5-1150		260	7.6	0.6		SOL 7.5kts 1150RPM
0012	Squat5-1150		260	7.7	0.6		EOL
0013	Squat5-1300		260	8.6	0.6		SOL 8.5 kts 1300 RPM
0014	Squat5-1300		260	8.7	0.6		EOL
							Run #5 complete
0018	Squat6-0000		080	0	0.7		SOL 0kts 0000RPM
0019	Squat6-0000		080	0	0.6		EOL
0021	Squat6-0600		080	3.6	0.7		SOL 3.5kts 0600 RPM
0023	Squat6-0600		080	3.6	0.6		EOL
0024	Squat6-0750		080	4.6	0.6		SOL 4.5kts 0750 RPM
0025	Squat6-0750		080	4.7	0.6		EOL
0027	Squat6-0850		080	5.6	0.6		SOL 5.5 KTS 0850RPM
0028	Squat6-0850		080	5.7	0.6		EOL
0029	Squat6-1000		080	6.5	0.6		SOL 6.5kts 1000RPM
0031	Squat6-1000		080	6.5	0.7		EOL
0032	Squat6-1150		080	7.4	0.7		SOL 7.5kts 1150RPM
0033	Squat6-1150		080	7.5	0.7		EOL

Project Log

	Squat Test			
	Job Number:	**121028**	**Page #:**	**04**
	Vessel Name:	**SEA SCOUT**	**Date** (YY/MM/DD):	**14/03/26**
	General Locality:	**Outside Cameron Jetties**	**Julian Day:**	**84**

Time (UTC)	Line Name	Fix	HDG	Speed	HDOP	Depth	
0034	Squat6-1300		080	8.4	0.6		SOL 8.5 kts 1300 RPM
0036	Squat6-1300		080	8.5	0.6		EOL
							Run #6 complete
							Return to dock
0130							Arrive at dock
							CNAV ANTENNA S/N 6924
							RADIO ANTENNA S/N FG4500
							RTK ROVER S/N 11426
							CNAV 3050 S/N 13709
							TS4000 RADIO S/N 16398
							RTK BASE 11512
		P/N 82-001020-3001 LF					CNAV 3050 S/N ~~6924~~ ~~5311~~
							TS4000 RADIO S/N23552
							CNAV ANTENNA S/N 5311
							RADIO ANTENNA S/N 40119

Dynamic Draft Report – R/V *C-Wolf*

General:

The draft of a vessel can change with varying speeds and cause the vessel to settle down in the water. The stern will squat, causing the relationship of the transducers to the water surface to change. In order to correct for the dynamic draft of the R/V *C-Wolf*, a squat and settlement test was performed in Vermillion Bay, LA on April 22, 2014.

The resultant corrections are added to the raw soundings to refer them back to a static state, as though the boat is stationary. 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:

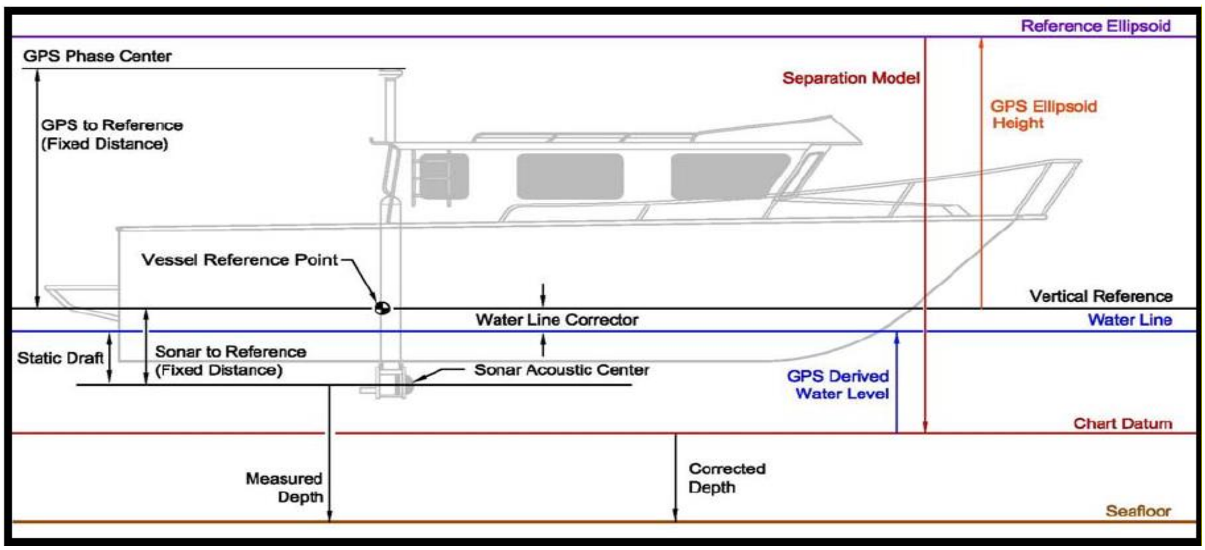


Figure 1. General definitions

Procedure:

An RTK base station was set up on land 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. The C-Navigator displays “RTK-I” denoting a RTK fixed position (highest accuracy) when there is a connection with the base station; when the radio connection is lost this will change to “RTK-F” (a lower accuracy for position). In addition, the Rx light on the radio should continue to blink once per second until the connection is lost. The survey crew is responsible to observe this connection carefully and only record when “RTK-I” is displayed.

A range of RPM values associated with survey speeds were established (Table 1). An arbitrary line was created in the navigational software (Hydromap) that was within the radio limits for the vessel to follow. The vessel ran at each predetermined RPM value along the line and the survey crew recorded each RPM run separately for a minimum of one minute. Survey crew also closely monitored the radio connection to ensure good data was recorded (RTK-I). This procedure was repeated 5 times although the first two runs are incomplete and only the last four are used for final processing.

Table 1. Range of RPM’s associated with survey speeds

RPM	Average Speed (kts)	Average Speed (m/s)
0	idle	idle
700	3.01	1.55
1000	4.18	2.15
1700	6.46	3.32
2000	7.19	3.7

Processing:

The GGA strings were extracted from each of the GPS files and all records without the ‘RTK-I’ level of accuracy (denoted by a ‘4’ in the raw data) removed. Each recording, once properly formatted, were brought into Microsoft Excel where the majority of the processing took place. The average Ellipsoid Height was calculated for each run. The data was normalized for ellipsoid height by subtracting the average of the ellipsoid heights at idle. The normalized ellipsoid heights were also normalized for tide, using predicted tidal values from Cypremort Point, LA station 8765251. The average ellipsoid height was then calculated for each speed.

Results:

The result of this normalization process is the average elevation differences of the vessel at different speeds. The first two runs are incomplete and only the last four are used for final processing (Run3 – Run6). The final vertical displacement of the R/V *C-Wolf* with speed is shown in Table 2 and Figure 2. All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file.

Table 2. Vertical displacement of the R/V *C-Wolf* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0
-0.01	1.55
-0.02	2.15
-0.07	3.32
-0.10	3.70

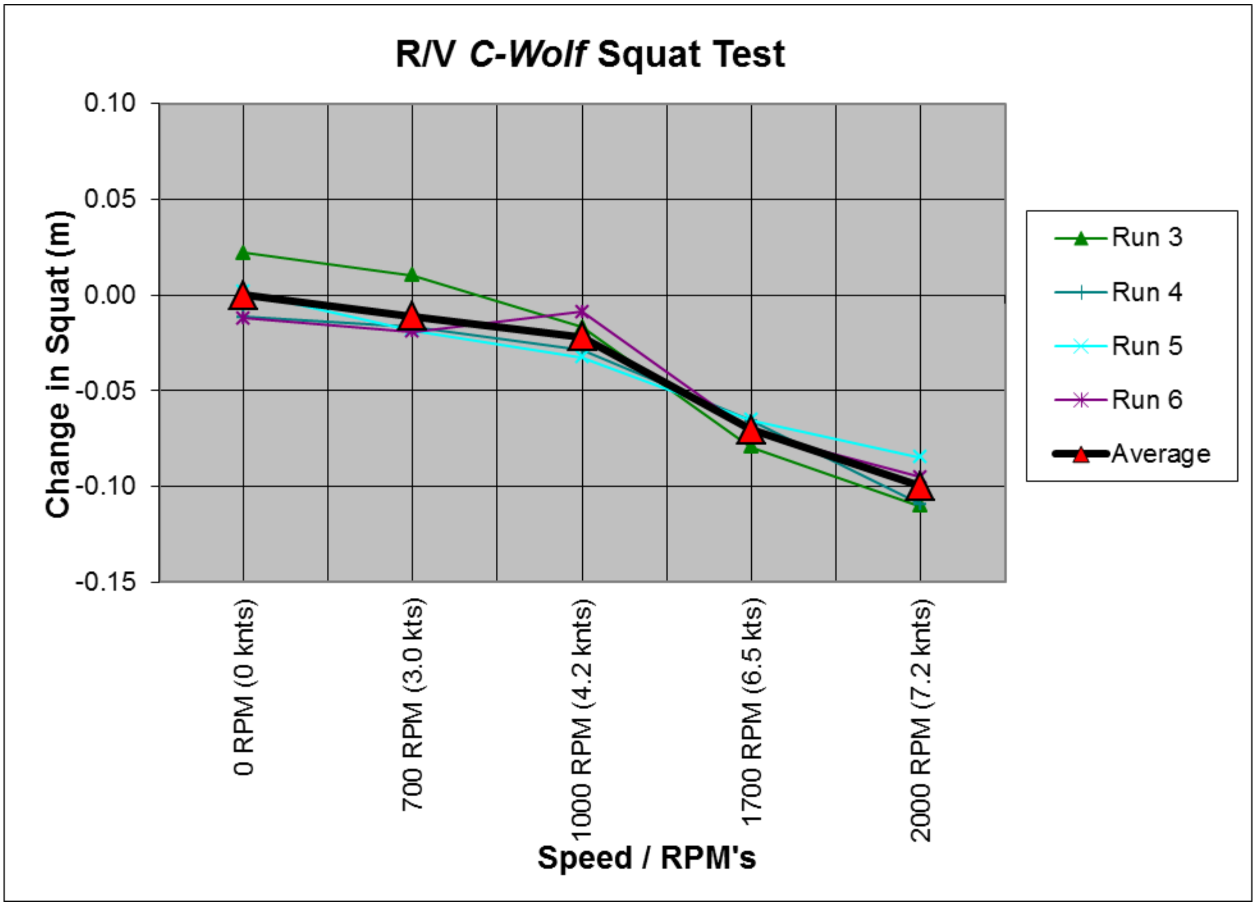


Figure 2. R/V *C-Wolf* squat test results.

Squat Test Project Log

C&C Technologies SURVEY SERVICES	**Vessel:**	R/V C-Wolf	**Page #:**	01
			Date (YY/MM/DD):	4/22/14
			Julian Day:	
	Location:	Cypremort Point, LA		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1811	0 rpm run 1			Idle			SOL
1814	0 rpm run 1			Idle			EOL
1815	700 rpm run 1		270	3.1			SOL
1818	700 rpm run 1		270	3.2			EOL
1819	1000 rpm run 1		270	3.9			SOL
1820	1000 rpm run 1		270	4.0			EOL – lost RTK signal
1829	1000 rpm run 2		90	4.2			SOL
1830	1000 rpm run 2		90	4.3			EOL – Lost RTK signal
1837	0 rpm run 3			Idle			SOL
1840	0 rpm run 3			Idle			EOL
1840	700 rpm run 3		90	3.0			SOL
1841	700 rpm run 3		90	3.1			EOL – Lost RTK signal
-							Changing radio antennas
1847	1000 rpm run 3		270	4.1			SOL
1850	1000 rpm run 3		270	4.0			EOL
1850	1700 rpm run 3		270	6.4			SOL
1853	1700 rpm run 3		270	6.4			EOL
1853	2000 rpm run 3		270	7.1			SOL
1856	2000 rpm run 3		270	7.2			EOL
1857	0 rpm run 4			Idle			SOL
1900	0 rpm run 4			Idle			EOL
1900	700 rpm run 4		90	3.0			SOL
1903	700rpm run 4		90	3.0			EOL
1904	1000 rpm run 4		90	4.6			SOL
1907	1000 rpm run 4		90	4.6			EOL
1907	1700 rpm run 4		90	6.6			SOL
1910	1700 rpm run 4		90	6.6			EOL
1910	2000 rpm run 4		90	7.2			SOL
1911	2000 rpm run 4		90	7.2			EOL
1913	0 rpm run 5			Idle			SOL
1916	0 rpm run 5			Idle			EOL
1917	700 rpm run 5		270	3.0			SOL
1920	700 rpm run 5		270	3.0			EOL

Squat Test Project Log

C&C Technologies SURVEY SERVICES	**Vessel:** R/V C-Wolf	**Page #:**	02
		Date (YY/MM/DD):	4/22/14
		Julian Day:	
	Location: Cypremort Point, LA		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1920	1000 rpm run 5		270	4.0			SOL
1923	1000 rpm run 5		270	4.1			EOL
1923	1700 rpm run 5		270	6.3			SOL
1926	1700 rpm run 5		270	6.2			EOL
1927	2000 rpm run 5		270	7.1			SOL
1930	2000 rpm run 5		270	7.2			EOL
1930	0 rpm run 6			Idle			SOL
1933	0 rpm run 6			Idle			EOL
1934	700 rpm run 6		90	3.0			SOL
1937	700 rpm run 6		90	3.0			EOL
1937	1000 rpm run 6		90	4.0			SOL
1940	1000 rpm run 6		90	4.0			EOL
1941	1700 rpm run 6		90	6.6			SOL
1944	1700 rpm run 6		90	6.6			EOL
1944	2000 rpm run 6		90	7.3			SOL
1947	2000 rpm run 6		90	7.2			EOL

Dynamic Draft Report – R/V *C-Ghost*

General:

The draft of a vessel can change with varying speeds and cause the vessel to settle down in the water. The stern will squat, causing the relationship of the transducers to the water surface to change. In order to correct for the dynamic draft of the R/V *C-Ghost*, a squat and settlement test was performed in Lake Duplechin, LA on March 18, 2015.

The resultant corrections are added to the raw soundings to refer them back to a static state, as though the boat is stationary. 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:

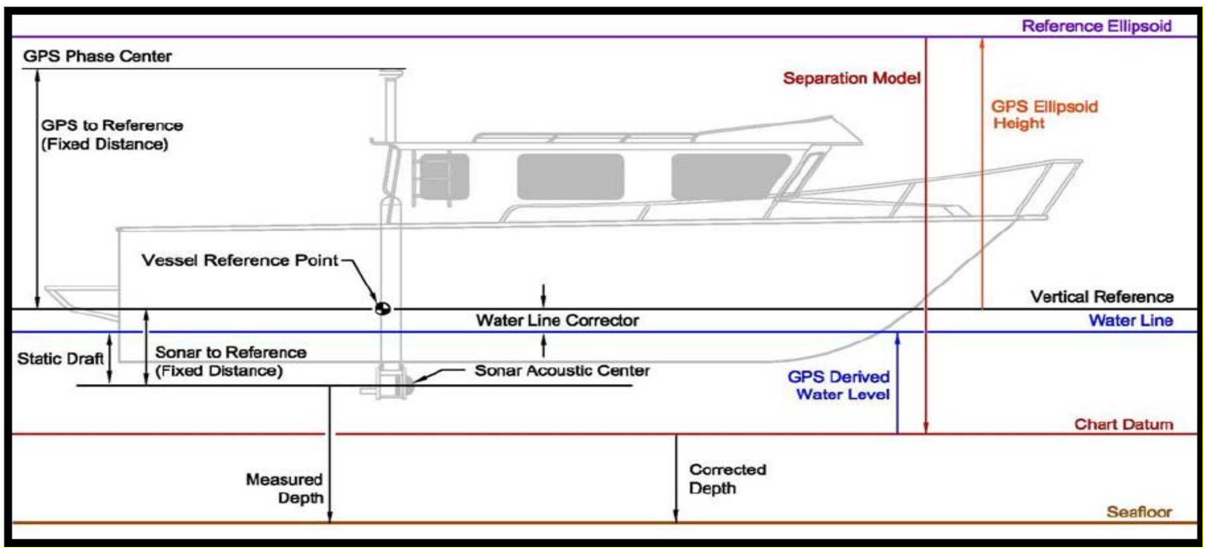


Figure 1. General definitions

Procedure:

An RTK base station was set up on land 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. The C-Navigator displays “RTK-I” denoting a RTK fixed position (highest accuracy) when there is a connection with the base station; when the radio connection is lost this will change to “RTK-F” (a lower accuracy for position). In addition, the Rx light on the radio should continue to blink once per second until the connection is lost. The survey crew is responsible to observe this connection carefully and only record when “RTK-I” is displayed.

A range of RPM values associated with survey speeds were established (Table 1). An arbitrary line was created in the navigational software (Hydromap) that was within the radio limits for the vessel to follow. The vessel ran at each predetermined RPM value along the line and the survey crew recorded each RPM run separately for a minimum of one minute. Survey crew also closely monitored the radio connection to ensure good data was recorded (RTK-I). This procedure was repeated six times although only the last five are used for final processing.

Table 1. Range of RPM's associated with survey speeds

RPM	Average Speed (kts)	Average Speed (m/s)
0000	0.0	0.0
0650	3.0	1.54
1000	4.0	2.06
1300	5.5	2.83
1700	6.5	3.34
2150	8.0	4.12
2500	10.0	5.14

Processing:

The GGA strings were extracted from each of the GPS files and all records without the 'RTK-I' level of accuracy (denoted by a '4' in the raw data) removed. Each recording, once properly formatted, were brought into Microsoft Excel where the majority of the processing took place. The average Ellipsoid Height was calculated for each run. The data was normalized for ellipsoid height by subtracting the average of the ellipsoid heights at idle. The average ellipsoid height was then calculated for each speed/RPM.

Results:

The result of this normalization process is the average elevation differences of the vessel at different speeds. The last five runs are used for final processing (Run2 – Run6). The final vertical displacement of the R/V *C-Ghost* with speed is shown in Table 2 and Figure 2. All values were applied to the data in CARIS during post-processing. Negative values indicate that the vessel is lower in the water. Because the z-direction is positive down in the reference frame used for CARIS, the signs are opposite in the vessel file.

Table 2. Vertical displacement of the R/V *C-Ghost* with speed.

Vertical Correction (m)	Speed (m/s)
0.00	0.0
-0.01	1.54
-0.02	2.06
-0.03	2.83
-0.05	3.34
-0.08	4.12
-0.08	5.14

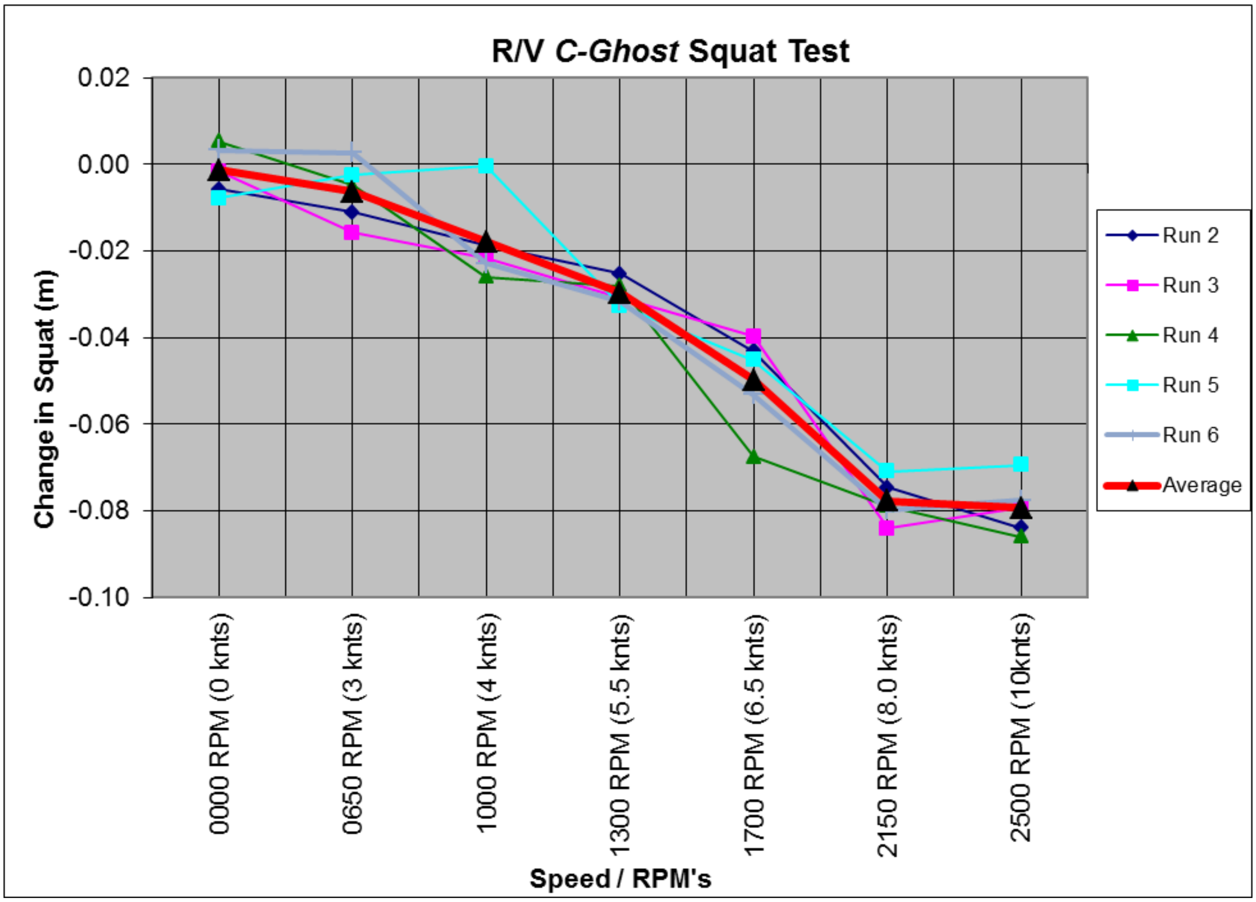


Figure 2. R/V *C-Ghost* squat test results.

Project Log

C&C Technologies SURVEY SERVICES	Vessel Name:	R/V C-Ghost	Page #:	01
	Project Number:	OPR-K339-KR-14	Date (YY/MM/DD):	15/03/18
	General Locality:	Lake Duplechin, LA	Julian Day:	

Time (UTC)	Line Name	HDG	RPMs	Speed (kts)	HDOP	Remarks
1645						Arrive @ Lake Duplechin
						Set up C-NAV 2050 RTK
						Base Station
						Base station static survey start
						C-Ghost launched. Power
						Up equipment. C-NAV 3050
						Base station
						TS 4000 radio with Laird
						Antennas for RTK correction
						Transmitted
						RTK base station sending
						corrections. Rover is receiving.
1828	Squat1-1	N/A	0000/0000	0	0.8	SOL 0000 RPM 0kts
1830	Squat1-1					EOL
1831	Squat1-2	196	600/600	3.0	0.8	SOL – 600 RPM 3 kts
1832	Squat1-2					EOL
1833	Squat1-3	196	800/800	3.6	0.8	SOL
1834	Squat1-3					EOL
1836	Squat1-4	196	1000/1000	4.5	0.8	SOL
1837	Squat1-4					EOL
1839	Squat1-5	026	1300/1300	5.5	0.8	SOL
1841	Squat1-5					EOL
1842	Squat1-6	026	1500/1500	6.2	0.8	SOL
1843	Squat1-6					EOL
1845	Squat1-7	207	2000/1800	7.5	0.8	SOL
1847	Squat1-7					EOL End of Run #1
						Test Run (previous run) do
						Not use in final calculations
1850	Squat2-1	N/A	0000/0000	0	0.8	SOL – Start of run #2
1852	Squat2-1					EOL
1852	Squat2-2	101	0800/0600	3.1	0.8	SOL
1854	Squat2-2					EOL
1855	Squat2-3	101	1000/1100	4.7	0.8	SOL

Project Log

Vessel Name:	R/V C-Ghost	Page #:	02
Project Number:	OPR-K339-KR-14	Date (YY/MM/DD):	15/03/18
General Locality:	Lake Duplechin, LA	Julian Day:	

Time (UTC)	Line Name	HDG	RPMs	Speed (kts)	HDOP	Remarks
1856	Squat2-3					EOL
1857	Squat2-4	103	1400/1300	5.5	0.7	SOL
1858	Squat2-4					EOL
1900	Squat2-5	285	1600/1700	6.4	0.7	SOL
1901	Squat2-5					EOL
1902	Squat2-6	282	2100/2200	8.2	0.7	SOL
1903	Squat2-6					EOL
1905	Squat2-7	100	2600/2500	9.8	0.9	SOL
1906	Squat2-7					EOL – End of run #2
1909	Squat3-1	N/A	0000/0000	0.0	1.0	SOL – Start of run #3
1911	Squat3-1					EOL
1912	Squat3-2	283	700/600	3.1	1.0	SOL
1913	Squat3-2					EOL
1916	Squat3-3	283	800/1000	4.3	1.0	SOL
1918	Squat3-3					EOL
1919	Squat3-4	096	1300/1300	5.5	1.0	SOL
1921	Squat3-4					EOL
1921	Squat3-5	110	1700/1600	6.5	0.9	SOL
1923	Squat3-5					EOL
1925	Squat3-6	287	2200/2100	8.1	1.0	SOL
1926	Squat3-6					EOL
1926	Squat3-7	287	2500/2500	9.9	1.0	SOL
1927	Squat3-7					EOL – End of run #3
1930	Squat4-1	N/A	0000/0000	0.0	1.0	SOL – Start of run #4
1931	Squat4-1					EOL
1932	Squat4-2	096	700/600	3.1	1.0	SOL
1933	Squat4-2					EOL
1935	Squat4-3	107	1000/1000	4.3	1.0	SOL
1936	Squat4-3					EOL
1937	Squat4-4	110	1400/1300	5.6	1.0	SOL
1938	Squat4-4					EOL
1941	Squat4-5	294	1600/1700	6.5	1.4	SOL
1942	Squat4-5					EOL

Project Log

C&C Technologies SURVEY SERVICES	Vessel Name:	R/V C-Ghost	Page #:	03
	Project Number:	OPR-K339-KR-14	Date (YY/MM/DD):	15/03/18
	General Locality:	Lake Duplechin, LA	Julian Day:	

Time (UTC)	Line Name	HDG	RPMs	Speed (kts)	HDOP	Remarks
1942	Squat4-6	277	2100/2200	8.2	1.4	SOL
	Squat4-6					EOL
1946	Squat4-7	105	2600/2600	9.9	1.4	SOL
1947	Squat4-7					EOL – end of run #4
1950	Squat5-1	N/A	0000/0000	0.0	1.4	SOL start of run #5
1951	Squat5-1					EOL
1953	Squat5-2	282	700/600	3.2	1.1	SOL
1954	Squat5-2					EOL
1955	Squat5-3	282	900/1100	4.4	1.1	SOL
1956	Squat5-3					EOL
1958	Squat5-4	288	1300/1300	5.3	1.1	SOL
1959	Squat5-4					EOL
2001	Squat5-5	080	1600/1700	6.5	1.1	SOL
2002	Squat5-5					EOL
2003	Squat5-6	098	2100/2200	8.1	1.1	SOL
2004	Squat5-6					EOL
2007	Squat5-7	271	2700/2500	10.4	1.0	SOL
2008	Squat5-7					EOL – end of run #5
2011	Squat6-1	N/A	0000/0000	0.0	1.0	SOL start of run #6
2013	Squat6-1					EOL
2014	Squat6-2	105	0800/0600	3.2	1.0	SOL
2015	Squat6-2					EOL
2016	Squat6-3	115	1000/1100	4.6	1.0	SOL
2017	Squat6-3					EOL
2018	Squat6-4	112	1400/1200	5.6	1.0	SOL
2020	Squat6-4					EOL
2022	Squat6-5	285	1600/1800	6.5	1.1	SOL
2023	Squat6-5					EOL
2024	Squat6-6	283	2100/2200	8.2	1.1	SOL
2025	Squat6-6					EOL
2027	Squat6-7	098	2700/2500	10.0	1.1	SOL
2028	Squat6-7					EOL – end of run #6

Project Log

C&C Technologies SURVEY SERVICES	**Vessel Name:**	**R/V C-Ghost**	**Page #:**	**04**
	Project Number:	**OPR-K339-KR-14**	**Date** (YY/MM/DD):	**15/03/18**
	General Locality:	**Lake Duplechin, LA**	**Julian Day:**	

Time (UTC)	Line Name	HDG	RPMs	Speed (kts)	HDOP	Remarks
						Taking down base station
						And de-mobing C-Ghost
						Of RTK rover
2055						Vessel secure of trailer
2105						Drive back to Lafayette

APPENDIX II

Echosounder Reports

APPENDIX II

Echosounder Reports

System Accuracy Tests

System Accuracy Test - R/V *Sea Scout*

Lead line comparisons were conducted several times during survey operations as an independent check on the multibeam bottom-detect and single beam systems. Lead lines were generally not taken in larger sea conditions and water depths greater than 15 -20 meters in order to avoid a misreading. These confidence checks were analyzed and statistics computed (Table 1).

Table 1. Lead line log and statistics for the R/V *Sea Scout*.

Sea Scout Lead Line Log									
Date (mm/dd/yyyy)	**Time (UTC)**	**X (m)**	**Y (m)**	**LL Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**ΔMB-SB (m)**	**ΔMB-LL (m)**
14/07/21	1635	255585.08	3220926.73	LL_140721a	11.32	11.35	11.25	-0.03	0.07
14/11/12	1953	262762.64	3205873.93	LL_141112a	7.30	7.33	7.25	-0.03	0.05
14/11/30	1630	259338.68	3200648.93	LL_141130a	11.80	11.70	11.65	0.10	0.15
								Average of Differences (m)	
								0.0350	0.1000
								Standard Deviation of Differences (m)	
								0.0919	0.0707

In addition, an Odom Echotrac MKIII single beam echo sounder continuously recorded singlebeam data and was monitored in real-time as an independent check of the nadir beam (bottom-detect) of the EM2040C multibeam echo sounder. In order to supplement the leadline comparisons, C & C Technologies' propriety software, Hydromap, was used to extract the single beam depths from several Echotrac files that are collected simultaneously with the multibeam data. This process outputs an .echotrac.xyz file. An EM2040C.xyz file was also generated from the corresponding EM2040C multibeam data from the same line. The singlebeam and multibeam data generally show good agreement; the mean of the differences does not exceed -0.31 meters (Table 2). The comparisons have been conducted on raw data, and some more extreme difference values may be associated with erroneous data.

Table 2. Lines and statistics for R/V *Sea Scout* singlebeam to multibeam comparison

Date	Line Name	Sheet	Min (m)	Max (m)	Mean (m)	Standard Deviation (m)
10/28/2004	2240-1	H12635	-0.71	-0.11	-0.31	0.07
11/03/2014	2268-1	H12635	-1.44	1.80	-0.07	0.14
11/12/2014	1097-1	H12634	-0.14	0.01	-0.05	0.02
11/19/2014	6164-1	H12634	-0.26	0.12	-0.05	0.03
11/21/2014	4083-1	H12635	-0.75	0.34	-0.12	0.11
12/01/2014	6180-2	H12634	-0.83	0.28	-0.12	0.09
12/09/2014	6164-3	H12634	-0.26	0.08	-0.09	0.04
12/15/2014	4034-3	H12635	-0.49	0.44	-0.03	0.04
12/22/2014	6085-2	H12634	-0.29	0.42	-0.01	0.08
12/28/2014	8082-1	H12634	-0.37	0.22	-0.14	0.07
01/30/2015	3075-1	H12636	-2.60	1.77	-0.08	0.26
02/10/2015	3122-1	H12636	-0.33	0.66	-0.10	0.06
02/20/2015	3130fill-1	H12636	-0.34	-0.05	-0.17	0.04
02/24/2015	3033-2	H12636	-2.54	2.66	-0.01	0.21

The following figures show multibeam to singlebeam depth data comparisons from the Sea Scout

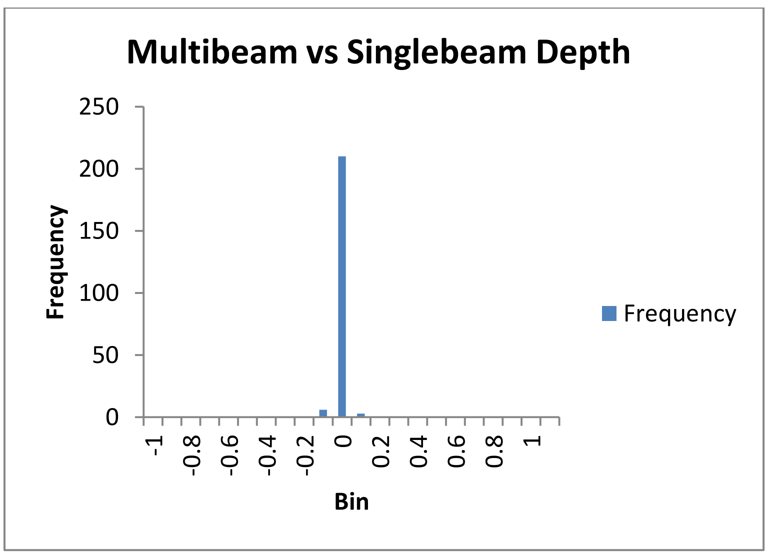


Figure 1: Data collected from line 1097-1

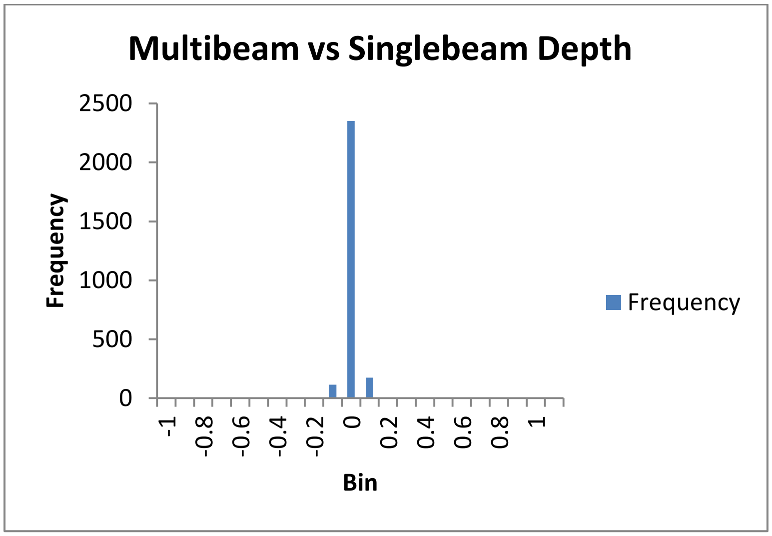


Figure 2: Data collected from line 4034-3

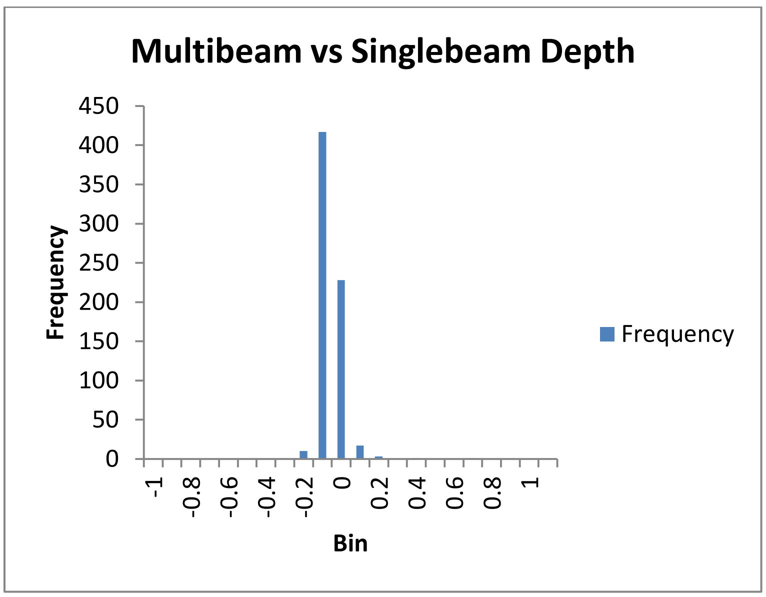


Figure 3: Data collected from line 3122-1

System Accuracy Test - R/V *C-Wolf*

Lead line comparisons were conducted several times during survey operations as an independent check on the multibeam bottom-detect and single beam systems. Lead lines were generally not taken in larger sea conditions and water depths greater than 15 -20 meters in order to avoid a misreading. These confidence checks were analyzed and statistics computed (Table 1).

Table 1. Lead line log and statistics for the R/V *C-Wolf*.

C-Wolf Lead Line Log									
Date (mm/dd/yyyy)	**Time (UTC)**	**X (m)**	**Y (m)**	**LL Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**ΔMB-SB (m)**	**ΔMB-LL (m)**
06/06/2014	1318	256856.23	3219946.98	LL_140606a	11.60	11.50	11.60	0.10	0.00
06/07/2014	1350	256647.75	3220516.38	LL_140607a	11.70	11.60	11.60	0.10	0.10
06/12/2014	1257	--	--	LL_140607a	12.90	13.00	13.00	-0.10	-0.10
06/20/2014	1213	254225.86	3212565.80	LL_140620	15.50	15.50	15.50	0.00	0.00
07/22/2014	2305	270584.00	3237894.88	LL_140722a	2.30	--	2.10	--	0.20
								Average of Differences (m)	
								0.0250	0.0400
								Standard Deviation of Differences (m)	
								0.0957	0.1140

In addition, an Odom Hydrotrac single beam echo sounder continuously recorded singlebeam data and was monitored in real-time as an independent check of the nadir beam (bottom-detect) of the EM3002 multibeam echo sounder. In order to supplement the leadline comparisons, C & C Technologies' propriety software, Hydromap, was used to extract the single beam depths from several Echotrac files that are collected simultaneously with the multibeam data. This process outputs an .echotrac.xyz file. An EM3002.xyz file was also generated from the corresponding EM3002 multibeam data from the same line. The singlebeam and multibeam data generally show good agreement; the mean of the differences does not exceed 0.36 meters (Table 2). The comparisons have been conducted on raw data, and some more extreme difference values may be associated with erroneous data.

Table 2. Lines and statistics for R/V *C-Wolf* singlebeam to multibeam comparison

Date	Line Name	Sheet	Min (m)	Max (m)	Mean (m)	Standard Deviation (m)
06/07/2014	2175-1	H12635	-0.25	5.67	0.26	0.55
06/17/2014	2067-1	H12635	-3.35	1.17	0.20	0.25
06/22/2014	2125-1	H12635	-0.35	6.81	0.36	0.33
07/02/2014	2152-1	H12635	-0.03	1.34	0.23	0.08
07/17/2014	2255-1	H12635	-0.29	1.60	0.21	0.15
07/22/2014	3167-1	H12636	-0.25	1.04	0.11	0.09

The following figures show multibeam to singlebeam depth comparisons from the C-Wolf

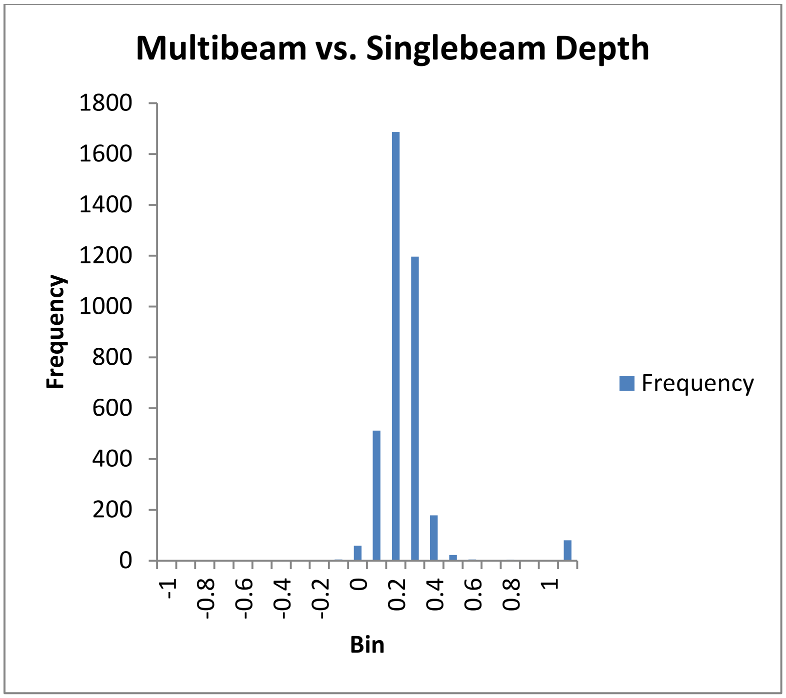


Figure 1: Data from line 2175-1

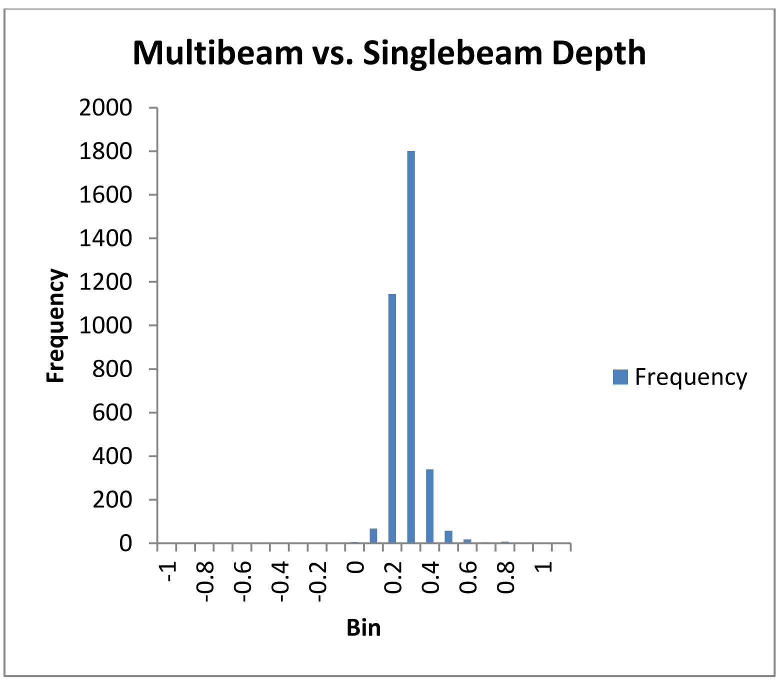


Figure 2: Data from line 2152-1

System Accuracy Test - R/V *C-Ghost*

Lead line comparisons were conducted several times during survey operations as an independent check on the multibeam bottom-detect and single beam systems. Lead lines were generally not taken in larger sea conditions and water depths greater than 15 -20 meters in order to avoid a misreading. These confidence checks were analyzed and statistics computed (Table 1).

Table 1. Lead line log and statistics for the R/V *C-Ghost*.

C-Ghost Lead Line Log									
LL 140111									
Date (mm/dd/yyyy)	**Time (UTC)**	**X (m)**	**Y (m)**	**LL Name**	**MB Depth (m)**	**SB Depth (m)**	**LL Depth (m)**	**ΔMB-SB (m)**	**ΔMB-LL (m)**
06/14/2014	1334	258675.27	3212797.50	LL_140612	13.14	13.00	13.10	0.14	0.04
07/12/2014	1321	253531.36	3212524.54	LL_140712	16.20	16.10	16.15	0.10	0.05
								Average of Differences (m)	
								0.1200	0.0450
								Standard Deviation of Differences (m)	
								0.0283	0.0071

In addition, an Odom CV100 single beam echo sounder continuously recorded singlebeam data and was monitored in real-time as an independent check of the nadir beam (bottom-detect) of the EM3002 multibeam echo sounder. In order to supplement the leadline comparisons, C & C Technologies' propriety software, Hydromap, was used to extract the single beam depths from several Echotrac files that are collected simultaneously with the multibeam data. This process outputs an .echotrac.xyz file. An EM3002.xyz file was also generated from the corresponding EM3002 multibeam data from the same line. The singlebeam and multibeam data generally show good agreement; the mean of the differences does not exceed 0.19 meters (Table 2). The comparisons have been conducted on raw data, and some more extreme difference values may be associated with erroneous data.

Table 2. Lines and statistics for R/V *C-Ghost* singlebeam to multibeam comparison

Date	Line Name	Sheet	Min (m)	Max (m)	Mean (m)	Standard Deviation (m)
07/17/2014	3158a-1	H12636	-0.19	0.40	0.02	0.05
08/06/2014	4017-1	H12635	-0.32	0.88	-0.08	0.06
08/14/2014	4036-1	H12635	-0.34	0.62	-0.06	0.06
08/19/2014	3146a-2	H12636	-0.64	0.41	-0.19	0.08
03/24/2015	5032-1	H12634	0	0.98	0.19	0.14

The following figures show multibeam to singlebeam depth data comparisons from the C-Ghost

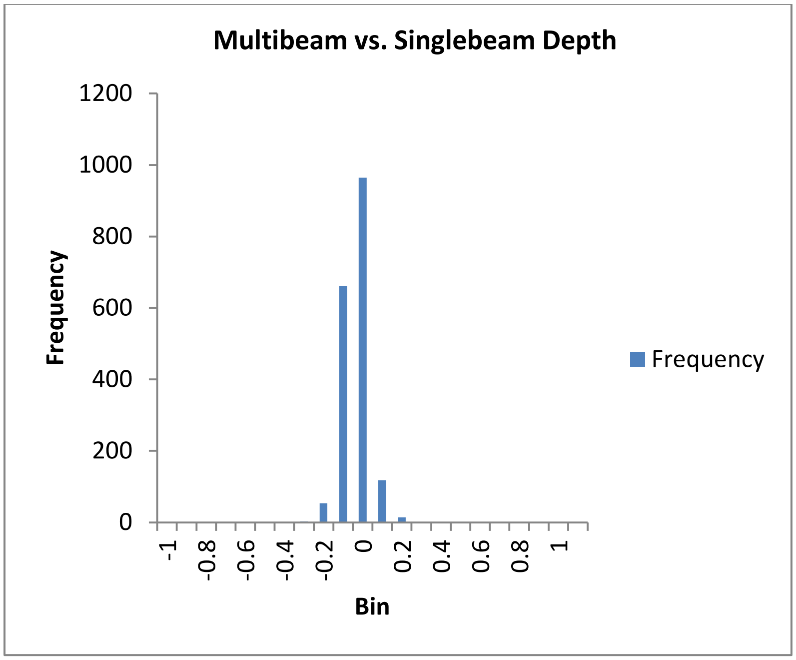


Figure 1: Data from line 4017-1

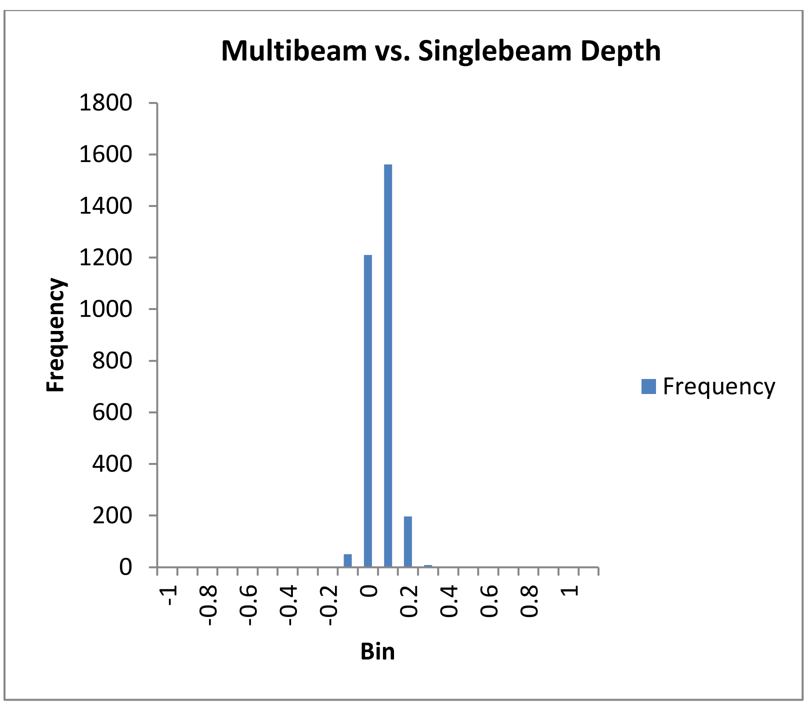


Figure 2: Date from line 3158a-1

APPENDIX II

Echosounder Reports

System Alignment Reports

C&C Technologies
An Oceaneering International Company

NOAA

System Alignment Test (Patch Test) Report – R/V *Sea Scout*

(17-July-2014)

<u>Purpose:</u>

Patch tests are performed in order to calculate the mounting angles of the multibeam transducer in the vessel reference frame. The angular offsets are applied in the topside transducer control software to ensure accurate depth calculations.

The R/V *Sea Scout* is equipped with two Kongsberg EM2040 multibeam echosounders. The patch test was conducted on July 17, 2014 in the Gulf of Mexico, off the coast of Louisiana (Figure 1).

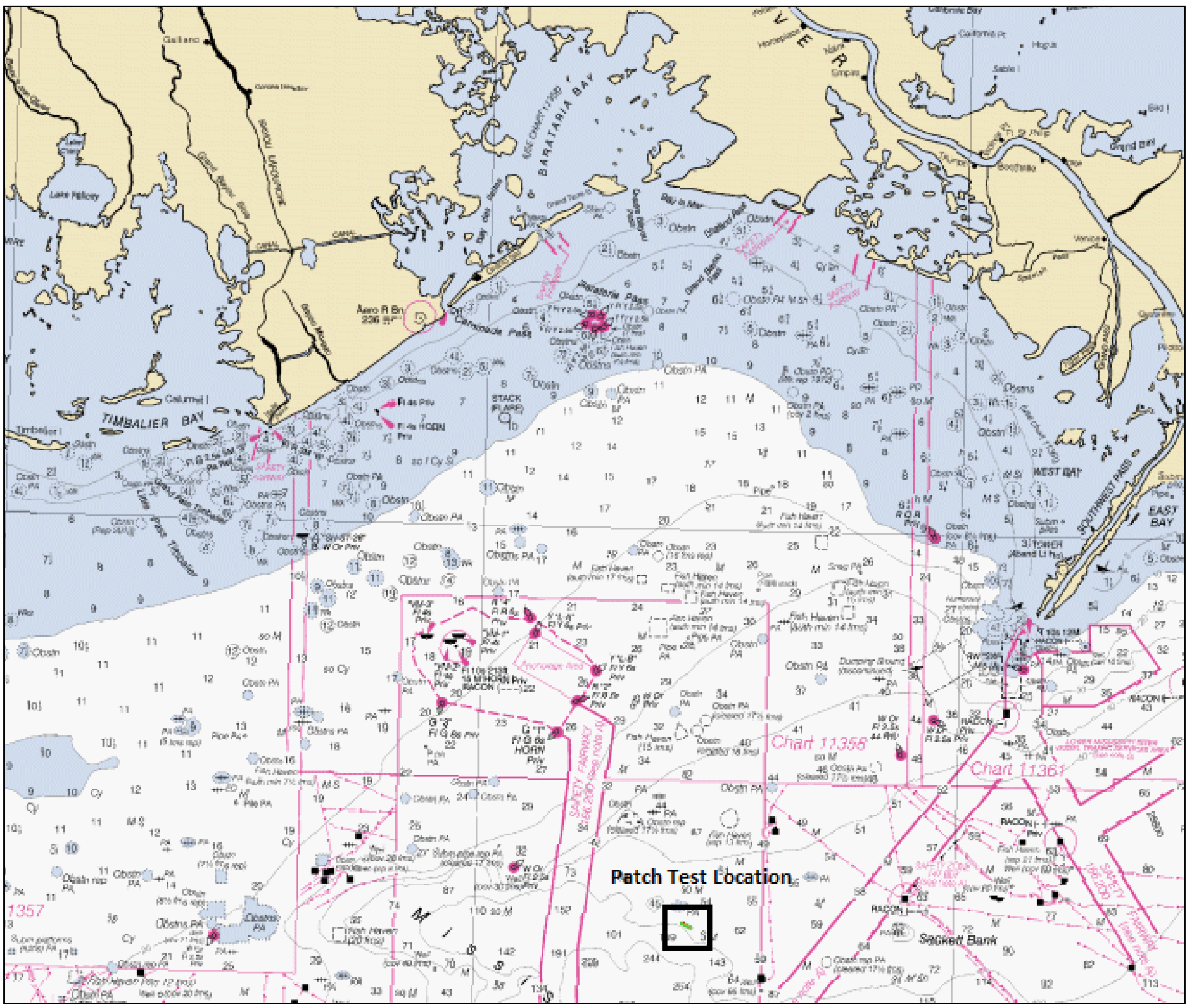


Figure 1. Patch Test Location for R/V *Sea Scout*.

Patch test data for C & C Technologies' surveys have been historically processed using the proprietary software Hydromap. The patch test data were also verified in CARIS 8.1.

Patch Test Processing Hydromap Procedure

Pitch: Two reciprocal lines run over a significant bottom feature.

$$\tan^{-1}\left(\frac{\Delta dx}{(\Delta \mathrm{wd} - \Delta \mathrm{dr}) * 2}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{wd}$ = water depth
$\Delta \mathrm{dr}$ = distance from the transducer to the surface of the water

Transducer	Angle Offset
SH1	0.000°
SH2	0.429°

Roll : Two reciprocal lines run over a relatively flat surface (no features present).

$$\tan^{-1}\left(\frac{\Delta ms}{2}\right)$$

Δms = mean slope calculated in the beam analysis tool in Hydromap (regression analysis)

Transducer	Angle Offset
SH1	0.388°
SH2	0.540°

Yaw: Two parallel lines run in the same direction with 10% to 20% overlap over a significant bottom feature. The overlapping areas must contain the feature.

$$\tan^{-1}\left(\frac{\Delta dx}{\Delta \mathrm{n}}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{n}$ = distance from the feature to nadir

Transducer	Angle Offset
SH1	0.050°
SH2	1.250°

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

Patch Test Processing CARIS Procedure

The patch test data were processed in CARIS 8.1 using the procedures outlined in the CARIS MBES Calibration Procedure Technical Note. Data was collected in the field with zero offsets in order to conduct the calibration procedure in CARIS. Specific lines used and the average offset values obtained are shown in Tables 1 and 2.

Table 1. Average angular offsets (port head) obtained from CARIS

Offset to be Resolved	Lines Used	Angular Offset Obtained
Pitch	SH1-P-1 and SH1-P-2	0.011
Roll	SH1-R-1 and SH1-R-2	0.394
Yaw	SH1-Y-1 and SH1-Y-2	0.031

Table 2. Average angular offsets (starboard head) obtained from CARIS

Offset to be Resolved	Lines Used	Angular Offset Obtained
Pitch	SH2-P-1 and SH2-P-2	0.510
Roll	SH2-R-1 and SH2-R-2	0.520
Yaw	SH2-Y-1 and SH2-Y-2	1.356

Patch Test Verification

The results from resolving the patch test biases several times by several people are shown in Tables 3 and 4. The CARIS project is located on the final hard drives and called SeaScoutCalibration_140717_Final.

Table 3. Results of comparing patch test biases (port head)

Port SH1	Pitch	Yaw	Roll
Processor1	0.000	0.050	0.450
Processor2	0.010	0.000	0.300
Processor3	0.002	0.100	0.400
Processor4	0.000	0.100	0.430
Processor5	0.000	0.000	0.300
Processor6	0.000	0.050	0.400
Processor7	0.000	-0.080	0.420
Processor8	0.077	0.060	0.450
Processor9	0.010	0.000	0.400
Average	0.011	0.031	0.394
Standard Deviation	0.025	0.057	0.057

Table 4. Results of comparing patch test biases (starboard head)

Starboard SH2	Pitch	Yaw	Roll
Processor1	0.500	1.300	0.500
Processor2	0.460	1.450	0.590
Processor3	0.500	1.380	0.450
Processor4	0.560	1.600	0.500
Processor5	0.540	0.900	0.580
Processor6	0.530	1.000	0.480
Processor7	0.500	1.560	0.500
Processor8	0.500	1.490	0.580
Processor9	0.500	1.520	0.500
Average	0.510	1.356	0.520
Standard Deviation	0.029	0.248	0.050

Conclusions

The review of the data in CARIS did not yield any significant additional offsets. For this reason the original patch test values obtained from Hydromap were retained. No additional post-processing occurred other than what is specified the Data Acquisition and Processing Report and in respective Descriptive Reports.

Project Log

C&C Technologies SURVEY SERVICES	**Job Number:**	**140111**	**Page #:**	**001**
	Client:	**NOAA**	**Date** (YY/MM/DD):	**14/07/15**
	Vessel Name:	**R/V Sea Scout**	**Julian Day:**	**196**
	Location:	**H12634**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
2000							Switched from job 140795
							At dock for crew change, groceries
							and fuel
2200							Depart for stone fuel
2300							Arrive at stone fuel
							Taking on stone fuel
0000							New Day 14/07/16 JD:197
0100							Depart stone fuel
0200							Arrive at Pitre dock
							Stand by for crew change,
							Groceries and Caprock tech
0400							Jay Scribner and Gillian
							Spears arrive on vessel
1400							Caprock tech arrives
							Survey crew departs
							Brad Daigle
							Tracy McMillan
							Chad Taylor
							Jason Settle
							Stand by for Caprock Repairs
1900							Groceries onboard
2000							Scott Lanclos onboard
0000							New Day 14/07/17 JD: 198
0500							Caprock tech. finished
							Departing Dock to transit
							to patch test site
1200	WX						Winds: East 2kts Seas 2 ft
							Vis: Unl
1215							Arrive at Patch Test site
							ON SHIFT: James C, Jeremy T,
							Gillian S.
							CTD_140717a_
							X:

Project Log

Job Number:	140111	Page #:	002
Client:	NOAA	Date (YY/MM/DD):	14/07/17
Vessel Name:	R/V Sea Scout	Julian Day:	198
Location:			

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
							LAT: 28.637240 LONG: -89.778252
							MB: 171.79 CTD depth: 173.29
							SB: N/A
							YSI: 1529 m/s HM: 1523.95 m/s
							Draft Reading Port: 1.50 m Stbd: 1.47 m
							Waterline to CRP: 4.92 m
1335	SH1-P-1	0	117	4.8	0.7	182.0	SOL (Beam Angles P= 30 & S=30)
1342	SH1-P-1	1	117	5.1	0.6	172.4	EOL
1350	SH1-P-2	1	297	5.3	0.6	176.7	SOL
1358	SH1-P-2	0	297	5.4	0.6	183.0	EOL
1403	SH1-R-1	0	117	5.9	0.6	173.4	SOL
1409	SH1-R-1	1	117	6.1	0.6	168.5	EOL Noticed high speed & slowing down
1415	SH1-R-2	1	297	6.3	0.6	169.7	SOL
1421	SH1-R-2	0	297	6.4	0.6	172.9	EOL
1427	SH1-Y-1	0	117	4.5	0.6	173.0	SOL
1436	SH1-Y-1	1	117	4.2	0.6	165.3	EOL
1450	SH1-Y-2	0	117	4.4	0.6	182.4	SOL
1457	SH1-Y-2	1	117	4.5	0.6	174.1	SOL
1508	SH1-P-3	0	029	6.8	0.6	189.0	SOL
1514	SH1-P-3	1	029	4.2	0.6	125.9	EOL – No Tracking
							Deleting Line and
							Re-running with same name
1524	SH1-P-3	1	209	4.2	0.6	146.9	SOL
1531	SH1-P-3	0	209	3.8	0.6	129.1	EOL – No Tracking on EOL
							Continue to previous lines &
							Switching to SH2
1544	SH2-P-1	0	117	4.2	0.6	174.4	SOL
1554	SH2-P-1	1	117	4.2	0.6	168.5	EOL
1600	SH2-P-2	1	297	3.8	0.6	168.3	SOL
1611	SH2-P-2	0	297	3.8	0.6	173.2	EOL
1618	SH2-R-1	0	117	4.2	0.6	181.8	SOL
1627	SH2-R-1	1	117	4.3	0.6	173.9	EOL
1635	SH2-R-2	2	297	3.4	0.6	176.7	SOL

Project Log

C&C Technologies SURVEY SERVICES	**Job Number:**	**140111**	**Page #:**	**003**
	Client:	**NOAA**	**Date** (YY/MM/DD):	**14/07/17**
	Vessel Name:	**R/V Sea Scout**	**Julian Day:**	**198**
	Location:			

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1646	SH2-R-2	0	297	3.4	0.6	181.7	EOL
1654	SH2-Y-1	0	117	4.4	0.6	180.8	SOL
1703	SH2-Y-1	1	117	4.5	0.6	176.9	EOL
1716	SH2-Y-2	0	117	4.3	0.6	171.8	SOL
1725	SH2-Y-2	1	117	4.5	0.6	164.0	EOL
1730							Perform Patch Test in
							Caris & Hydromap
1800	WX						Wind: 0-5 knt Vis: 10m Bar: 1014
1934	SH1-verify-1	0	117	4.3	0.7	174.0	SOL
1943	SH1-verify-1	1	117	4.4	0.7	162.7	EOL
1952	SH1-verify-2	1	297	3.4	0.7	169.0	SOL
2004	SH1-verify-2	0	297	3.3	0.7	171.1	EOL
2011	SH2-verify-1	0	117	3.7	0.7	173.5	SOL
2019	SH2-verify-1	1	117	4.3	0.7	165.5	EOL
2029	SH2-verify-2	1	297	3.4	0.7	168.6	SOL
2040	SH2-verify-2	0	297	3.3	0.7	174.0	EOL
2049	Both-verify-1	0	117	4.2	0.7	174.7	SOL
2058	Both-verify-1	1	117	4.4	0.7	166.3	EOL
2110	Both-verify-2	1	297	3.4	0.7	171.3	SOL
2120	Both-verify-2	0	297	3.5	0.7	173.4	EOL
2130							Patch Test Complete
							SH1 Final Offsets:
							P: 0.000 R: 0.388 Y: 0.050
							SH2 Final Offsets:
							P: 0.429 R: 0.540 Y:1.250
2130							Transit to find location
							For SSS testing
0000	WX						Winds S-SE 5 kts Seas 0 ft Vis Unl
							Bar 1013 mb Temp 87̊
0000							New Day 14/07/28 JD: 199
							X: 250348.75 Y: 3189892.64
							LAT: 28.812437 LONG: -89.558093

System Alignment Test (Patch Test) Report – R/V *Sea Scout*

(29-April-2015)

Purpose:

Patch tests are performed in order to calculate the mounting angles of the multibeam transducer in the vessel reference frame. The angular offsets are applied in the topside transducer control software to ensure accurate depth calculations.

The R/V *Sea Scout* is equipped with two Kongsberg EM2040 multibeam echosounders. The patch test was conducted on April 29, 2015 in the Gulf of Mexico, off the coast of Louisiana (Figure 1).

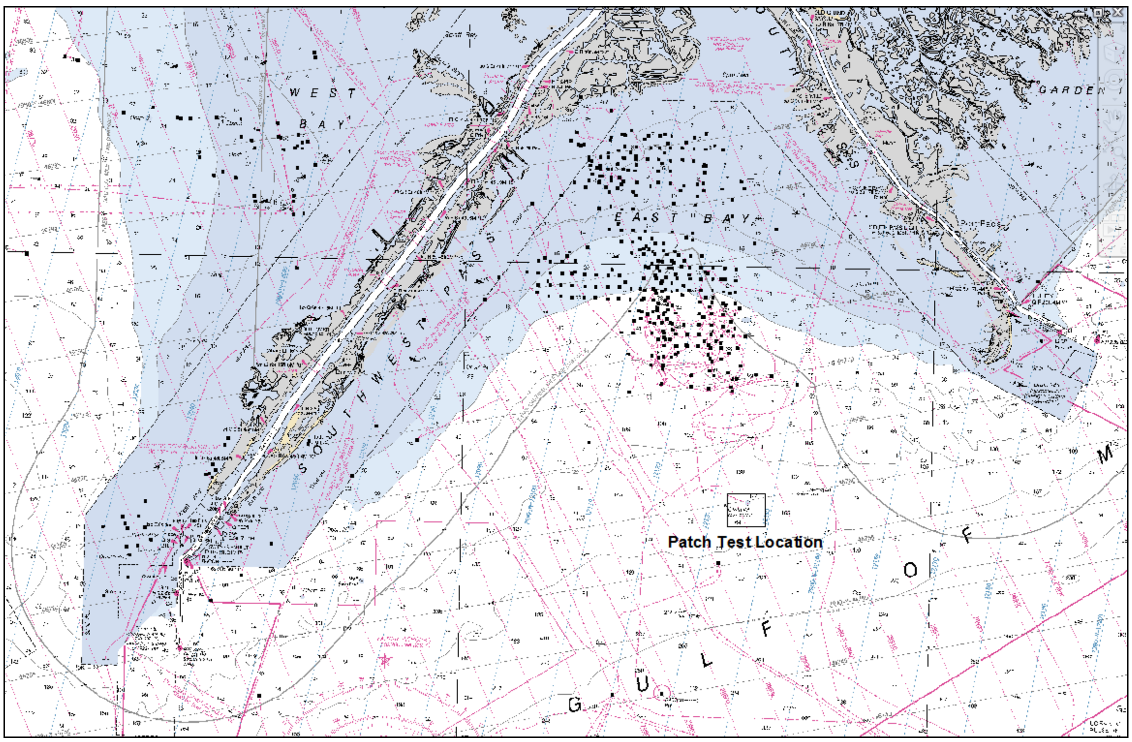


Figure 1. Patch Test Location for R/V *Sea Scout*.

Patch test data for C & C Technologies' surveys have been historically processed using the proprietary software Hydromap, but for this patch test, Hydromap was used only for data collection and vessel navigation. CARIS 8.1 was used during the patch test to calculate the angular offsets.

Patch Test Collection Procedure and Final Results

Latency: One line run twice over a significant bottom feature. One line run at a fast speed and one line run at half the speed of the first.

Latency
No latency calculated

Pitch: Two reciprocal lines run over a significant bottom feature.

Transducer	Angle Offset
SH1	-0.47°
SH2	-0.22°

Roll : Two reciprocal lines run over a relatively flat surface (no features present).

Transducer	Angle Offset
SH1	-1.05°
SH2	-0.90°

Yaw: Two parallel lines run in the same direction with 10% to 20% overlap over a significant bottom feature. The overlapping areas must contain the feature.

Transducer	Angle Offset
SH1	+1.79°
SH2	+2.40°

Patch Test Processing CARIS Procedure

The patch test data was processed in CARIS 8.1 using the procedures outlined in the CARIS MBES Calibration Procedure Technical Note. Data for the first set of lines for each test (Latency, Pitch, Roll, and Yaw) were collected in the field with zero offsets in order to conduct the calibration procedure in CARIS. The calculated angular offsets were input into SIS for verification lines. See the patch test log for details. Specific lines used and the offset values obtained are shown in Tables 1 and 2.

Table 1. Angular offsets (port head) obtained from CARIS

Offset to be Resolved	Lines Used	Angular Offset Obtained
Latency	SH1-Latency-1 and SH1-Latency-2	No latency calculated
Pitch	SH1-Latency-2 and SH1-Pitch-2	-0.47°
Pitch Verification	SH1-Pitch-4 and SH1-Pitch-5	-0.47° (final)
Roll	SH1-Roll-1 and SH1-Roll-2	-1.05°
Roll Verification	SH1-Roll-3 and SH1-Roll-4	-1.05° (final)
Yaw	SH1-Yaw-2 and SH1-Yaw-3	+1.79°
Yaw Verification	SH1-Yaw-4 and SH1-Yaw-5	+1.79° (no change)
Yaw Verification	SH1-Yaw-6 and SH1-Yaw-7	+2.04° (adjusted yaw)
Yaw Verification	SH1-Yaw-8 and SH1-Yaw-9	+1.79° (final)

Table 2. Angular offsets (starboard head) obtained from CARIS

Offset to be Resolved	Lines Used	Angular Offset Obtained
Latency	No need to run latency for SH2 (Same PU as SH1)	
Pitch	SH2-Pitch-1 and SH2-Pitch-2	-0.26°
Pitch Verification	SH2-Pitch-3 and SH2-Pitch-4	-0.16° (adjusted pitch)
Pitch Verification	SH2-Pitch-5 and SH2-Pitch-6	-0.22° (final)
Roll	SH2-Roll-1 and SH2-Roll-2	-0.97°
Roll Verification	SH2-Roll-3 and SH2-Roll-4	-0.90° (adjusted roll)
Roll Verification	SH2-Roll-5 and SH2-Roll-6	-0.90° (final)
Yaw	SH2-Yaw-1 and SH2-Yaw-2	+2.70°
Yaw Verification	SH2-Yaw-3 and SH2-Yaw-4	+2.40° (adjusted yaw)
Yaw Verification	SH2-Yaw-5 and SH2-Yaw-6	+2.40° (final)

Patch Test Verification

The results from resolving the patch test biases several times by several people are shown in Tables 3 and 4. The CARIS project is located on the final hard drives and called SeaScoutCalibration_150429_Final.

Table 3. Results of comparing patch test biases (port head)

Port SH1	Pitch	Yaw	Roll
Processor1 (GG)	-0.500	1.89	-1.07
Processor2 (TM)	-0.75	1.92	-1.02
Processor3 (JAB)	-0.50	1.78	-1.06
Processor4 (JST)	-0.45	1.75	-1.01
Average	-0.55	1.84	-1.04
Standard Deviation	0.14	0.07	0.03

Table 4. Results of comparing patch test biases (starboard head)

Starboard SH2	Pitch	Yaw	Roll
Processor1 (GG)	-0.20	2.42	-0.95
Processor2 (TM)	-0.15	2.68	-0.96
Processor3 (JAB)	-0.23	2.44	-0.89
Processor4 (JST)	-0.20	2.39	-0.87
Average	-0.20	2.48	-0.92
Standard Deviation	0.03	0.12	0.04

Patch Test Processing Hydromap Procedure

Pitch: Two reciprocal lines run over a significant bottom feature.

$$\tan^{-1}\left(\frac{\Delta dx}{(\Delta \mathrm{wd} - \Delta \mathrm{dr}) * 2}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{wd}$ = water depth
$\Delta \mathrm{dr}$ = distance from the transducer to the surface of the water

Transducer	Angle Offset
SH1	-0.46°
SH2	-0.29°

Roll : Two reciprocal lines run over a relatively flat surface (no features present).

$$\tan^{-1}\left(\frac{\Delta ms}{2}\right)$$

Δms = mean slope calculated in the beam analysis tool in Hydromap (regression analysis)

Transducer	Angle Offset
SH1	-1.05°
SH2	-0.96°

Yaw: Two parallel lines run in the same direction with 10% to 20% overlap over a significant bottom feature. The overlapping areas must contain the feature.

$$\tan^{-1}\left(\frac{\Delta dx}{\Delta \mathrm{n}}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{n}$ = distance from the feature to nadir

Transducer	Angle Offset
SH1	1.97°
SH2	2.86°

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

Conclusions

The values obtained using the Hydromap method are an independent check of the CARIS processing and will not be used for real-time data acquisition. The review of the data in Hydromap did not yield any significant additional offsets. For this reason the original patch test values obtained from CARIS were retained. No additional post-processing occurred other than what is specified the Data Acquisition and Processing Report and in respective Descriptive Reports.

Patch Test Log

C&C Technologies An Oceaneering International Company				
	Vessel Name:	**Sea Scout**	**Page #:**	**01**
	Project Number:	**OPR-K379-KR-15**	**Date (YY/MM/DD):**	**15/04/29**
	General Locality:	**South Pass, GOM**	**Julian Day:**	**119**

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
1600	Recon 1-5		100	4.0		Running multibeam recon lines to look
						For suitable patch test site
1700	Recon 1-6		100	4.0		Next line
1830	Recon 1-9		80	4.3		Next line
1859						Patch test location found
						Stopping for CTD
1911						CTD_150429a S/N 2791 used
						X: 282001.99 m Y: 3201281.41 m
						Lat: 28.920913° Long: -89.236169°
						WD: 49.89 m CTD depth: 49.27 m
						YSI: 1510 m/s HM: 1527 m/s
						Draft Port: 1.546 m Stbd: 1.614 m
						WL to CRP: 4.787 m
						Angular offsets have been zeroed
						Out in SIS
						Starboard head (SH2) has been
						Turned off
1938	SH1-Latency-1	051	17.6	8.0	0.6	SOL – Port Head Latency (fast line)
1952	SH1-Latency-2	051	47.7	4.0	0.6	SOL – Port Head Latency (slow line)
						Port/Stbd beam angles set to 40/40 for latency
						Checking data in CARIS
						Delayed while SIS is re-installed to
						Make patch test tool work
						No latency calculated
						Using SH1-Latency-2 for Pitch line # 1
2059	SH1-Pitch-2	230	47.0	4.0	0.6	SOL - Port Head Pitch line # 2
						Pitch of -0.47° calculated in CARIS
						This value has been entered into
						SIS for verification lines
2113	SH1-Pitch-3	051	47.6	4.4	0.6	SOL – Pitch verification line # 1
2122	SH1-Pitch-4	230	46.2	4.4	0.6	SOL – Pitch verification line # 2
						Running more verification lines
2141	SH1-Pitch-5	051	47.5	4.5	0.6	SOL – Pitch verification line # 3

Patch Test Log

C&C Technologies — An Oceaneering International Company			
Vessel Name:	Sea Scout	Page #:	02
Project Number:	OPR-K379-KR-15	Date (YY/MM/DD):	15/04/29
General Locality:	South Pass, GOM	Julian Day:	119

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
						Final Pitch value of –0.47° used
						Pitch has been zeroed out in SIS
2150	SH1-Roll-1	052	46.8	4.5	0.7	SOL – Roll line # 1
2204	SH1-Roll-2	232	39.6	4.5	0.7	SOL – Roll line # 2
						Roll of –1.05° calculated in CARIS
						SIS values: Roll: -1.05° Pitch: -0.47°
2222	SH1-Roll-3	051	46.9	4.0	0.7	SOL – Roll verification line # 1
2226	SH1-Roll-4	231	39.6	4.3	0.7	SOL – Roll verification line # 2
						Roll value of –1.05° is good
						All values in SIS have been zeroed
						Out for Yaw lines
2250	SH1-Yaw-1	230	47.2	4.6	0.7	SOL – Yaw line # 1
						Yaw # 1 is a bad line. Do not use.
2259	SH1-Yaw-2	057	47.7	4.6	0.7	SOL – Yaw line # 2
2311	SH1-Yaw-3	056	46.9	4.5	0.9	SOL – Yaw line # 3
						Yaw of +1.79° calculated in CARIS
						All values entered into SIS
						Pitch: -0.47° Roll: -1.05° Yaw: +1.79°
2324	SH1-Yaw-4	236	46.5	4.8	0.9	SOL – Yaw verification line # 1
2340	SH1-Yaw-5	236	45.2	4.8	0.7	SOL – Yaw verification line # 2
						Yaw value of +1.79° good
2357						CTD_150430a S/N 2645 used
						X: 281977.71 m Y: 3201361.31 m
						Lat: 28.921629° Long: -89.236434°
						WD: 49.62 m CTD depth: 49.10 m
						HM: 1526 m/s YSI: 1511 m/s
0016	SH1-Yaw-6	053	47.7	4.6	0.7	SOL – Yaw verification line # 3
0028	SH1-Yaw-7	053	47.1	4.8	0.7	SOL – Yaw verification line # 4
						Yaw of +2.04° calculated
						Value in SIS updated to Yaw: +2.04°
0041	SH1-Yaw-8	234	45.6	4.5	0.7	SOL – Yaw verification line # 5
0055	SH1-Yaw-9	234	45.4	4.3	0.7	SOL – Yaw verification line # 6
						Yaw of +1.79° good

Patch Test Log

C&C Technologies — An Oceaneering International Company

Vessel Name:	**Sea Scout**	**Page #:**	**03**
Project Number:	**OPR-K379-KR-15**	**Date (YY/MM/DD):**	**15/04/30**
General Locality:	**South Pass, GOM**	**Julian Day:**	**120**

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
						Final angular offsets for
						SH 1 (Port)
						Pitch: -0.47° Roll: -1.05° Yaw: +1.79°
						Turning off SH 1 (Port)
						Turning on SH 2 (Stbd)
						All offsets for SH 2 have been
						Set to zero in SIS
0110	SH2-Pitch-1	065	47.6	4.5	0.9	SOL – Pitch line # 1
0118	SH2-Pitch-2	245	46.0	4.8	0.6	SOL – Pitch line # 2
						Pitch value of -0.26° calculated in CARIS
0135	SH2-Pitch-3	065	47.3	4.6	0.6	SOL – Pitch verification # 1
0143	SH2-Pitch-4	245	45.9	4.4	0.6	SOL – Pitch verification # 2
						Pitch verification line # 1&2 are run with
						-0.26° Pitch offset in SIS
						Pitch of -0.16° calculated in CARIS
						-0.16° Pitch entered into SIS
0157	SH2-Pitch-5	065	47.2	5.0	0.6	SOL – Pitch verification # 3
0203	SH2-Pitch-6	244	45.8	4.3	0.6	SOL – Pitch verification # 4
						Final Pitch value of -0.22° calculated
						In CARIS
						All values have been zeroed out
						In SIS for Yaw lines
0215	SH2-Roll-1	065	45.7	4.9	0.7	SOL – Roll line # 1
0225	SH2-Roll-2	246	46.6	4.9	0.6	SOL – Roll line # 2
						Roll of -0.97° calculated in CARIS
						-0.97 Roll and -0.22 Pitch have
						Been entered into SIS
0241	SH2-Roll-3	066	46.2	4.7	0.6	SOL – Roll verification line # 1
0250	SH2-Roll-4	246	46.7	4.9	0.6	SOL – Roll verification line # 2
						Roll of -0.90° calculated in CARIS
						-0.90° entered into SIS
0307	SH2-Roll-5	066	46.9	4.8	0.8	SOL – Roll verification line # 3
0316	SH2-Roll-6	246	45.1	4.9	0.6	SOL – Roll verification line # 4

Patch Test Log

	Vessel Name:	Sea Scout	Page #:	04
	Project Number:	OPR-K379-KR-15	Date (YY/MM/DD):	15/04/30
	General Locality:	South Pass, GOM	Julian Day:	120

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
						Final Roll value of -0.90°
						Confirmed
0337						CTD_150430b S/N 2645 used
						X: 282345.27 m Y: 3201423.94 m
						Lat: 28.922257° Long: -89.232678°
						WD: 50.52 m CTD depth: 49.54 m
						HM: 1526 m/s YSI: 1502 m/s
						All values in SIS have been
						Zeroed out for Yaw-1 & Yaw-2
0358	SH2-Yaw-1	066	47.5	4.3	0.6	SOL – Yaw line # 1
0409	SH2-Yaw-2	066	46.9	3.8	0.6	SOL – Yaw line # 2
						Yaw of +2.70° calculated in CARIS
						All offsets have been entered into SIS
						For verification lines
						Pitch: -0.22° Roll: -0.90° Yaw: +2.70°
0424	SH2-Yaw-3	246	45.5	4.4	0.7	SOL – Yaw verification line # 1
0438	SH2-Yaw-4	246	46.2	4.9	0.7	SOL – Yaw verification line # 2
						Yaw of +2.40° calculated in CARIS
						Value of +2.40° entered into SIS
0454	SH2-Yaw-5	065	46.5	4.7	0.7	SOL – Yaw verification line # 3
0505	SH2-Yaw-6	065	47.1	4.6	0.7	SOL – Yaw verification line # 4
						Final Yaw value of +2.40° verified
						All values entered into SIS
						Both heads turned on
0520	Verify-1	197	47.8	4.4	0.6	SOL – Patch test verification line # 1
0523	Verify-1	197	48.6	4.7	0.7	EOL
						Patch test complete
						SH 1 (Port)
						Pitch: -0.47° Roll: -1.05° Yaw: +1.79°
						SH2 (Stbd)
						Pitch: -0.22° Roll: -0.90° Yaw: +2.40°

System Alignment Test (Patch Test) Report – R/V *C-Wolf*

(2-June-2014)

<u>Purpose:</u>

Patch tests are performed in order to calculate the mounting angles of the multibeam transducer in the vessel reference frame. The angular offsets are applied in the topside transducer control software to ensure accurate depth calculations.

The R/V *C-Wolf* is equipped with an EM3002 multibeam echosounder. The patch test was conducted on June 2, 2014 in the Gulf of Mexico off of Southwest Pass, Louisiana. Figure 1 shows the location of the R/V *C-Wolf* patch test.

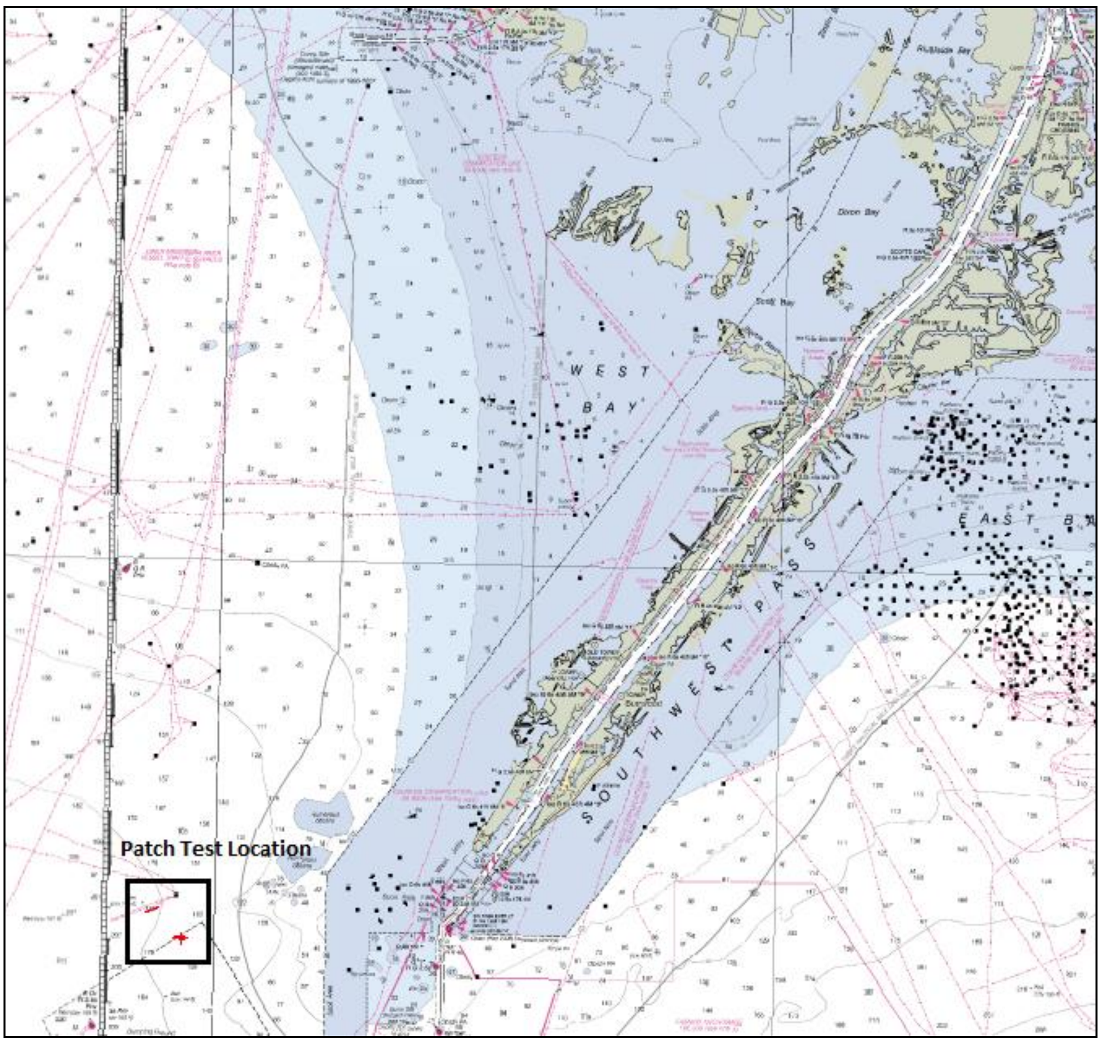


Figure 1. Patch Test Location for the R/V *C-Wolf*.

Patch test data for C & C Technologies' surveys have been historically processed using the proprietary software Hydromap. The patch test data were verified in CARIS 8.1.

Patch Test Processing Hydromap Procedure

Pitch: Two reciprocal lines run over a significant bottom feature.

$$\tan^{-1}\left(\frac{\Delta dx}{(\Delta \mathrm{wd} - \Delta \mathrm{dr}) * 2}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{wd}$ = water depth
$\Delta \mathrm{dr}$ = distance from the transducer to the surface of the water

Transducer	Angle Offset
SH1	-2.12°

Roll : Two reciprocal lines run over a relatively flat surface (no features present).

$$\tan^{-1}\left(\frac{\Delta ms}{2}\right)$$

Δms = mean slope calculated in the beam analysis tool in Hydromap (regression analysis)

Transducer	Angle Offset
SH1	-0.15°

Yaw: Two parallel lines run in the same direction with 10% to 20% overlap over a significant bottom feature. The overlapping areas must contain the feature.

$$\tan^{-1}\left(\frac{\Delta dx}{\Delta \mathrm{n}}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{n}$ = distance from the feature to nadir

Transducer	Angle Offset
SH1	-1.00°

Note: The values obtained are neither positive nor negative in Hydromap. The signs of the values are determined after processing the patch test data.

Patch Test Processing CARIS Procedure

The patch test data were processed in CARIS 8.1 using the procedures outlined in the CARIS MBES Calibration Procedure Technical Note. Data was collected in the field with zero offsets in order to conduct the calibration procedure in CARIS. Specific lines used and the average offset values obtained are shown in Table 1.

Table 1. Lines used in CARIS to detetmine average offsets for the R/V *C-Wolf*.

Offset to be Resolved	Lines Used	Average Offset Obtained
Latency	latency1 and latency2	0.00 s
Pitch	pitch3 and latency2	-2.06º
Roll	roll4 and roll5	-0.14º
Yaw	yaw4 and yaw5	-1.00º

Patch Test Verification

The results from resolving the patch test biases several times by several people are shown in Table 2. The CARIS project is located on the final hard drives and called CWolf_PatchTest_140602_final.

Table 2. Results of resolving patch test biases several times in CARIS for the R/V *C-Wolf*.

	Latency	Pitch	Roll	Yaw
Processor 1	0.00	-2.11	-0.13	-1.00
Processor 1	0.01	-2.12	-0.15	-1.00
Processor 1	0.00	-2.12	-0.15	-1.01
Processor 2	0.01	-2.11	-0.10	-0.99
Processor 2	0.00	-2.01	-0.15	-1.01
Processor 2	0.00	-2.10	-0.14	-1.00
Processor 3	0.00	-2.00	-0.15	-1.00
Processor 3	0.00	-1.90	-0.17	-1.10
Processor 3	0.00	-2.10	-0.12	-0.90
Average	0.00	-2.06	-0.14	-1.00
Standard Deviation	0.00	0.08	0.02	0.05

Conclusions

Review of the patch test data in CARIS did not yield any significant additional offsets than what was calculated using the Hydromap method. No additional post-processing was applied to the data other than what is specified in the Data Acquisition and Processing Report and in respective Descriptive Reports.

Project Log

	Project Number:	**OPR-K339-KR-14**	**Page #:**	**003**
	Registry Number:	**H12635**	**Date (YY/MM/DD):**	**14/06/02**
	Vessel Name:	**R/V C-Wolf**	**Julian Day:**	**153**
	Sublocality:	**7 NM NW of Southwest Pass**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1730							Depart dock for patch test
							Recon
							Joe Roche, Chris Hartman, J Carlsen
							Survey crew present
1904							Arrived in waters 45m and deeper
							Lowering MB head
1909							Begin recon
2028							Target found 42m, prepping for
							CTD
2037							CTD_140602a_5221
							Not good only recorded to 1m
							Depth
2051							Moving to CTD location again
	WX						Winds:10kts SE seas:2-3ft vis:clear
2105							CTD_140602b_5221
							Lat:28.925541 Long:-89.516924
							X:254586.86 Y:3200126.98
							WD:47.67m CTD depth:43.41m
							SB depth:47m Draft reading:1.23ft
							HM:1530m/s YSI:1499m/s
							Transit to patch test target
2132	Latency1	-	090	1.4			SOL Slow line
2135	Latency1	-	090	1.5			EOL
2141	Latency2	-	090	4.1			SOL Fast line
2142	Latency2	-	090	3.9			EOL
2147	Pitch1	-	290	6.0			SOL use latency2 for pitch comparison
2149	Pitch1	-	270	5.8			EOL-could not stay online current
							Making N/S lines. Do not use
2157	Pitch2	-	028				Could not steer vessel N/S
							Attempting NE/SW lines
2158	Pitch2	-	028	6.0			Due to current crabbing too much
							EOL
2200	Pitch3	-	270	6.0			SOL

Project Log

C&C Technologies SURVEY SERVICES	**Project Number:**	**OPR-K339-KR-14**	**Page #:**	**004**
	Registry Number:	**H12635**	**Date** (YY/MM/DD):	**14/06/02**
	Vessel Name:	**R/V C-Wolf**	**Julian Day:**	**153**
	Sublocality:	**7 NM NW of Southwest Pass**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
2202	Pitch3	-	270	6.0			EOL-use latency2 for pitch
							Comparison
2208	Yaw1	-	270	5.8			SOL
2209	Yaw1	-	270	5.7			EOL-too far offline
2220	Yaw2	-	270	4.2			SOL
2223	Yaw2	-	270	8.1			EOL
2231	Yaw3	-	089	3.9			SOL
2233	Yaw3	-	089	4.6			EOL
2235							MB ram up, transiting back
							To boat slip. Will return tomorrow
							To complete patch test
2236	WX						Winds:5-10kts seas:2-3ft SE vis:clear
2355							Arrive at boat slip
							Secure vessel, hook up to shore
							Power
2359							Depart vessel
0000							New day 14/06/03
1115							Arrive at slip, launch vessel
							Head to fuel dock
1130							Fuel vessel 42.4 gallons gas
							9.8 gallons diesel
1142							Depart fuel dock for patch test
							Target
							J Roche, C Hartman, J Carlsen
							Crew
1301							Arrived at CTD location, prepping
							For deployment
	WX						Winds:10kts SE seas:2-3ft vis:clear
1304							MB ram down
							Draft reading 1.25ft, waterline to
							CRP changed to 0.03
							SB draft:0.10m SB depth:43.0
							MB depth:43.01m

Project Log

	Project Number:	OPR-K339-KR-14	Page #:	005
C&C Technologies SURVEY SERVICES	Registry Number:	H12635	Date (YY/MM/DD):	14/06/13
	Vessel Name:	R/V C-Wolf	Julian Day:	154
	Sublocality:	7 NM NW of Southwest Pass		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1314							CTD_140606a_5221
							X:255412.04m Y:3200376.65m
							Lat:28.907950 Long:-89.508522
							WD:45.01m YSI:1504m/s
							HM:1531.41m CTD depth:47.94
1332	Yaw4	-	270	7.4			SOL
1332	Yaw4	-	270	7.3			EOL
1338	Yaw5	-	090	5.5			SOL
1339	Yaw5	-	090	3.9			EOL
1350							Recon for flat bottom for roll lines
							No flat bottom in the general vicinity
							Of patch test target
1421	Roll1	-	040	2.8			SOL
1424	Roll1	-	040	3.0			EOL
1428	Roll2	-	220	7.8			SOL current strong
1430	Roll2	-	220	7.9			EOL-could not hold the line
1434	Roll3	-	220	8.5			SOL
1435	Roll3	-	220	8.5			EOL-current pushing vessel
							Examined Caris data too noisy
							Will have to rerun roll calibration
1458	Roll4	-	069	3.8			SOL
1500	Roll4	-	069	3.8			EOL
1504	Roll5	-	249	6.1			SOL-current pushing vessel
							In this direction
1506	Roll5	-	249	5.7			EOL
							Examining roll lines in Caris
							Running verification lines
							Latency_0 pitch=-2.12
							Yaw=-1.00 roll=-0.15
No line	verification						Verification 1 numbers entered into
							SIS 359 entered for yaw
1541	Verification2	-	359	5.0			SOL
1543	Verification2	-	359	5.0			EOL

Project Log

C&C Technologies SURVEY SERVICES	**Project Number:**	**OPR-K339-KR-14**	**Page #:**	**006**
	Registry Number:	**H12635**	**Date** (YY/MM/DD):	**14/06/03**
	Vessel Name:	**R/V C-Wolf**	**Julian Day:**	**154**
	Sublocality:	**7 NM NW of Southwest Pass**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1546	Verification3	1	179	5.7			SOL
1549	Verification3	2	179	5.6			EOL
1553	Verification4	1	270	6.8			SOL
1555	Verification4	2	270	6.7			EOL
1559	Verification5	1	090	4.6			SOL
1602	Verification5	2	090	4.8			EOL
							Checking verification lines in Caris
1635							Lines look good in Caris, heading
							To CTD for tie lines
							Arrive at CTD location
1658							CTD_140603b_5221
							X:257237.23m Y:3206039.37m
							Lat:28.959361 Long:-89.491039
							WD:34.49m SB depth:34m
							CTD depth:34.13m YSI1509.68m/s
							HM:1529m/s
							Waterline same as last CTD
							Transit to tie 220
1714	Tie-220	64	067	6.5			SOL
1742	Tie-220	106	067	6.1			EOL
	WX						Winds:10-15kts E seas:1ft chop vis:clear
1747	Tie-119	106	247	6.7			SOL
1818	Tie-119	64	247	6.2			EOL
1828	Tie-118	53	067	4.9			SOL
1912	Tie-118	111	067	6.3			EOL
1922	Tie-117	113	247	6.2			SOL
1955	Tie-117	59	247	8.1			EOL
							Offline due to platform
2004	Tie-117	44	247	6.6			SOL WD79a
2018	Tie-216	28	067	5.1			EOL
2037	Tie-216	56	067	6.7			SOL WD79E
2046	Tie-216	70	067	7.0			EOL SIS crashed
2049	Tie-216-2	70	067	6.7			SOL

System Alignment Test (Patch Test) Report – R/V *C-Ghost*

Purpose:

Patch tests are performed in order to calculate the mounting angles of the multibeam transducer in the vessel reference frame. The angular offsets are applied in the topside transducer control software to ensure accurate depth calculations.

The R/V *C-Ghost* is equipped with an EM3002 multibeam echosounder. A patch test was conducted on July 16, 2014 in the Gulf of Mexico between Southwest Pass and South Pass, Louisiana. An additional patch test was conducted on March 21, 2015 in the approximate same position prior to collecting the 2015 data. Figure 1 shows the location of the R/V *C-Ghost* patch tests.

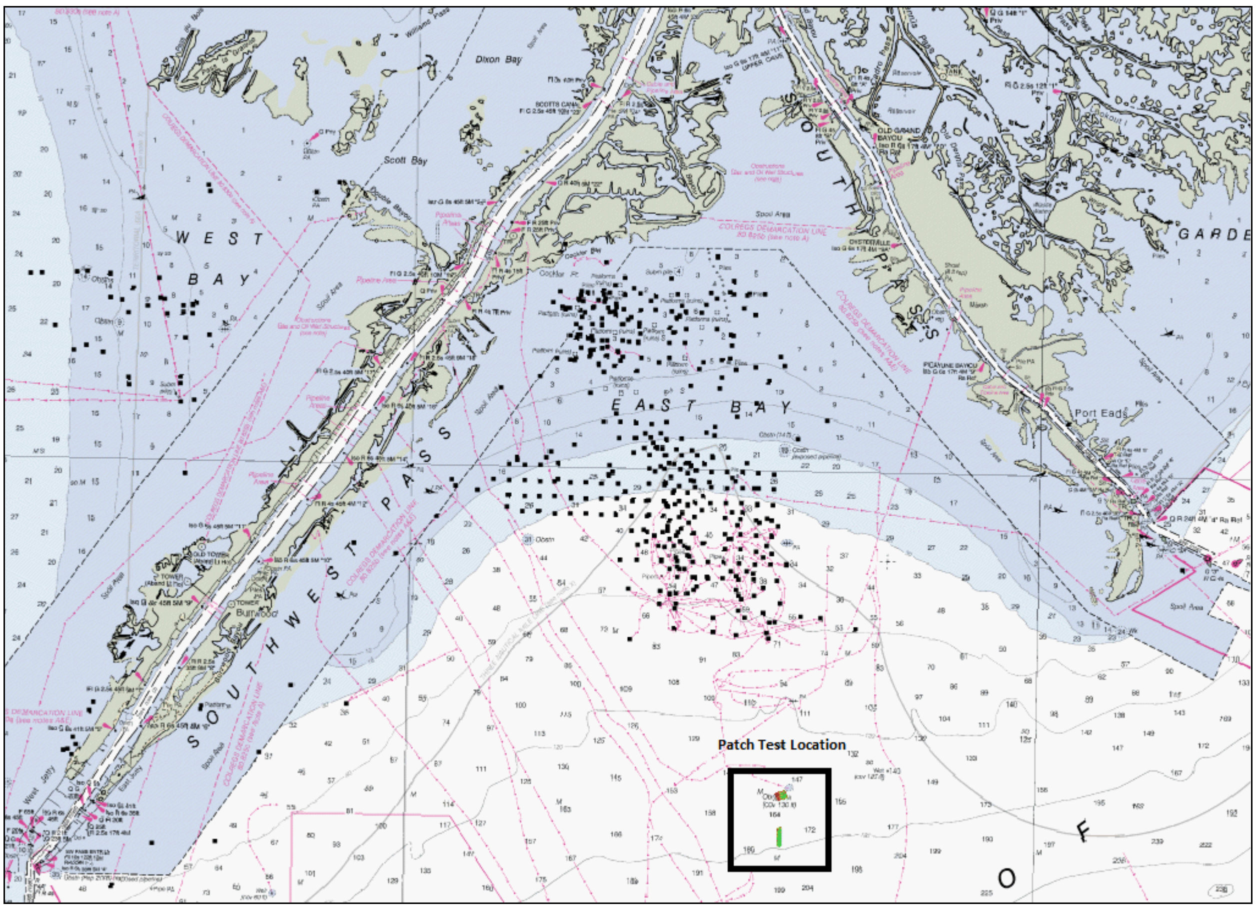


Figure 1. Patch Test Location for the R/V *C-Ghost*.

Patch test data for C & C Technologies' surveys have been historically processed using the proprietary software Hydromap. The patch test data were verified in CARIS 8.1. A full work up and explanation of the July 16, 2014 calibration is shown in the following text. A verification of the Hydromap values was performed for the March 21, 2015 calibration.

Patch Test Processing Hydromap Procedure

Pitch: Two reciprocal lines run over a significant bottom feature.

$$\tan^{-1}\left(\frac{\Delta dx}{(\Delta \mathrm{wd} - \Delta \mathrm{dr}) * 2}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{wd}$ = water depth
$\Delta \mathrm{dr}$ = distance from the transducer to the surface of the water

Transducer	Angle Offset
SH1	1.96°

Roll : Two reciprocal lines run over a relatively flat surface (no features present).

$$\tan^{-1}\left(\frac{\Delta ms}{2}\right)$$

Δms = mean slope calculated in the beam analysis tool in Hydromap (regression analysis)

Transducer	Angle Offset
SH1	1.42°

Yaw: Two parallel lines run in the same direction with 10% to 20% overlap over a significant bottom feature. The overlapping areas must contain the feature.

$$\tan^{-1}\left(\frac{\Delta dx}{\Delta \mathrm{n}}\right)$$

Δdx = difference in along-track positions
$\Delta \mathrm{n}$ = distance from the feature to nadir

Transducer	Angle Offset
SH1	1.26°

Note: The values obtained are neither positive nor negative in Hydromap. The signs of the values are determined after processing the patch test data.

Patch Test Processing CARIS Procedure

The patch test data were processed in CARIS 8.1 using the procedures outlined in the CARIS MBES Calibration Procedure Technical Note. Specific lines used and the average offset values obtained are shown in Table 1. The Hydromap patch test method typically involves entering an offset value into the MBES control software once a value had been obtained and the next lines collected and the next offset obtained. Following the same order as the field (pitch, roll, yaw) it was possible to verify the values but not update any in the vessel file. The CARIS project is located on the final hard drives and called CGhost_PatchTest_140716_final.

Table 1. Lines used in CARIS to detetmine average offsets for the R/V *C-Ghost* (calibration conducted on July 16, 2014).

Offset to be Resolved	Lines Used	Average Offset Obtained
Latency	latency1 and latency2	0.04s
Pitch	pitch1 and pitch2	1.81º
Roll	roll1 and roll2	1.22º
Yaw	yaw1 and yaw2	1.46º

During the calibration conducted on March 21, 2015, at least one set of lines for each offset was collected with zero angular offsets in the field. In this case, a full CARIS Calibration was conducted and the vessel file updated with offsets obtained. The CARIS project is located on the final hard drives and called CGhost_PatchTest_150321_final.

Table 2. Lines used in CARIS and results from CARIS and Hydromap calibrations for the R/V *C-Ghost* for patch test on March 21, 2015.

Offset to be Resolved	Lines Used	Hydromap Results	CARIS Results
Latency	latency1 and latency2	0.00s	0.00s
Pitch	pitch1 and pitch2	1.85º	1.90º
Roll	roll14 and roll15	1.17º	1.20º
Yaw	yaw9 and yaw10	0.77º	0.80º

Patch Test Verification

The results from resolving the July 16, 2014 patch test biases several times by several people are shown in Table 3.

Table 3. Results of resolving July 16, 2014 patch test biases several times in CARIS for the R/V *C-Ghost.*

	Latency	Pitch	Roll	Yaw
Processor 1	0.00	1.50	1.45	1.26
Processor 1	0.10	1.75	1.42	1.20
Processor 1	-0.10	2.00	1.47	1.29
Processor 2	0.10	1.85	1.45	1.20
Processor 2	0.15	1.90	1.50	1.30
Processor 2	0.10	1.75	1.45	1.10
Processor 3	0.00	1.90	1.50	1.20
Processor 3	0.00	1.85	1.45	1.30
Processor 3	0.00	1.80	1.48	1.10
Average	0.04	1.81	1.46	1.22
Standard Deviation	0.08	0.14	0.03	0.08

Conclusions

The review of the data in CARIS did not yield any significant additional offsets than what was calculated using the Hydromap method. No additional post-processing was applied to the data other than what is specified in the Data Acquisition and Processing Report and in respective Descriptive Reports.

Project Log

Project Number:	**OPR-K339-KR-14**	**Page #:**	**04**
Registry Number:	**Patch Test**	**Date (YY/MM/DD):**	**14/07/16**
Vessel Name:	**R/V C-Ghost**	**Julian Day:**	**197**
Sublocality:	**South of H12636**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1100							Arrive @ vessel and power up
1123							Begin transit to survey area
1240							Arrive on site
1242							MB pole down
							Draft Reading: 1.66ft
							WL to CRP: 0.066m
							Single beam draft:
1246							CTD_140716a_1174
							X: 282830.89m Y: 3201477.16m
							Lat: 28.922819° Long: -89.227710°
							WD: 53.46m CTD depth: 52.53m
							HM: 1527 m/s YSI: 1520.88 m/s
1257							SIS angular offsets set to 0
							Heading to SOL
1259	Latency-1	1	254	7.6	1.2	52.8	SOL-fast line
1308	Latency-2	1	254	3.9	1.2	52.8	SOL-slow line
1333							Latency offset of 0.0
1408	Pitch-1	1	254	5.4	1.1	52.8	SOL
1412	Pitch-2	2	74	5.7	1.1	48.8	SOL
1432							Pitch offset of 1.96° entered
							Into SIS
1439	Pitch-3	1	254	5.3	1.3	52.8	SOL
1444	Pitch-4	2	74	5.2	1.3	48.8	SOL
1500							Pitch offset verified as +1.96°
1505	Roll-1	1	180	6.7	1.3	51.9	SOL
1511	Roll-2	2	0	5.4	1.2	55.0	SOL
1527							Roll offset of +1.42° entered in SIS
1524	Roll-3	1	180	6.0	1.2	54.0	SOL
1538	Roll-4	2	0	5.5	1.2	55.1	SOL
1551							Roll offset verified as +1.42°
1557	Yaw-1	2	71	5.1	1.1	48.3	SOL
1605	Yaw-2	1	74	5.1	1.1	48.9	SOL
1620							Heading offset of +1.26° entered into SIS

Project Log

C&C Technologies SURVEY SERVICES

Project Number:	**OPR-K339-KR-14**	**Page #:**	**05**
Registry Number:	**Patch Test**	**Date (YY/MM/DD):**	**14/07/16**
Vessel Name:	**R/V C-Ghost**	**Julian Day:**	**197**
Sublocality:	**South of H12636**		

Time (UTC)	Line Name	Fix	HDG	Speed (kts)	HDOP	Depth (m)	Remarks
1628	Yaw-3	1	72	5.2	1.0	48.3	SOL
1635	Yaw-4	1	74	5.3	1.0	48.9	SOL
1846							Heading offset verified at +1.26°
							Patch test complete
							Final values
							Yaw: +1.26°
							Pitch: +1.96°
							Roll: +1.42°

Project Log

	Patch Test			
C&C Technologies SURVEY SERVICES	Vessel Name:	C-Ghost	Page #:	01
	Project Number:	OPR-K339-KR-14	Date (YY/MM/DD):	15/03/21
	General Locality:	East of Southwest Pass, LA	Julian Day:	80

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
1200						Survey crew arrives @
						Vessel. Jim Wade, John Baker
						Waiting for fog to lift
						@ Cypress Cove Marina
						On March 19/2015 the F180
						S/N
						Failed. It was replaced
						With S/N F0907076
						A new Patch test is necessary.
1520						Conditions improving
						Begin transit to Patch
						test location
1755						Arrive at patch test
						Location
						MB Ram down
1757						Draft Reading: 1.77ft
						WL to CRP: 0.032m
1804						CTD_150321a S/N 1174
						X:282390.78m Y:3201558.90m
						Lat: 28.923482° Long: -89.232237°
						MB Depth: 53.5m CTD Depth: 53.52m
						SB Depth: 53.5m
						YSI: 1457 m/s
						HM: 1520 m/s
1818						Running Recon line
1822						Found area for patch test
1825	Latency-1	251	49.0	3.5	0.7	SOL – Slow speed 3.5 kts
1827	Latency-1	251	48.5	3.5	0.7	EOL
1830	Latency-2	251	48.4	7.4	0.7	SOL – fast speed
1831	Latency-2	251	48.0	7.4	0.7	EOL – No latency calculated
						Latency-1 and latency-2 were
						Run with no angular
						Offsets in SIS

Project Log

	Patch Test			
C&C Technologies SURVEY SERVICES	**Vessel Name:**	**C-Ghost**	**Page #:**	**02**
	Project Number:	**OPR-K339-KR-14**	**Date (YY/MM/DD):**	**15/03/21**
	General Locality:	**East of Southwest Pass, LA**	**Julian Day:**	**80**

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
1833	Pitch-1	071	48.3	4.5	0.7	SOL – pitch line #1
1835	Pitch-1	071	48.3	4.5	0.7	EOL
1836	Pitch-2	251	48.4	4.5	0.7	SOL – pitch line #2
1839	Pitch-2	251	48.3	4.5	0.7	EOL
						Pitch-1 & Pitch-2 have
						Zero angular offsets in SIS
						+1.85° pitch calculated
						In hydromap
						+ 1.85° pitch entered into SIS
						For verification lines
1851	Pitch-3	071	48.1	4.5	0.7	SOL – Pitch verification line #1
1853	Pitch-3	071	48.2	4.4	0.7	EOL
1855	Pitch-4	251	48.3	4.4	0.7	SOL – Pitch verification line #2
1857	Pitch-4	251	48.5	4.5	0.7	EOL
1901	Pitch-5	251	48.2	4.7	0.7	SOL – Pitch verification line #3
1902	Pitch-5	251	48.8	4.9	0.7	EOL
						Pitch of +1.85° verified
						Removing value from SIS
						All angular offsets in SIS
						Are zero for roll-1
						And roll-2
1907	Roll-1	197	48.2	5.0	0.7	SOL – Roll line #1
1912	Roll-1	197	52.1	4.9	0.8	EOL
1915	Roll-2	017	51.5	4.4	0.8	SOL – Roll line #2
1922	Roll-2	017	48.0	4.5	0.8	EOL
						Roll of +1.27° calculated
						Angular offsets in SIS for Roll
						Verification lines
						ROLL +1.27°
						Pitch +1.85°
1944	Roll-3	197	47.9	4.5	0.8	SOL – Roll verification line #1
1951	Roll-3	197	51.7	4.5	0.8	EOL
1954	Roll-4	017	51.6	4.4	0.8	SOL – Roll verification line #2

Project Log

C&C Technologies SURVEY SERVICES	Patch Test			
	Vessel Name:	C-Ghost	Page #:	03
	Project Number:	OPR-K339-KR-14	Date (YY/MM/DD):	15/03/21
	General Locality:	East of Southwest Pass, LA	Julian Day:	80

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
2002	Roll-4	017	47.9	4.5	0.8	EOL
						Additional roll of –0.10°
						Calculated. Roll changed
						To +1.17° in SIS
2007	Roll-5	197				SOL – Roll verification line #3
						Abort roll-5
						Change roll to +1.37° in SIS
						(subtracted 0.10° when it
						Should have been added)
2008	Roll-6	197	48.4	4.9	0.7	SOL – roll verification line #4
2011	Roll-6	197	49.9	4.7	0.7	EOL
2013	Roll-7	017	49.8	4.7	0.7	SOL – roll verification line #5
2015	Roll-7	017	48.1	4.6	0.7	EOL
						Final roll value of +1.37°
						Calculated
						All offsets (angular) have
						Been zeroed out in
						SIS for yaw-1 and yaw-2
2022	Yaw-1	250	47.2	4.9	0.7	SOL – yaw line #1
2024	Yaw-1	250	47.4	4.5	0.6	EOL
2030	Yaw-2	250	49.5	4.9	0.6	SOL – yaw line #2
2033	Yaw-2	250	47.8	4.8	0.6	EOL
2035	Yaw-3	071	47.9	4.6	0.6	SOL – yaw line #3 (no offsets in SIS)
2037	Yaw-3	071	48.7	4.8	0.6	EOL
2044	Yaw-4	071	47.2	4.6	0.6	SOL – yaw line #4 (no offsets in SIS)
2046	Yaw-4	071	46.9	4.8	0.6	EOL
2059	Yaw-5	253	47.1	4.8	0.7	SOL – yaw line #5 (no offsets in SIS)
2101	Yaw-5	253	47.9	4.9	0.6	EOL
2107	Yaw-6	253	46.0	4.9	0.6	SOL – yaw line #6 (no offsets in SIS)
2109	Yaw-6	253	47.2	4.8	0.6	EOL
						Yaw of +0.97° calculated
						In SIS the angular offsets
						Have been entered

Project Log

	Patch Test			
C&C Technologies SURVEY SERVICES	**Vessel Name:**	**C-Ghost**	**Page #:**	**04**
	Project Number:	**OPR-K339-KR-14**	**Date** (YY/MM/DD):	**15/03/21**
	General Locality:	**East of Southwest Pass, LA**	**Julian Day:**	**80**

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
						Roll: +1.37°
						Pitch: +1.85°
						Yaw: +0.97°
2119	Yaw-7	074	46.5	4.7	0.6	SOL – yaw verification line #1
2121	Yaw-7	074	46.7	4.7	0.6	EOL
2127	Yaw-8	074	47.1	4.7	0.6	SOL – yaw verification line #2
2129	Yaw-8	074	47.2	4.8	0.6	EOL
						Something seems wrong
						With the offsets. Will have to
						Come back tomorrow
0000						New Day 15/03/22
0015						Arrive at dock. Vessel
						Secure at Cypress Cove Marina
1200						Survey crew arrives
						At vessel. Waiting for
						Fog to lift
1408						Begin transit to survey area
1430						Too foggy. Return to Venice
1500						Resume transit
1650						Arrive on site
						MB pole down
						Draft reading: 1.85ft
						WL to CRP: 0.008m
1656						CTD_150322a
						X: 282592.12m Y: 3201594.55m
						Lat: 28.923837° Long: -89.230180°
						MB depth: 54.1m CTD Depth: 54.13m
						SB Depth: 54.0m
						HM: 1524 m/s YSI: 1467 m/s
						Returned to patch test site
						To run verification lines for
						Roll and Yaw
						A pitch of +1.85° will be

Project Log

	Patch Test			
C&C Technologies SURVEY SERVICES	Vessel Name:	C-Ghost	Page #:	05
	Project Number:	OPR-K339-KR-14	Date (YY/MM/DD):	15/03/22
	General Locality:	East of Southwest Pass, LA	Julian Day:	81

Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
						Input in SIS for all lines (+1.85° pitch)
1717	Roll-8	071	46.3	5.6	0.8	SOL – Roll verification line #1
1719	Roll-8	071	45.4	5.5	0.8	EOL
1721	Roll-9	251	45.5	5.4	0.8	SOL – Roll verification line #2
1723	Roll-9	251	46.0	5.2	0.8	EOL
						+1.25° roll calculated in hydromap, and
						Input into SIS for verification lines
						+1.25° roll and +1.85° pitch in SIS
1732	Roll-10	073	46.2	4.5	0.6	SOL – Roll verification line #3
1735	Roll-10	073	45.5	4.7	0.6	EOL
1738	Roll-11	253	45.5	4.2	0.6	SOL – Roll verification line #4
1740	Roll-11	253	45.8	4.2	0.6	EOL – additional roll of –0.08° calculated
						Roll of +1.17° entered into SIS
1749	Roll-12	071	46.7	4.5	0.6	SOL – Roll verification line #5
1752	Roll-12	071	45.6	4.5	0.7	EOL
1755	Roll-13	251	45.6	4.0	0.7	SOL – Roll verification line #6
1758	Roll-13	251	46.7	4.2	0.7	EOL
						Roll of +1.17° is good (Final)
						All offsets in SIS have been zeroed out
						For next two lines
1803	Roll-14	071	47.4	4.8	0.7	SOL – extra roll line for office
1807	Roll-14	071	45.6	5.0	0.7	EOL
1810	Roll-15	251	45.6	4.3	0.7	SOL – extra roll line for office
1814	Roll-15	251	47.3	4.3	0.7	EOL
						Final roll: +1.17° Final pitch: + 1.85°
						Values will be zero in SIS for next
						Two lines
1819	Yaw-9	255	4.2	0.7	47.5	SOL - re-running yaw test line #1
1821	Yaw-9	255	4.2	0.7	54.8	EOL
1826	Yaw-10	255	4.1	0.7	46.5	SOL – re-running yaw test line #2
1828	Yaw-10	255	4.6	0.7	51.4	EOL
						+0.77 yaw calculated. Entered into SIS
						Along with roll +1.17° and pitch +1.85°

Project Log

	Patch Test			
	Vessel Name:	**C-Ghost**	**Page #:**	**06**
	Project Number:	**OPR-K339-KR-14**	**Date (YY/MM/DD):**	**15/03/22**
	General Locality:	**East of Southwest Pass, LA**	**Julian Day:**	**81**

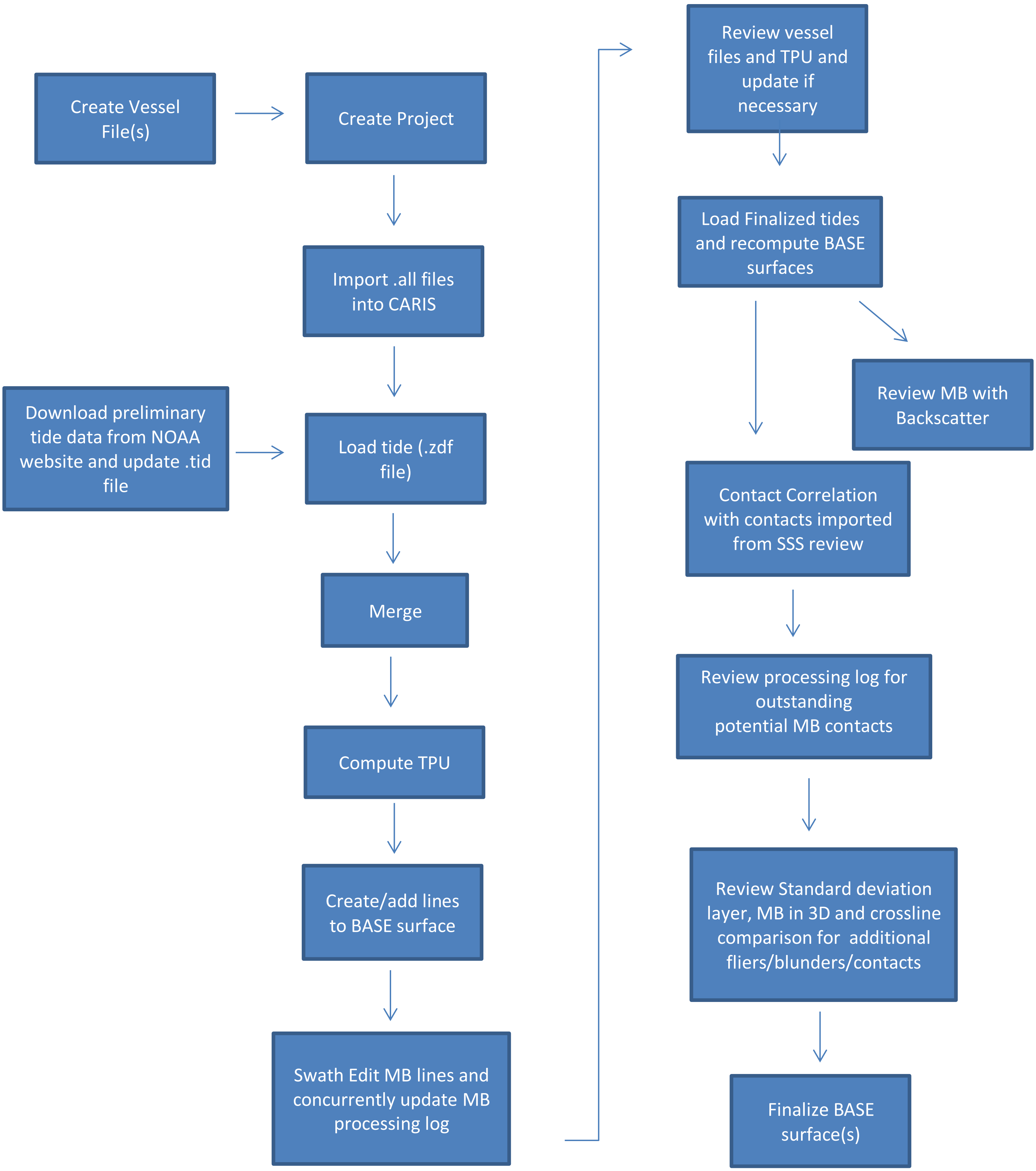
Time (UTC)	Line Name	HDG	Depth (m)	Speed (kts)	HDOP	Comments
1834	Yaw-11	078	47.0	4.4	0.6	SOL – Yaw verification line #1 (all offsets in SIS)
1837	Yaw-11	078	46.5	4.4	0.6	EOL
1840	Yaw-12	078	47.2	4.6	0.6	SOL – Yaw verification line #2 (all offsets in SIS)
1843	Yaw-12	078	47.7	4.6	0.6	EOL
						Final roll value of +0.77 is good
						Patch test complete
						Final Values
						Pitch +1.85° Roll" +1.17° Yaw: +0.77°
						MB Ram up. Transit to H12634.

APPENDIX II

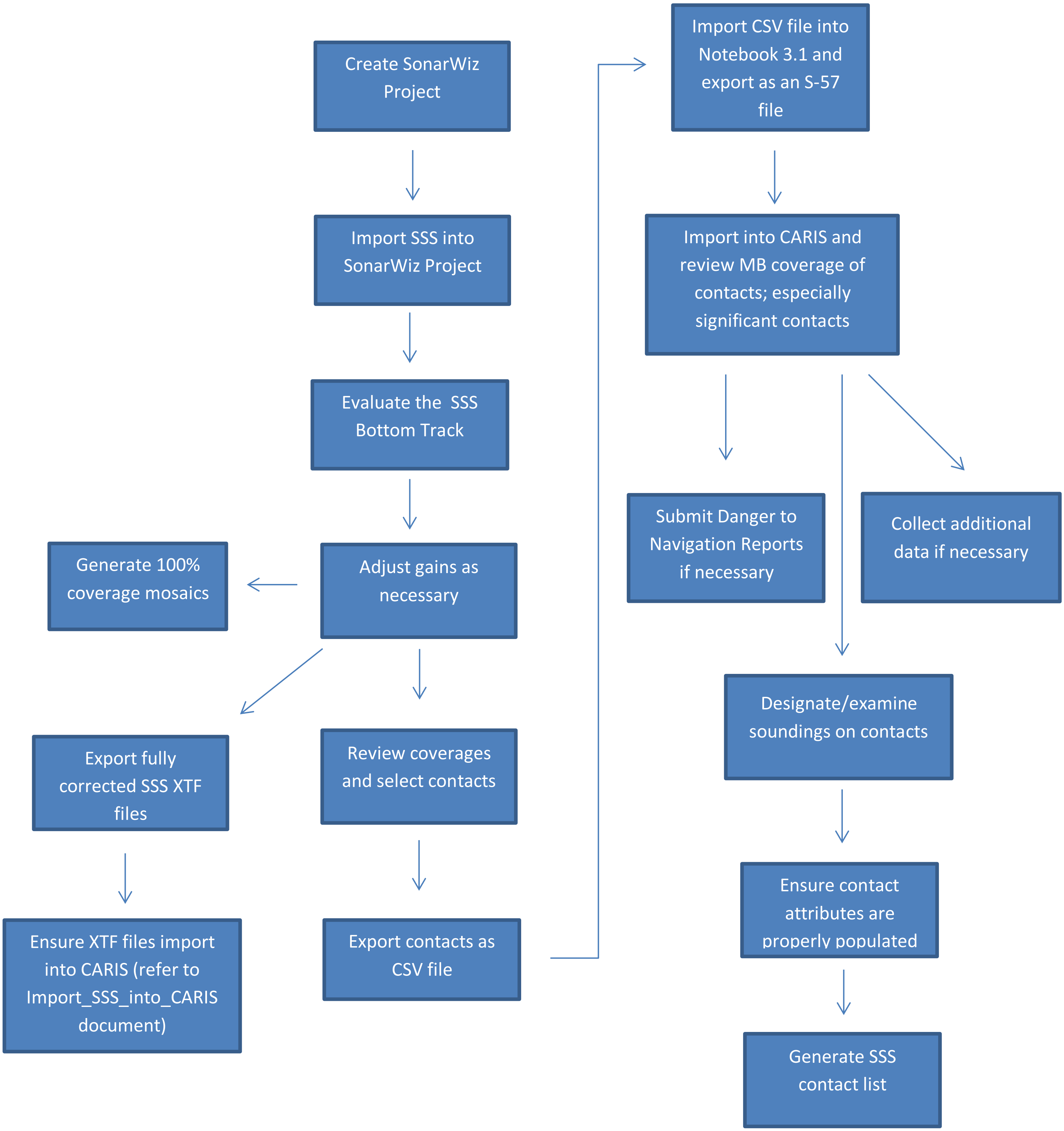
Echosounder Reports

Processing Diagrams

MB Processing Workflow



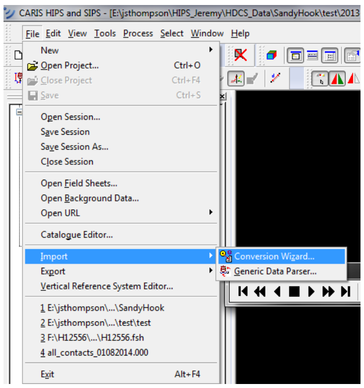
SSS Processing Workflow



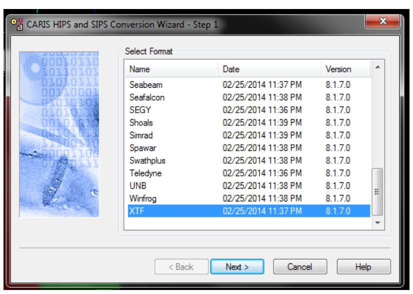
Import SSS XTF files into CARIS

This workflow imports processed XTF files into CARIS. All layback corrections are completed in SonarWiz and the fully corrected files are exported. These files are located in Data\Processed\SSS. A zero Side Scan Sonar vessel file was created for import purposes.

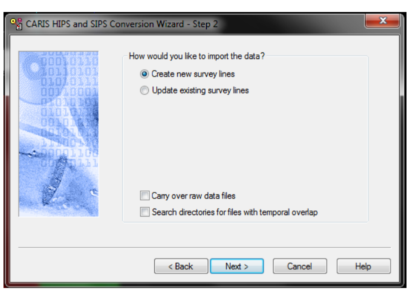
1. File -> Import -> Conversion Wizard



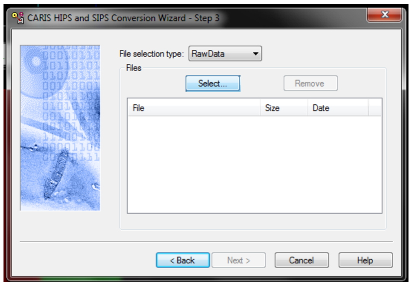
2. Select File Format <XTF>. Select <Next >.



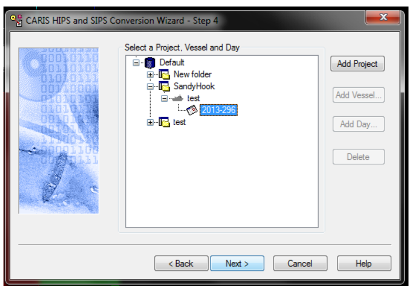
3. Select <Create new survey lines>. Select <Next >.



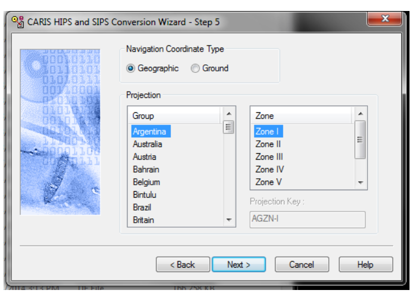
4. Select <RawData> for File Selection Type. Navigate to folder containing XTF files, select appropriate XTF files. Select <Next >.



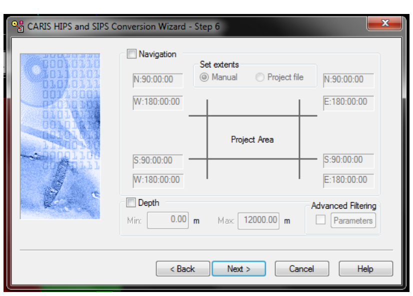
5. Select the Project Name, vessel file and choose a day for the data. Select <Next >.



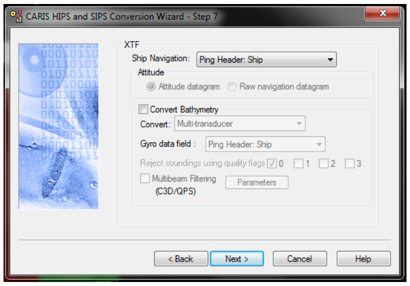
6. Select Coordinate Type and select <Next >. (Can usually select Geographic as it will automatically find the coordinate system).



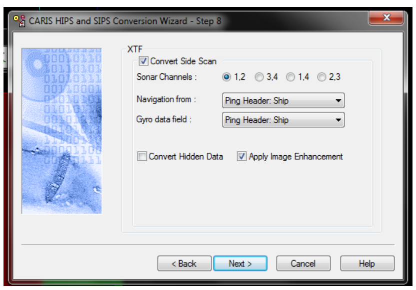
7. Select Project Area (this was left unchecked) and select <Next >.



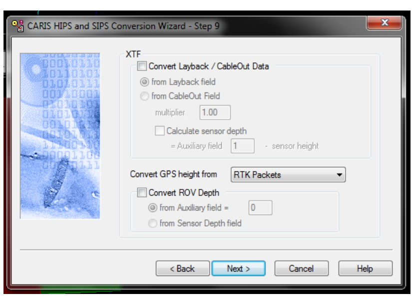
8. Select <Ping Header: Ship> for Ship Navigation. Make sure Convert Bathymetry is unchecked. Select <Next >.



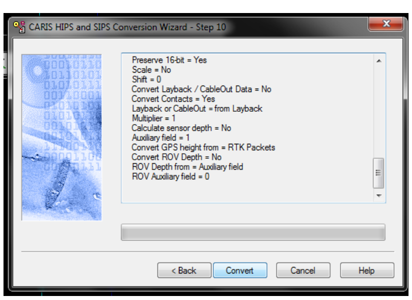
9. Make sure <Convert Side Scan> is checked and select <1,2> for Sonar Channels. Select <Ping Header: Ship> for 'Navigation from' and 'Gyro data field'. Select <Next >.



10. Make sure Convert Layback / CableOut Data is unchecked. Select <Next >.

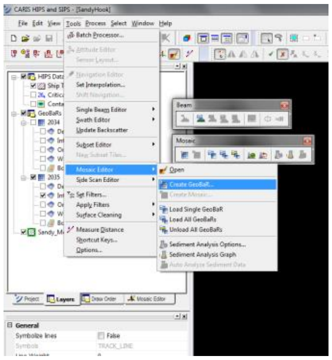


11. Select Convert.



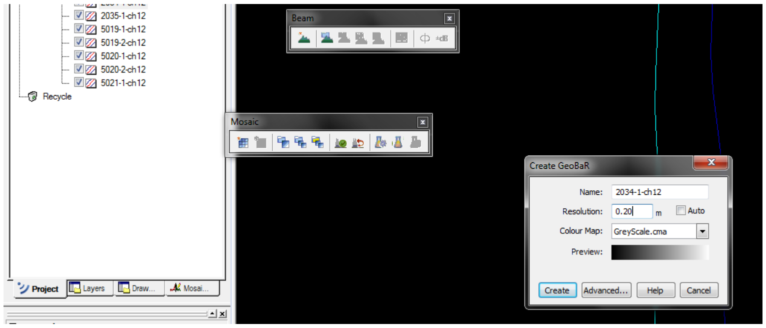
Create GeoBars

1. Tools → Mosaic Editor → Open
2. Tools → Mosaic Editor → Create GeoBar



*Note that because this data only contains sonar channels, only the SIPS Processing Engine works to create GeoBars.

3. Create GeoBar: Enter Name, Resolution and Colour Map. Select <Create>. The gains may need to be adjusted in the ‘Advanced’ options before creating the Geobar.



APPENDIX III

Positioning and Attitude Sensor Reports

APPENDIX III

Positioning and Attitude Sensor Reports

F180 Calibration Reports

Coda Octopus
Sound Underwater Intelligence

Certificate of Calibration and Configuration

Issued By: CodaOctopus Products Ltd
Anderson House
1 Breadalbane Street
Edinburgh
EH6 5JR
UK

24-Hr Technical Support
Phone Worldwide: +44 (0)131 553 7003
Phone USA & Canada: +1 888340 CODA
E-mail: support@codaoctopus.com
Web: http://support.codaoctopus.com

This equipment has been calibrated, configured and tested in accordance with the standards, specifications and procedures of the Manufacturer.

Equipment Description: F180

Serial Number: F0907069

Date of Certification: 6th October 2014

Product Engineer: S Narraway

CodaOctopus PRODUCTS

Certificate of Calibration and Configuration

Issued By: **CodaOctopus Products Ltd**
Anderson House
1 Breadalbane Street
Edinburgh
EH6 5JR
UK

24-Hr Technical Support
Phone Worldwide: +44 (0)131 553 7003
Phone USA & Canada: +1 888340 CODA
E-mail: support@codaoctopus.com
Web: http://support.codaoctopus.com

This equipment has been calibrated, configured and tested in accordance with the standards, specifications and procedures of the Manufacturer.

Equipment Description: F180

Serial Number: F0803009

Date of Certification: 4th July 2012

Product Engineer: S Narraway **Signed:** ____________

Operations Manager: I Fleming **Signed:** I Fleming ____________

Coda Octopus
Sound Underwater Intelligence

Certificate of Calibration and Configuration

Issued By: **CodaOctopus Products Ltd**
Anderson House
1 Breadalbane Street
Edinburgh
EH6 5JR
UK

24-Hr Technical Support
Phone Worldwide: +44 (0)131 553 7003
Phone USA & Canada: +1 888340 CODA
E-mail: support@codaoctopus.com
Web: http://support.codaoctopus.com

This equipment has been calibrated, configured and tested in accordance with the standards, specifications and procedures of the Manufacturer.

Equipment Description: F180

Serial Number: F0104012

Date of Certification: 18th April 2013

Product Engineer: S Narraway

Coda Octopus
Sound Underwater Intelligence

Certificate of Calibration and Configuration

Issued By: CodaOctopus Products Ltd
Anderson House
1 Breadalbane Street
Edinburgh
EH6 5JR
UK

24-Hr Technical Support
Phone Worldwide: +44 (0)131 553 7003
Phone USA & Canada: +1 888340 CODA
E-mail: support@codaoctopus.com
Web: http://support.codaoctopus.com

This equipment has been calibrated, configured and tested in accordance with the standards, specifications and procedures of the Manufacturer.

Equipment Description: F180

Serial Number: F0907076

Date of Certification: 4th August 2014

Product Engineer: S Narraway

CodaOctopus Products Ltd
Anderson House, 1 Breadalbane Street, Edinburgh, EH6 5JR,UK. Tel: +44 (0)131 553 1380 Fax: +44(0)131 554 7143

24-Hr Technical Support
USA & Canada: + 1 888 340 CODA
Worldwide: +44 (0) 131 553 7003
E-mail: support@codaoctopus.com Web: http://support.codaoctopus.com

APPENDIX III

Positioning and Attitude Sensor Reports

F180 Configuration Reports

Calibration settings for F180 Series.
10/4/2014 8:22:00 PM

Calibration status is: Complete

Attitude Accuracy: 0.043 degrees.
Heading Accuracy: 0.063 degrees.

Calibration Configuration Parameters

X GPS Offset: -5.809 metres.
X GPS Accuracy: 0.006 metres.

Y GPS Offset: -0.389 metres.
Y GPS Accuracy: 0.004 metres.

Z GPS Offset: -4.643 metres.

Z GPS Accuracy: 0.015 metres.

GPS Rotation: 88.89 degrees.
GPS Rotation Accuracy: 0.01 degrees.

GPS Elevation: -0.76 degrees.
GPS Elevation Accuracy: 0.00 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: .
Serial 1 baud: 19200.
Serial 1 data bits: 8.
Serial 1 stop bits: 1.
Serial 1 parity: None.
Serial 1 update rate: 100 Hz Hz.

Serial 2 Output Parameters

Serial 2 string: .
Serial 2 baud: 19,200.
Serial 2 data bits: 8.
Serial 2 stop bits: 1.
Serial 2 parity: None.
Serial 2 update rate: 100 Hz Hz.

Calibration settings for F180 Series.
5/24/2015 4:41:24 PM

Calibration status is: Complete

Attitude Accuracy: 0.043 degrees.
Heading Accuracy: 0.054 degrees.

Calibration Configuration Parameters

X GPS Offset: -5.801 metres.
X GPS Accuracy: 0.006 metres.

Y GPS Offset: -0.401 metres.
Y GPS Accuracy: 0.004 metres.

Z GPS Offset: -4.653 metres.

Z GPS Accuracy: 0.017 metres.

GPS Rotation: 90.17 degrees.
GPS Rotation Accuracy: 0.01 degrees.

GPS Elevation: -0.32 degrees.
GPS Elevation Accuracy: 0.00 degrees.

Other Configuration Parameters

GPS Antenna Separation: 2.160 metres.
GPS Correction Type: DGPS.
Heading Offset: 0.00 degrees.
Pitch Offset: 0.34 degrees.
Roll Offset: 0.87 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: .
Serial 1 baud: 19200.
Serial 1 data bits: 8.
Serial 1 stop bits: 1.
Serial 1 parity: None.
Serial 1 update rate: 100 Hz Hz.

Serial 2 Output Parameters

Serial 2 string: .
Serial 2 baud: 19,200.
Serial 2 data bits: 8.
Serial 2 stop bits: 1.
Serial 2 parity: None.
Serial 2 update rate: 100 Hz Hz.

Calibration settings for F180 Series - C-Wolf
5/3/2014 2:01:30 PM

Calibration status is: Complete

Attitude Accuracy: 0.036 degrees.
Heading Accuracy: 0.187 degrees.

Calibration Configuration Parameters

X GPS Offset: -3.235 metres.
X GPS Accuracy: 0.015 metres.

Y GPS Offset: -0.435 metres.
Y GPS Accuracy: 0.013 metres.

Z GPS Offset: -2.450 metres.

Z GPS Accuracy: 0.047 metres.

GPS Rotation: 88.85 degrees.
GPS Rotation Accuracy: 0.18 degrees.

GPS Elevation: -0.14 degrees.
GPS Elevation Accuracy: 0.05 degrees.

Other Configuration Parameters

GPS Antenna Separation: 1.485 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: OFF 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: 100 Hz.

Calibration settings for F180 Series.
7/15/2014 1:36:44 AM

Calibration status is: Complete

Attitude Accuracy: 0.034 degrees.
Heading Accuracy: 0.171 degrees.

Calibration Configuration Parameters

X GPS Offset: -3.374 metres.
X GPS Accuracy: 0.009 metres.

Y GPS Offset: -0.792 metres.
Y GPS Accuracy: 0.009 metres.

Z GPS Offset: -2.314 metres.

Z GPS Accuracy: 0.010 metres.

GPS Rotation: 90.52 degrees.
GPS Rotation Accuracy: 0.16 degrees.

GPS Elevation: -1.52 degrees.
GPS Elevation Accuracy: 0.42 degrees.

Other Configuration Parameters

GPS Antenna Separation: 1.560 metres.
GPS Correction Type: DGPS.
Heading Offset: 0.00 degrees.
Pitch Offset: -1.96 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: OFF Hz.
Serial 1 GGA update rate: 10 Hz.
Serial 1 VTG update rate: 5 Hz.
Serial 1 ZDA update rate: 1 Hz.
Serial 1 GST update rate: OFF 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: 100 Hz.

Calibration settings for F180 Series.
5/26/2015 10:39:55 AM

Calibration status is: Complete

Attitude Accuracy: 0.030 degrees.
Heading Accuracy: 0.175 degrees.

Calibration Configuration Parameters

X GPS Offset: -3.374 metres.
X GPS Accuracy: 0.010 metres.

Y GPS Offset: -0.792 metres.
Y GPS Accuracy: 0.010 metres.

Z GPS Offset: -2.314 metres.

Z GPS Accuracy: 0.010 metres.

GPS Rotation: 90.48 degrees.
GPS Rotation Accuracy: 0.12 degrees.

GPS Elevation: -1.55 degrees.
GPS Elevation Accuracy: 0.11 degrees.

Other Configuration Parameters

GPS Antenna Separation: 1.560 metres.
GPS Correction Type: DGPS.
Heading Offset: 0.00 degrees.
Pitch Offset: -1.96 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: .
Serial 1 baud: 19200.
Serial 1 data bits: 8.
Serial 1 stop bits: 1.
Serial 1 parity: None.
Serial 1 update rate: 100 Hz Hz.

Serial 2 Output Parameters

Serial 2 string: .
Serial 2 baud: 19,200.
Serial 2 data bits: 8.
Serial 2 stop bits: 1.
Serial 2 parity: None.
Serial 2 update rate: 100 Hz Hz.

APPENDIX IV

Sound Speed Sensor 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: 07-Jan-14

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

GHIJ COEFFICIENTS

g = -4.00999516e+000
h = 4.78052022e-001
i = 1.36185316e-003
j = -3.85731758e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS

a = 4.88712776e-002
b = 4.26149696e-001
c = -3.99886188e+000
d = -1.42588842e-004
m = 2.1
CPcor = -9.5700e-008 (nominal)

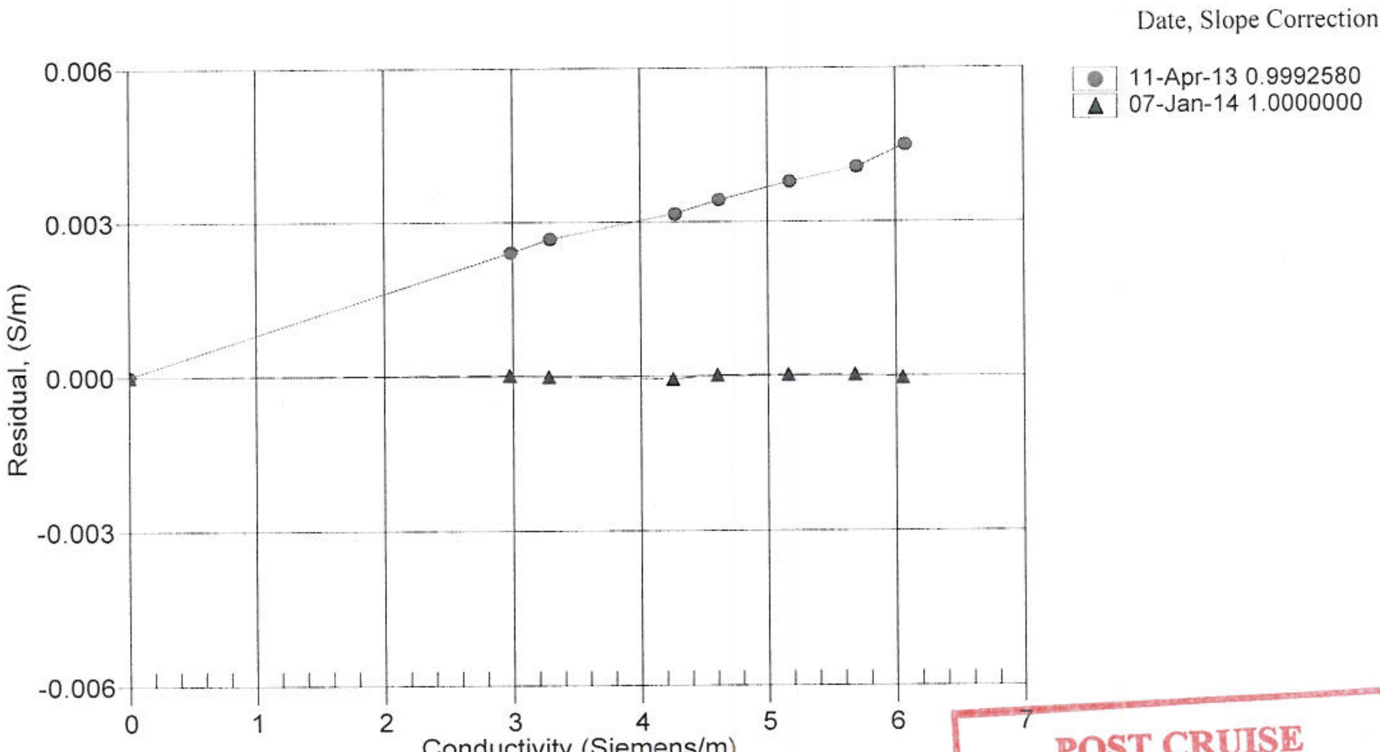
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88537	0.00000	0.00000
1.0000	34.7090	2.96767	8.31945	2.96769	0.00002
4.5000	34.6879	3.27380	8.68695	3.27379	-0.00001
14.9999	34.6435	4.25264	9.76873	4.25258	-0.00006
18.5000	34.6341	4.59680	10.12148	4.59682	0.00002
23.9999	34.6238	5.15314	10.66672	5.15316	0.00003
28.9999	34.6178	5.67344	11.15236	5.67347	0.00003
32.5000	34.6133	6.04458	11.48609	6.04455	-0.00003

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

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: 07-Jan-14

SBE19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.15474820e-003
h = 5.86233969e-004
i = 1.59335480e-006
j = -2.40026689e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.64763661e-003
b = 5.78152464e-004
c = 7.88032072e-006
d = -2.40001426e-006
f0 = 2386.380

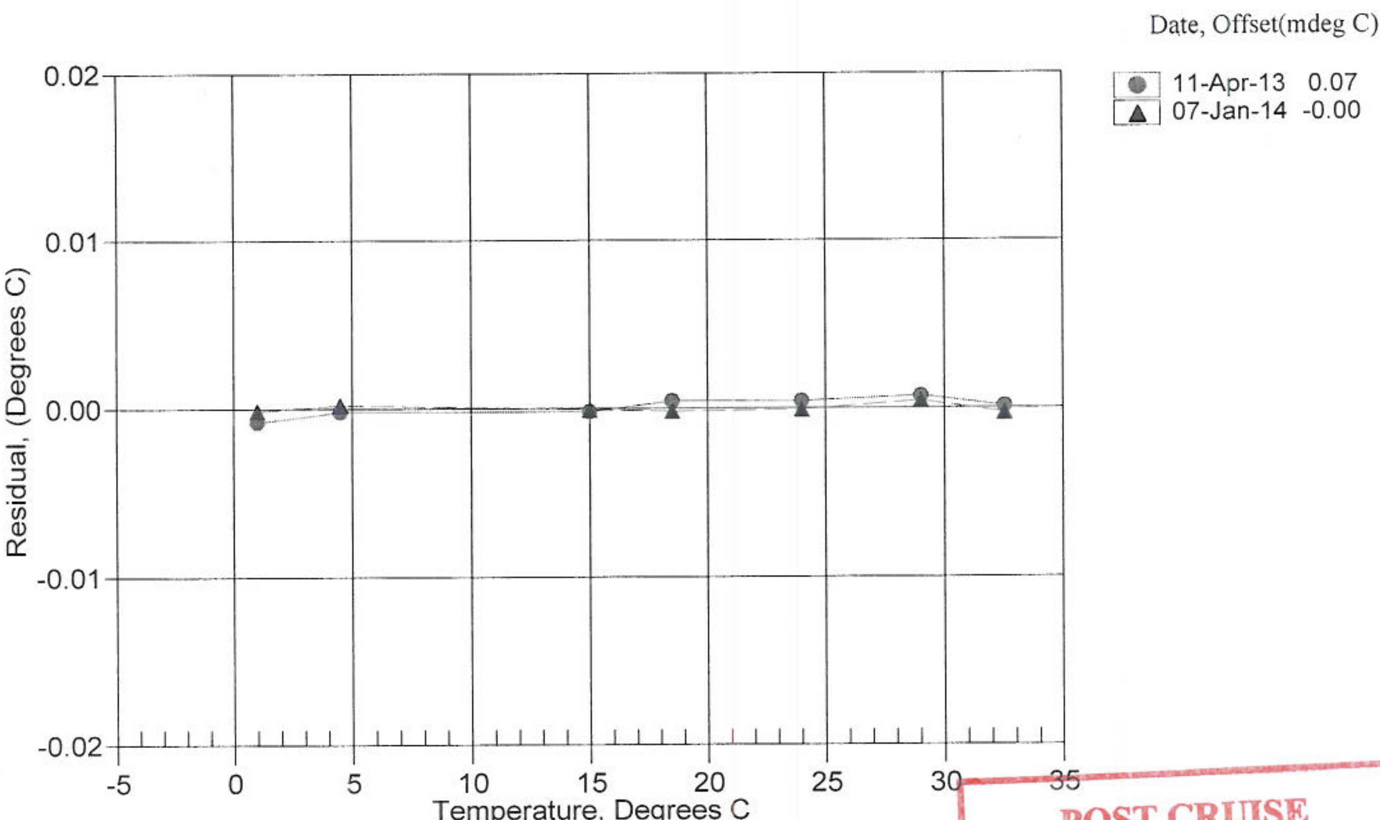
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2386.380	0.9999	-0.00012
4.5000	2584.221	4.5002	0.00021
14.9999	3247.207	14.9998	-0.00005
18.5000	3492.570	18.4998	-0.00015
23.9999	3904.077	23.9998	-0.00006
28.9999	4306.737	29.0003	0.00044
32.5000	4605.254	32.4997	-0.00026

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

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: 03-Jan-14

SBE19 PRESSURE CALIBRATION DATA
500 psia S/N 151844 TCV: 785

QUADRATIC COEFFICIENTS:

PA0 = 2.508052e+002
PA1 = -6.524586e-002
PA2 = 3.672856e-008

STRAIGHT LINE FIT:

M = -6.522420e-002
B = 2.509866e+002

PRESSURE PSIA	INST OUTPUT(N)	COMPUTED PSIA	ERROR %FS	LINEAR PSIA	ERROR %FS
14.70	3629.0	14.51	-0.04	14.29	-0.08
111.58	2138.8	111.43	-0.03	111.49	-0.02
208.38	652.3	208.26	-0.02	208.44	0.01
305.30	-834.6	305.28	-0.00	305.42	0.03
402.15	-2315.9	402.11	-0.01	402.04	-0.02
499.29	-3800.3	499.29	0.00	498.86	-0.09
305.33	-837.1	305.45	0.02	305.59	0.05
208.42	648.9	208.48	0.01	208.66	0.05
111.69	2132.8	111.82	0.03	111.88	0.04
14.70	3622.9	14.91	0.04	14.69	-0.00

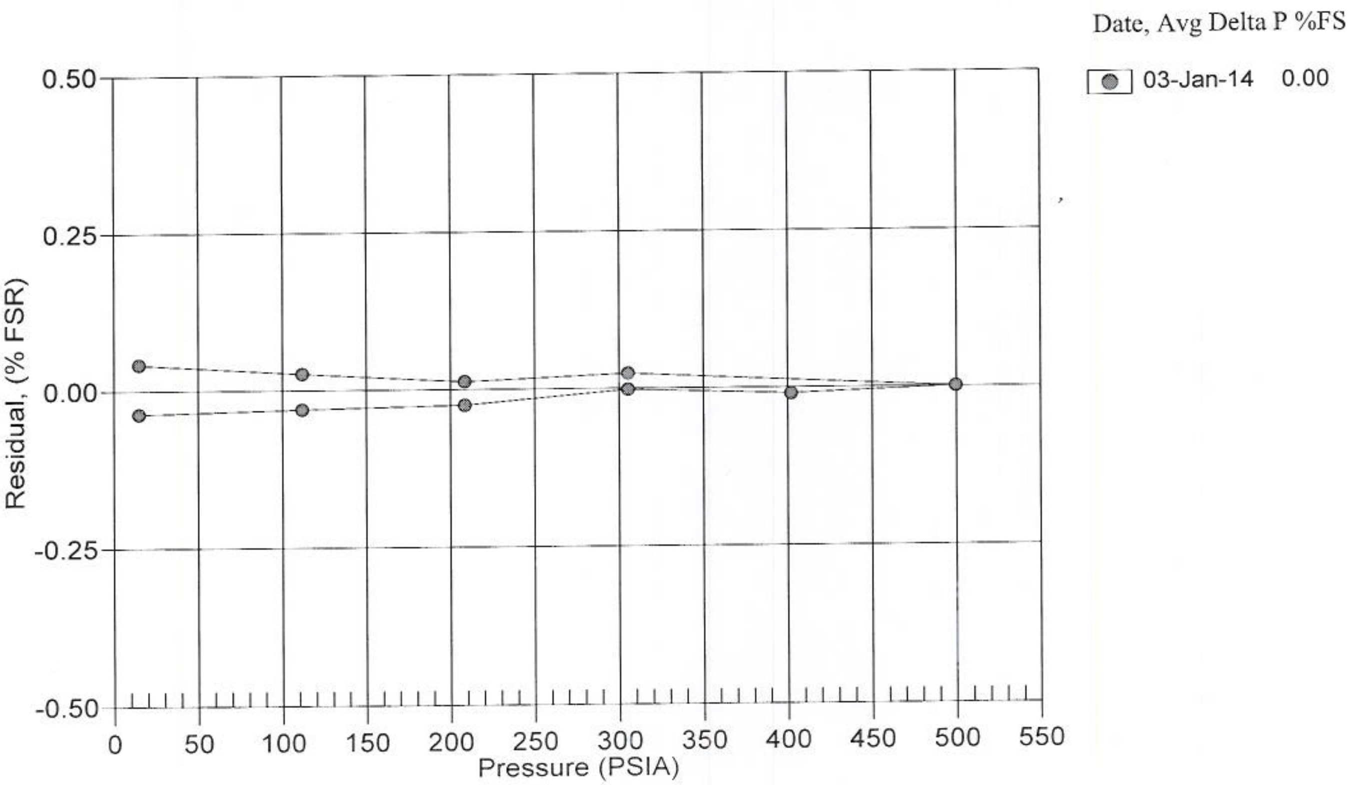
Straight Line Fit:

Pressure (psia) = M * N + B (N = binary output)

Quadratic Fit:

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

Residual = (instrument pressure - true pressure) * 100 / Full Scale Range



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13431 NE 20th Street, Bellevue, WA 98005-2010 USA
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SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 11-Apr-14

SBE 19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.035307e+000
h = 1.599548e-001
i = -4.457984e-004
j = 6.031087e-005

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

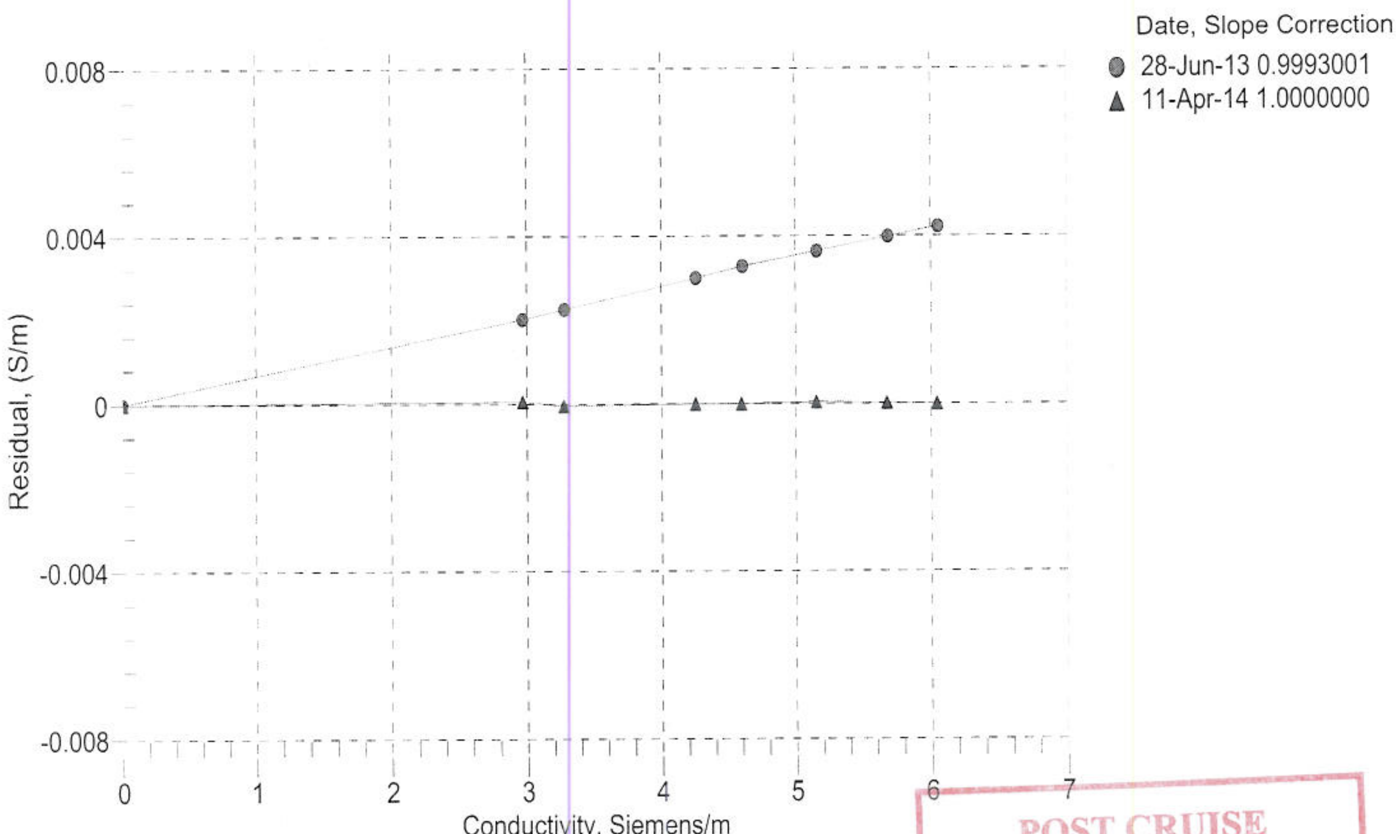
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2550.05	0.0000	0.00000
1.0000	34.7207	2.96857	5014.45	2.9686	0.00005
4.5000	34.6928	3.27422	5201.76	3.2742	-0.00005
15.0000	34.6516	4.25354	5760.51	4.2535	-0.00001
18.5015	34.6429	4.59799	5944.27	4.5980	-0.00000
24.0000	34.6331	5.15438	6229.37	5.1544	0.00003
28.9999	34.6278	5.67490	6484.39	5.6749	0.00001
32.5000	34.6244	6.04630	6660.17	6.0463	-0.00002

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

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

Residual = instrument conductivity - bath conductivity



POST CRUISE CALIBRATION

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	C&C Technologies		
Job Number:	79067	Date of Report:	4/15/2014
Model Number	SBE 19Plus	Serial Number:	19P47719-5221

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

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

'AS RECEIVED CALIBRATION' ✔ Performed ☐ Not Performed

Date: 4/11/2014 Drift since last cal: -0.00220 PSU/month*

Comments:

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

Date: Drift since Last cal: PSU/month*

Comments:

**Measured at 3.0 S/m*

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

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SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 11-Apr-14

SBE 19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.226415e-003
a1 = 2.573013e-004
a2 = 2.449376e-007
a3 = 1.280662e-007

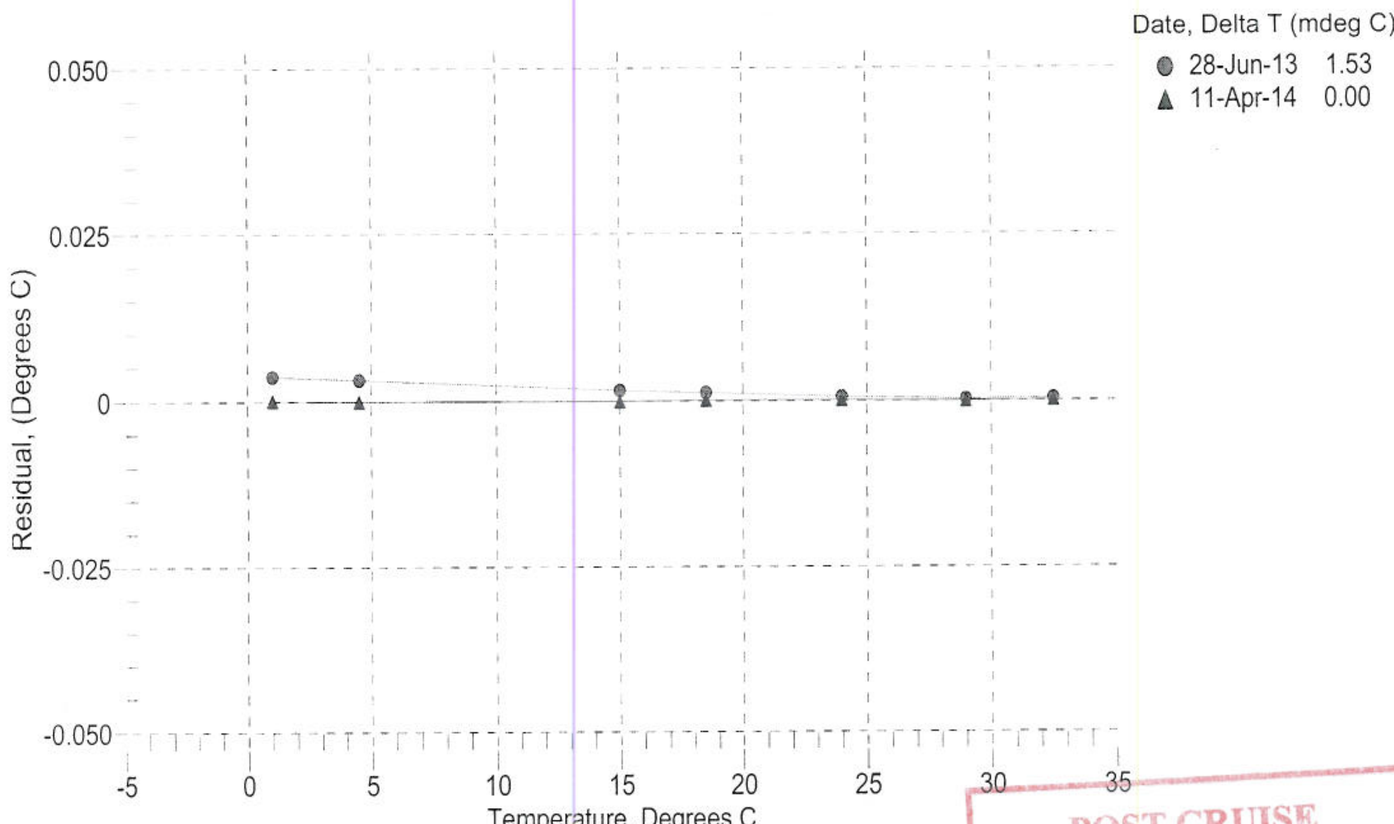
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	735957.085	1.0000	0.0000
4.5000	658737.034	4.5000	-0.0000
15.0000	462178.763	15.0000	-0.0000
18.5015	408205.797	18.5016	0.0001
24.0000	334217.169	24.0000	0.0000
28.9999	277307.220	28.9998	-0.0001
32.5000	242698.661	32.5001	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



POST CRUISE CALIBRATION

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	C&C Technologies		
Job Number:	79067	Date of Report:	4/15/2014
Model Number	SBE 19Plus	Serial Number:	19P47719-5221

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

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

'AS RECEIVED CALIBRATION' ✓ Performed ☐ Not Performed

Date: 4/11/2014 Drift since last cal: -0.00195 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ✓ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

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SENSOR SERIAL NUMBER: 5221
CALIBRATION DATE: 09-Apr-14

SBE 19plus PRESSURE CALIBRATION DATA
FSR: 870 psia S/N 2494572

COEFFICIENTS:

PA0 = -1.004580e+000
PA1 = 2.642780e-003
PA2 = 1.926691e-011
PTEMPA0 = -6.395690e+001
PTEMPA1 = 5.144135e+001
PTEMPA2 = -2.021833e-001

PTCA0 = 5.251880e+005
PTCA1 = -2.660893e+001
PTCA2 = 4.406030e-001
PTCB0 = 2.556488e+001
PTCB1 = 5.750000e-004
PTCB2 = 0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FS
14.74	530776.0	1.7	14.75	0.00
180.01	593277.0	1.7	179.94	-0.01
360.01	661344.0	1.7	360.00	-0.00
540.03	729323.0	1.7	540.01	-0.00
720.04	797238.0	1.7	720.02	-0.00
870.02	853770.0	1.7	870.00	-0.00
720.05	797269.0	1.7	720.10	0.01
540.06	729352.0	1.7	540.08	0.00
360.05	661372.0	1.7	360.07	0.00
180.04	593320.0	1.7	180.05	0.00
14.74	530775.0	1.7	14.76	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.89	530831.97
29.00	1.82	530843.25
24.00	1.72	530858.65
18.50	1.61	530894.39
15.00	1.54	530935.33
4.50	1.34	531122.12
1.00	1.27	531216.66

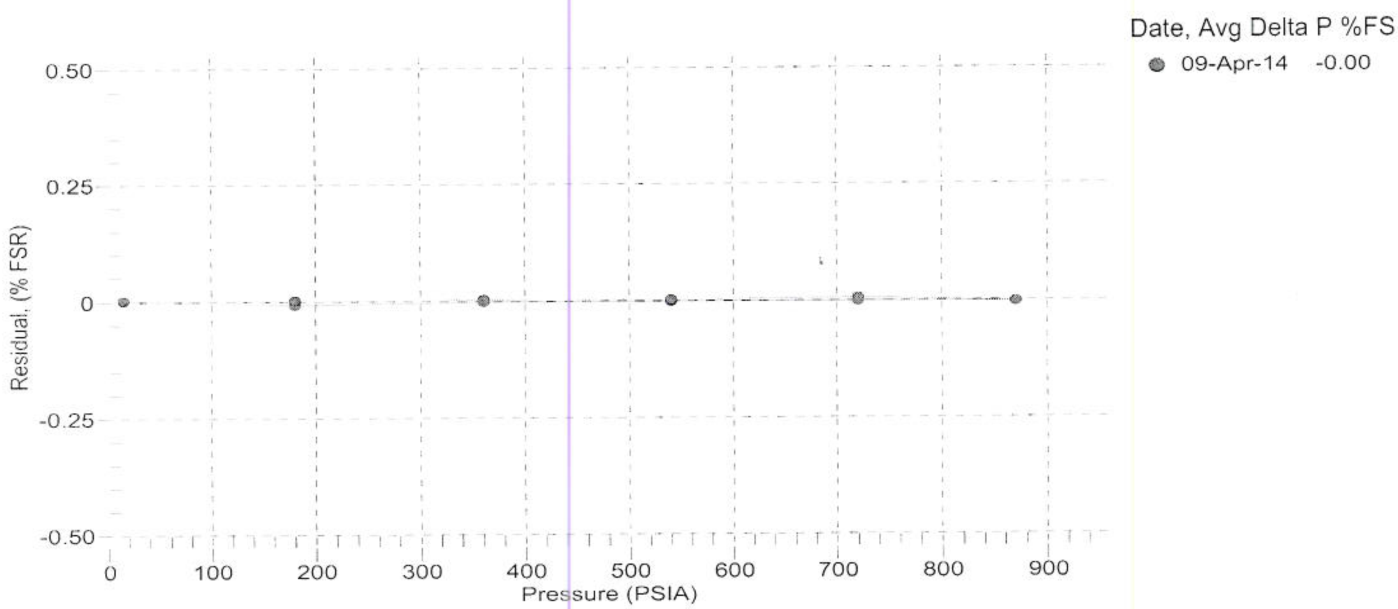
TEMP(ITS90)	SPAN(mV)
-5.00	25.56
35.00	25.59

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

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

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

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



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: 18-Apr-14

SBE 19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -1.002092e+000
h =  1.566067e-001
i = -5.408264e-004
j =  6.744597e-005

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

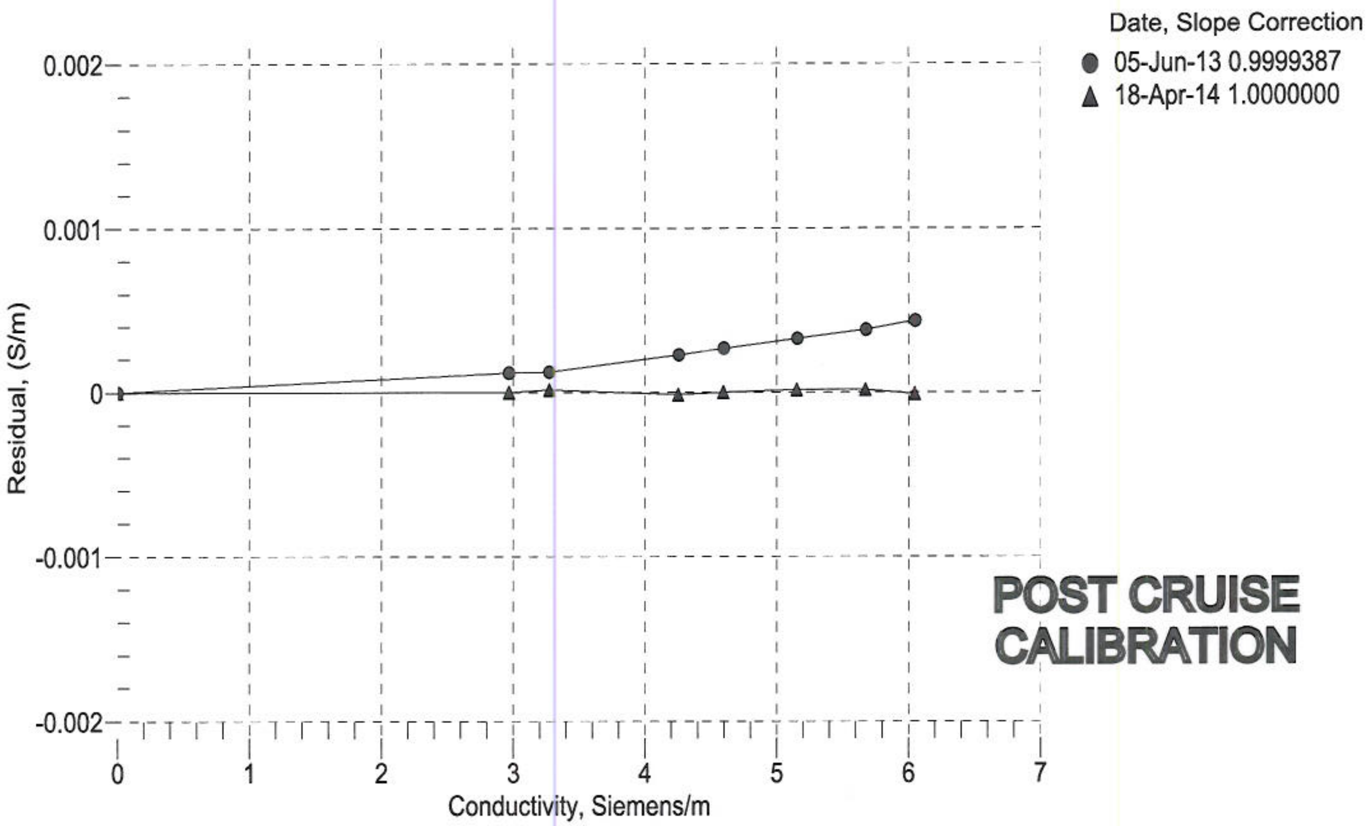
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2537.19	0.0000	0.00000
1.0000	34.7293	2.96924	5052.07	2.9692	-0.00000
4.5000	34.7097	3.27566	5242.89	3.2757	0.00001
15.0000	34.6675	4.25529	5810.19	4.2553	-0.00002
18.5000	34.6586	4.59970	5996.61	4.5997	-0.00000
24.0000	34.6489	5.15647	6285.94	5.1565	0.00001
29.0000	34.6437	5.67722	6544.59	5.6772	0.00001
32.5000	34.6410	6.04887	6722.87	6.0489	-0.00001

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

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

Residual = instrument conductivity - bath conductivity



POST CRUISE CALIBRATION

SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	C&C Technologies		
Job Number:	79067	**Date of Report:**	4/18/2014
Model Number	SBE 19Plus	**Serial Number:**	19P47719-5222

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

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

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 4/18/2014 Drift since last cal: -0.00020 PSU/month

Comments:

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

Date: Drift since Last cal: PSU/month

Comments:

**Measured at 3.0 S/m*

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

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SENSOR SERIAL NUMBER: 5222
CALIBRATION DATE: 18-Apr-14

SBE 19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

a0 = 1.292914e-003
a1 = 2.525103e-004
a2 = 1.077278e-006
a3 = 1.015447e-007

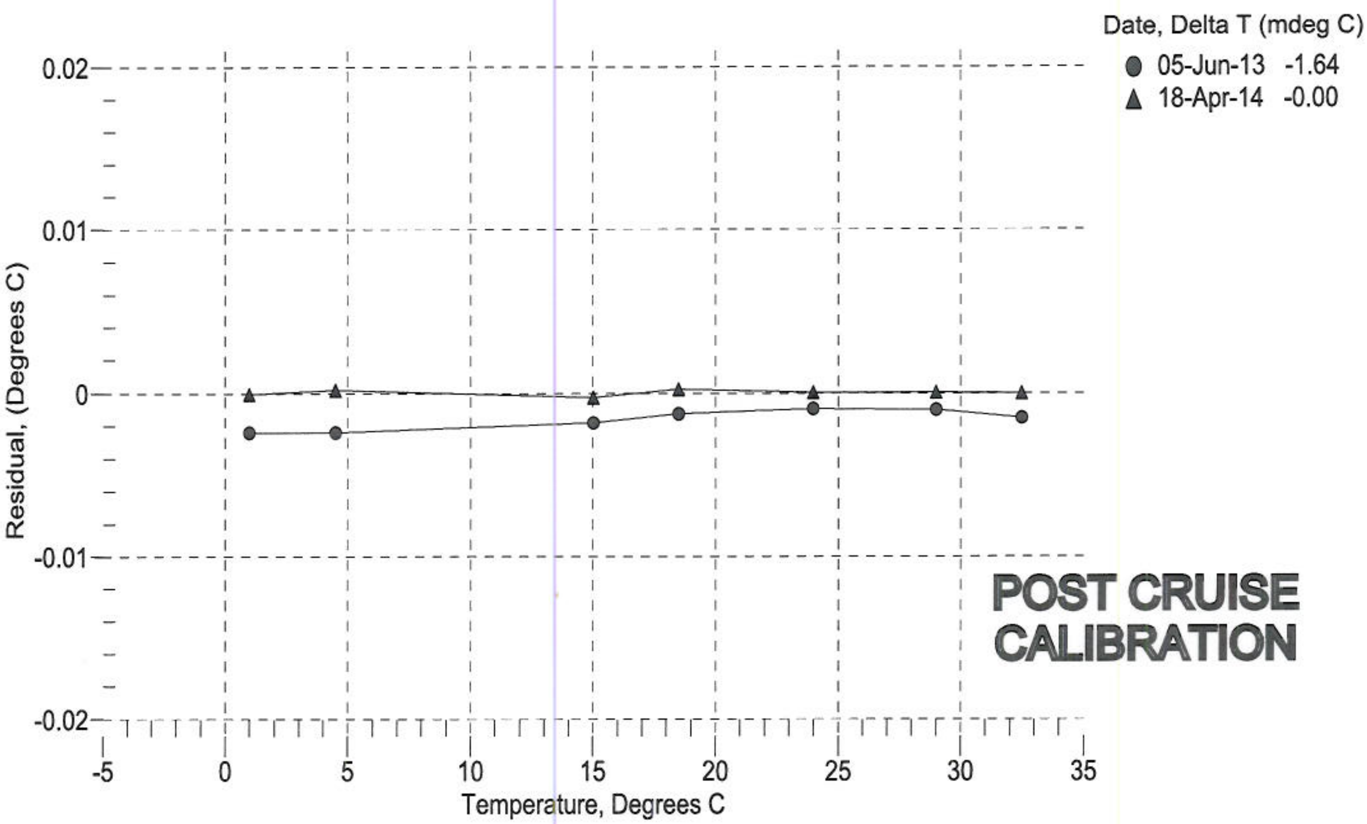
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	619216.966	0.9999	-0.0001
4.5000	549245.119	4.5002	0.0002
15.0000	375949.068	14.9997	-0.0003
18.5000	329516.729	18.5002	0.0002
24.0000	266583.661	24.0000	0.0000
29.0000	218760.136	29.0000	0.0000
32.5000	189914.576	32.5000	-0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	C&C Technologies		
Job Number:	79067	Date of Report:	4/18/2014
Model Number	SBE 19Plus	Serial Number:	19P47719-5222

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

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

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 4/18/2014 Drift since last cal: +0.00188 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

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SENSOR SERIAL NUMBER: 5222
CALIBRATION DATE: 16-Apr-14

SBE 19plus PRESSURE CALIBRATION DATA
FSR: 870 psia S/N 2494573

COEFFICIENTS:

```
PA0 =      -6.590128e-001
PA1 =       2.649428e-003
PA2 =       2.201620e-011
PTEMPA0 = -6.502936e+001
PTEMPA1 =  5.298806e+001
PTEMPA2 = -3.302614e-001
```

```
PTCA0 =  5.244138e+005
PTCA1 = -1.574805e+001
PTCA2 =  2.028902e-001
PTCB0 =  2.549788e+001
PTCB1 =  1.375000e-003
PTCB2 =  0.000000e+000
```

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FS
14.63	529955.0	1.7	14.66	0.00
179.92	592357.0	1.7	179.90	-0.00
359.93	660260.0	1.7	359.89	-0.00
539.93	728102.0	1.7	539.93	0.00
719.94	795852.0	1.7	719.92	-0.00
869.94	852253.0	1.7	869.92	-0.00
719.96	795883.0	1.7	720.01	0.01
539.97	728122.0	1.7	539.98	0.00
359.95	660283.0	1.7	359.95	0.00
179.94	592378.0	1.7	179.95	0.00
14.63	529940.0	1.7	14.62	-0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.86	529965.58
29.00	1.79	529976.89
24.00	1.70	529999.82
18.50	1.59	530037.43
15.00	1.52	530070.04
4.50	1.32	530207.61
1.00	1.26	530237.97

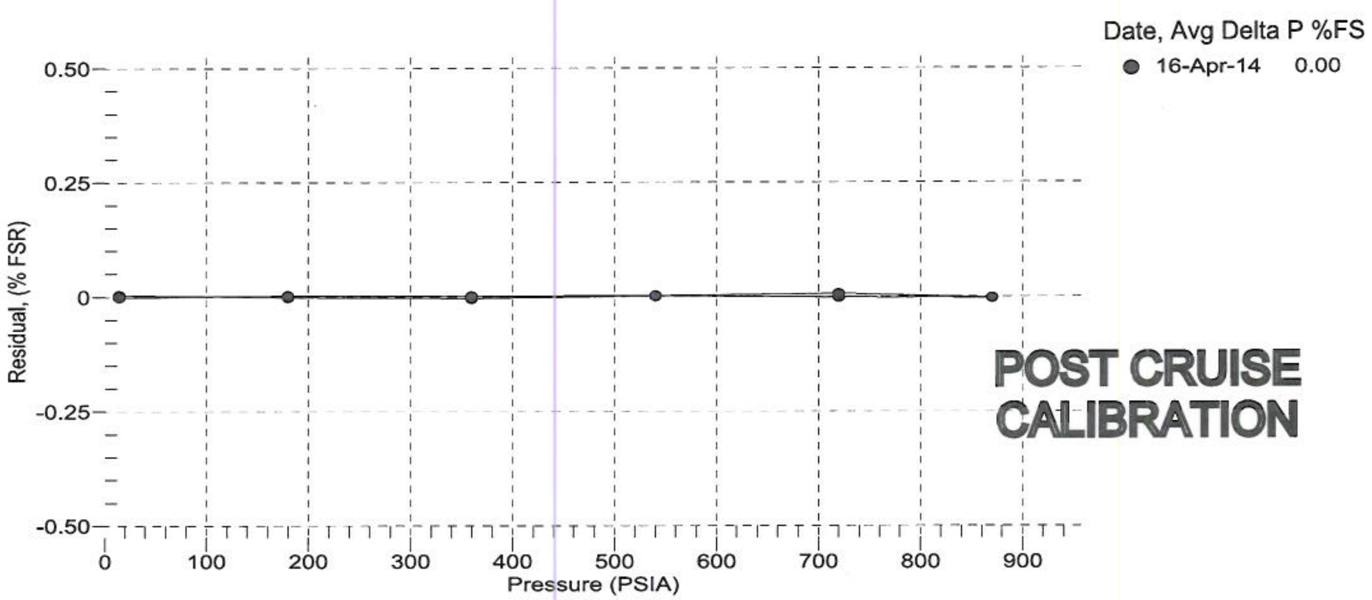
TEMP(ITS90)	SPAN(mV)
-5.00	25.49
35.00	25.55

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

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

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

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



SBE 19plus V2 SeaCAT Profiler

Instrument Configuration

Instrument Serial Number:	19-7515
Instrument Firmware Version:	2.5.2
Zero Conductivity Frequency:	2592.21
Communications Format:	RS232
Communications Settings:	9600 baud, 8 Data Bits, No Parity

Installed Devices/Sensors

Data Format	*Measurement*	*Sensor Type*	*Serial Number*	*Rating*
Count	Temperature	Internal	N/A	N/A
Frequency	Conductivity	Internal	N/A	N/A
Count	Pressure Sensor	Druck	4121113	600m(600 dBar)
NONE	N/A	SBE 5	05-7194	600m

Maximum Depth: **600m**

CAUTION - The maximum deployment depth will be limited by the measurement range of the pressure sensor, if installed, an attached sensor, if installed, or the housing.

SEA·BIRD SCIENTIFIC

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SENSOR SERIAL NUMBER: 7515
CALIBRATION DATE: 01-Aug-14

SBE 19plus V2 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.240613e-003
a1 = 2.775088e-004
a2 = -1.416743e-006
a3 = 1.955392e-007

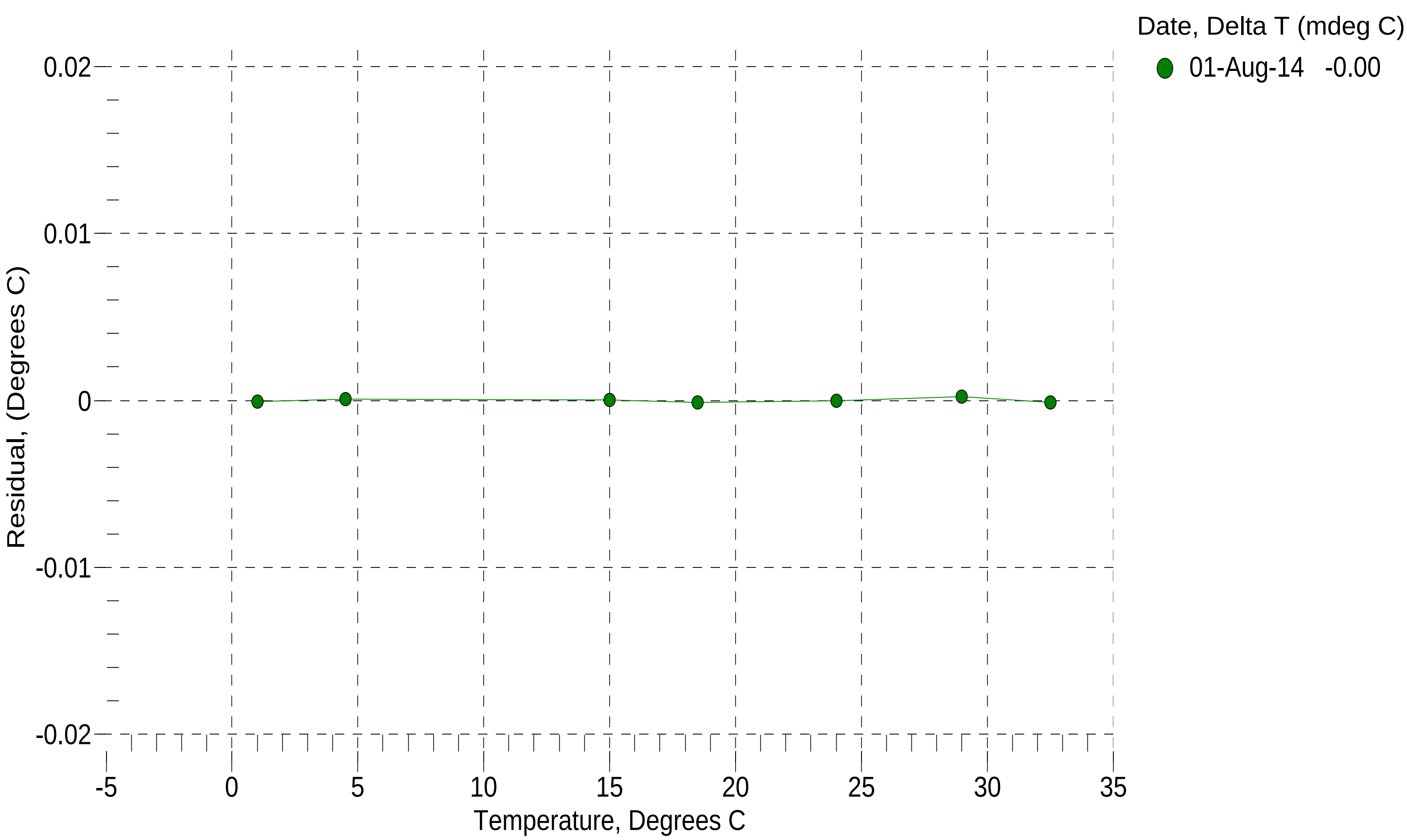
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
0.9999	561038.983	0.9998	-0.0001
4.5000	495527.085	4.5001	0.0001
15.0000	335359.356	15.0000	0.0000
18.5000	292935.627	18.4999	-0.0001
24.0000	235726.254	24.0000	-0.0000
29.0000	192476.373	29.0002	0.0002
32.5000	166481.017	32.4999	-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



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SENSOR SERIAL NUMBER: 7515
CALIBRATION DATE: 01-Aug-14

SBE 19plus V2 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.884252e-001
h =  1.473585e-001
i = -1.915547e-004
j =  3.500458e-005

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

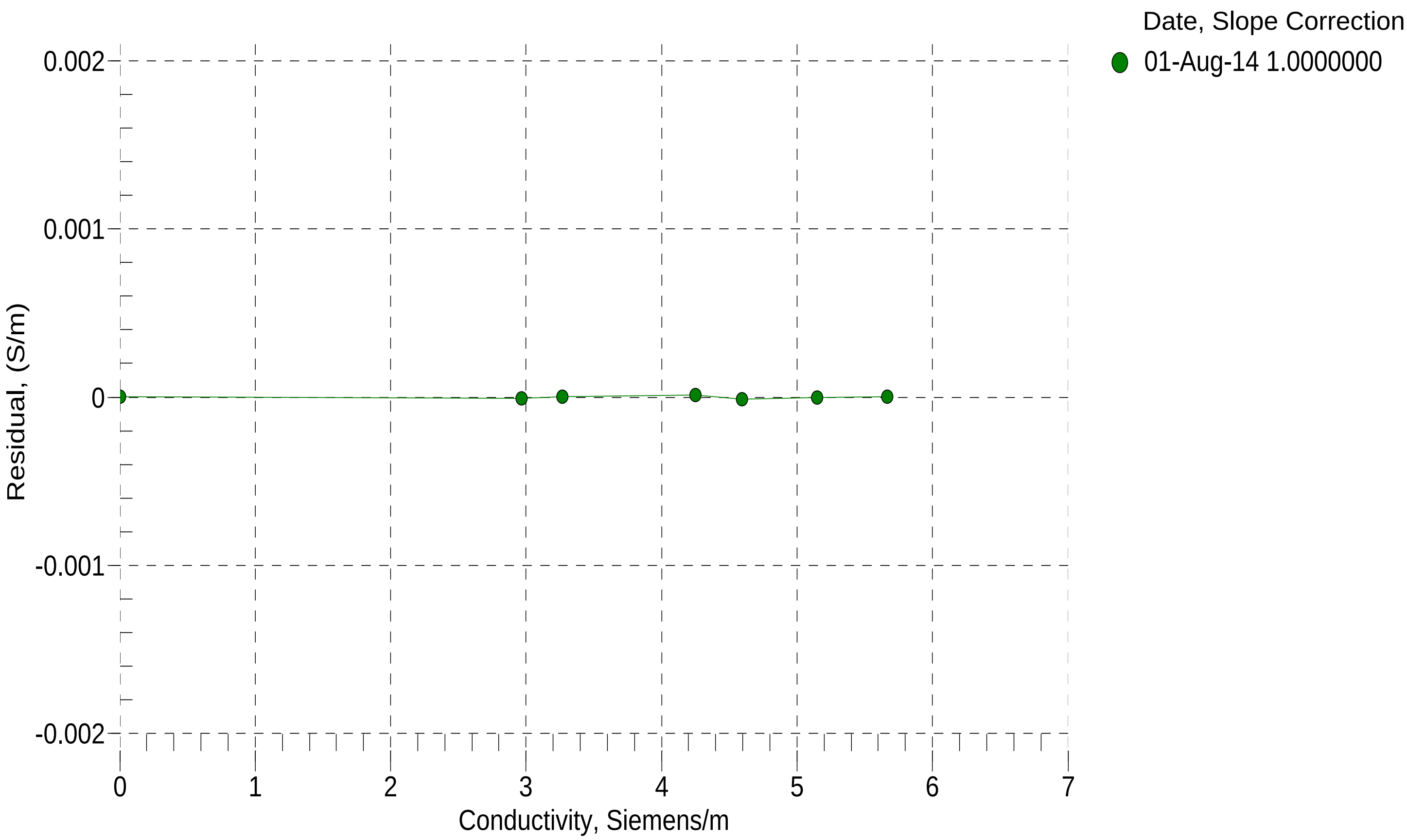
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2592.21	0.0000	0.00000
0.9999	34.6620	2.96402	5179.93	2.9640	-0.00001
4.5000	34.6420	3.26990	5376.02	3.2699	0.00000
15.0000	34.5995	4.24782	5959.12	4.2478	0.00001
18.5000	34.5906	4.59165	6150.74	4.5916	-0.00001
24.0000	34.5807	5.14744	6448.22	5.1474	-0.00000
29.0000	34.5717	5.66675	6713.98	5.6668	0.00000
32.5000	34.5689	6.03771	6897.34	6.0376	-0.00008

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

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

Residual = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 7515
CALIBRATION DATE: 25-Jul-14

SBE 19plus V2 PRESSURE CALIBRATION DATA
FSR: 870 psia S/N 4121113

COEFFICIENTS:

PA0 = -1.692682e-001
PA1 = 2.638354e-003
PA2 = 1.668844e-011
PTEMPA0 = -6.682134e+001
PTEMPA1 = 5.144249e+001
PTEMPA2 = -1.955499e-001

PTCA0 = 5.250864e+005
PTCA1 = -1.994691e+000
PTCA2 = -3.995177e-002
PTCB0 = 2.515312e+001
PTCB1 = -7.750000e-004
PTCB2 = 0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FS
14.67	530642.0	1.8	14.68	0.00
179.94	593198.0	1.8	179.92	-0.00
359.94	661286.0	1.8	359.92	-0.00
539.95	729321.0	1.8	539.94	-0.00
719.95	797289.0	1.8	719.93	-0.00
869.93	853879.0	1.8	869.91	-0.00
719.97	797310.0	1.8	719.99	0.00
539.98	729345.0	1.8	540.01	0.00
359.98	661314.0	1.8	360.00	0.00
179.97	593215.0	1.8	179.97	-0.00
14.67	530642.0	1.8	14.68	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.95	530719.14
29.00	1.88	530733.85
24.00	1.78	530752.95
18.50	1.67	530774.58
15.00	1.60	530786.98
4.50	1.39	530817.91
1.00	1.33	530821.48

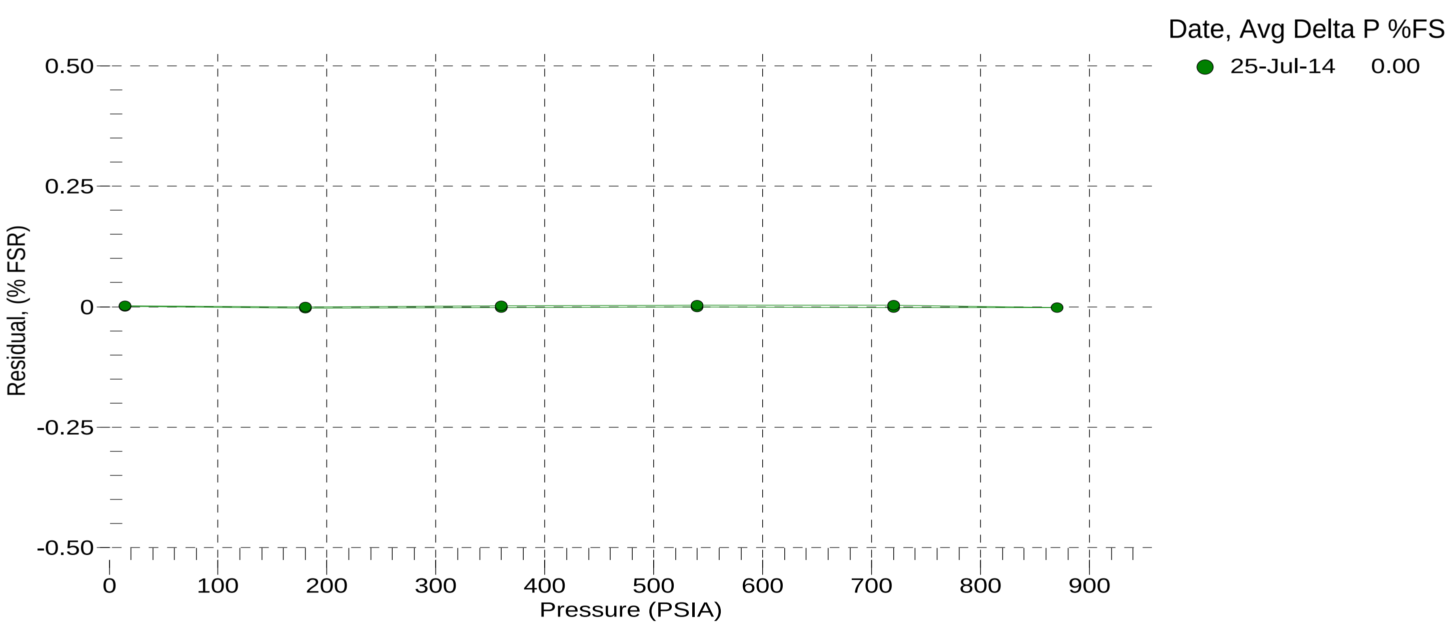
TEMP(ITS90)	SPAN(mV)
-5.00	25.16
35.00	25.13

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

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

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

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



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Pressure Test Certificate

Test Date: 07/24/14

Description: SBE-19Plus SeaCat Profiler

Sensor Information:

Model Number: 19P

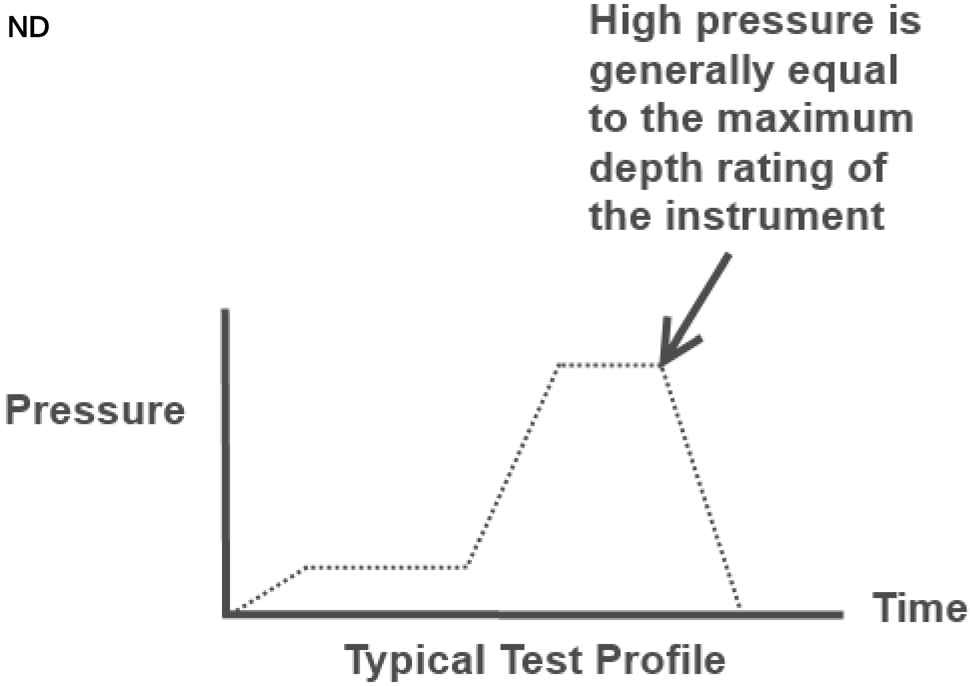
Serial Number: 7515

Pressure Test Protocol:

Low Pressure Test:	40	PSI	Held For:	15	Minutes
High Pressure Test:	870	PSI	Held For:	15	Minutes

Passed Test: Yes

Tested By: ND



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SBE 5M SUBMERISIBLE PUMP CONFIGURATION SHEET

Serial Number:	**05-7194**	MRP PN:	**90623**
Pressure Rating:	**600m**	Test Date:	**07/29/2013**
Housing Type:	**Plastic**		

Maxon Motor Type

P/N 801606, Motor PN 20127 (Continuous Duty 9 VDC, 2000 RPM MAX)

Pump Specifications:

V_{IN} at 6.0V, no load, voltage across C2:	**6.34**	VDC	Current:	**0.33**	mA
V_{IN} at 9.0V, no load, voltage across C2:	**7.87**	VDC	Current:	**5.94**	mA
V_{IN} at 15.0V, no load, voltage across C2:	**7.99**	VDC	Current:	**5.96**	mA
Pump submerged, no load, V_{IN} 12VDC	**82.09**	mA			

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SBE Pressure Test Certificate

Test Date: **7/30/2013** Description **SBE-5M Submersible Pump**

SBE Sensor Information:

Model Number: **5M**
Serial Number: **7194**

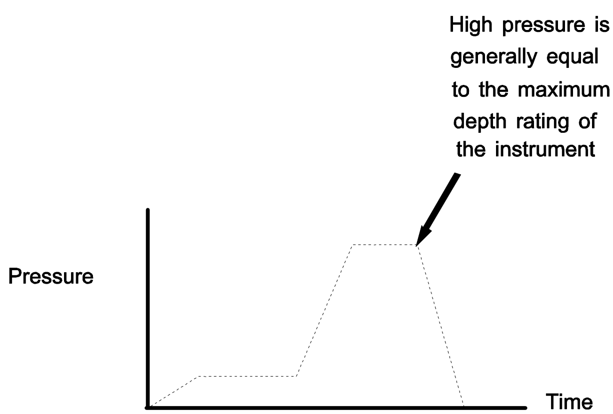
Pressure Test Protocol:

Low Pressure Test: **40** PSI Held For **15** Minutes

High Pressure Test: **870** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: VG



typical Test Profile

SBE

Sea-Bird Electronics, Inc.

Advancing the Science of Ocean Measurement

SBE 19plus V2 SeaCAT Profiler

Instrument Configuration

Instrument Serial Number:	19-7516
Instrument Firmware Version:	2.5.2
Zero Conductivity Frequency:	2555.06
Communications Format:	RS232
Communications Settings:	9600 baud, 8 Data Bits, No Parity

Installed Devices/Sensors

Data Format	*Measurement*	*Sensor Type*	*Serial Number*	*Rating*
Count	Temperature	Internal	N/A	N/A
Frequency	Conductivity	Internal	N/A	N/A
Count	Pressure Sensor	Druck	4121114	600m(600 dBar)
NONE	N/A	SBE 5	05-7533	600m

Maximum Depth: **600m**

CAUTION - The maximum deployment depth will be limited by the measurement range of the pressure sensor, if installed, an attached sensor, if installed, or the housing.

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SENSOR SERIAL NUMBER: 7516
CALIBRATION DATE: 01-Aug-14

SBE 19plus V2 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.248802e-003
a1 = 2.771580e-004
a2 = -1.542096e-006
a3 = 1.974517e-007

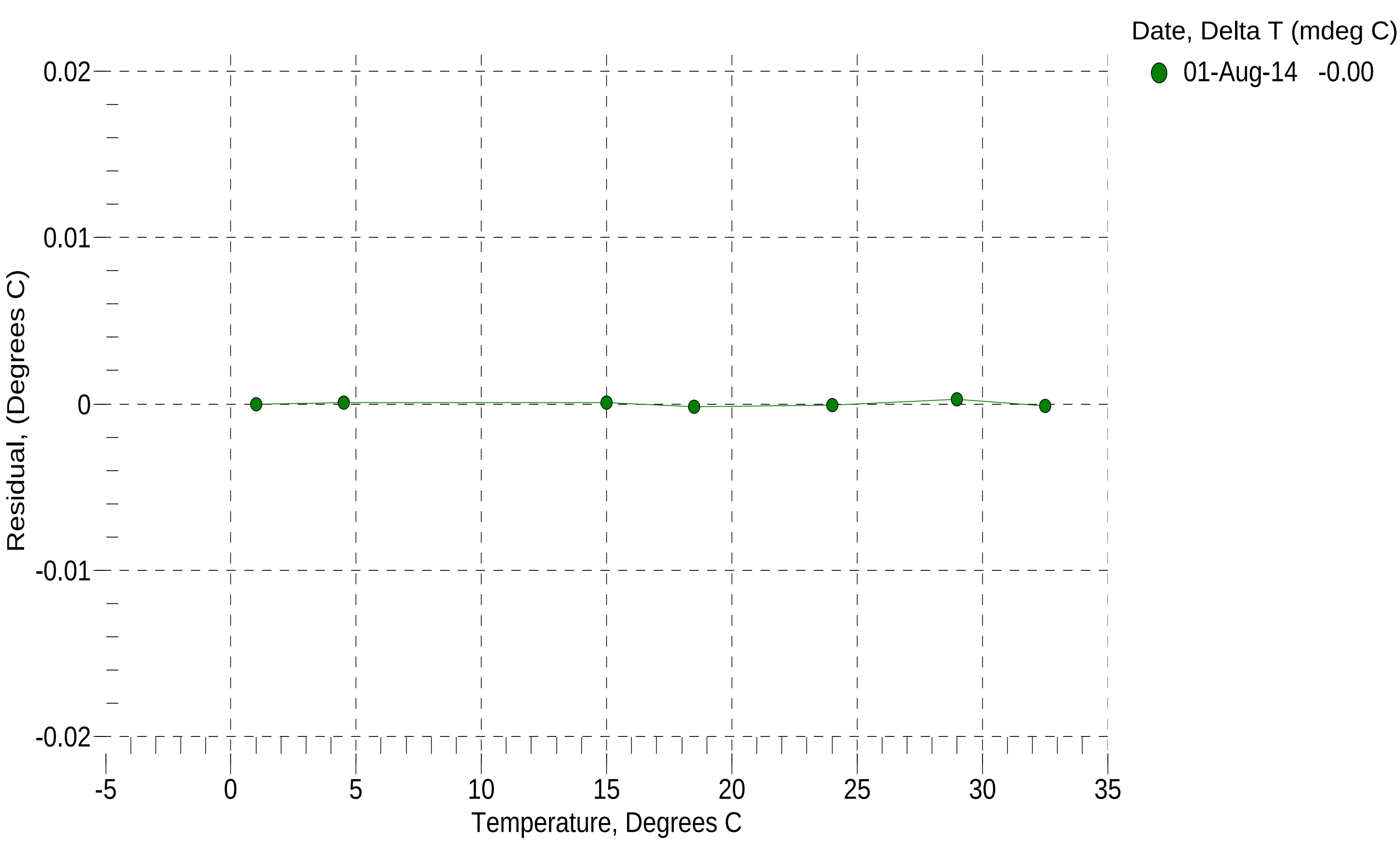
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
0.9999	565337.169	0.9999	-0.0000
4.5000	499083.763	4.5001	0.0001
15.0000	337146.881	15.0001	0.0001
18.5000	294287.169	18.4998	-0.0002
24.0000	236528.169	23.9999	-0.0001
29.0000	192902.051	29.0003	0.0003
32.5000	166702.661	32.4999	-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



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SENSOR SERIAL NUMBER: 7516
CALIBRATION DATE: 01-Aug-14

SBE 19plus V2 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.655529e-001
h =  1.483665e-001
i = -2.947140e-004
j =  4.411481e-005

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

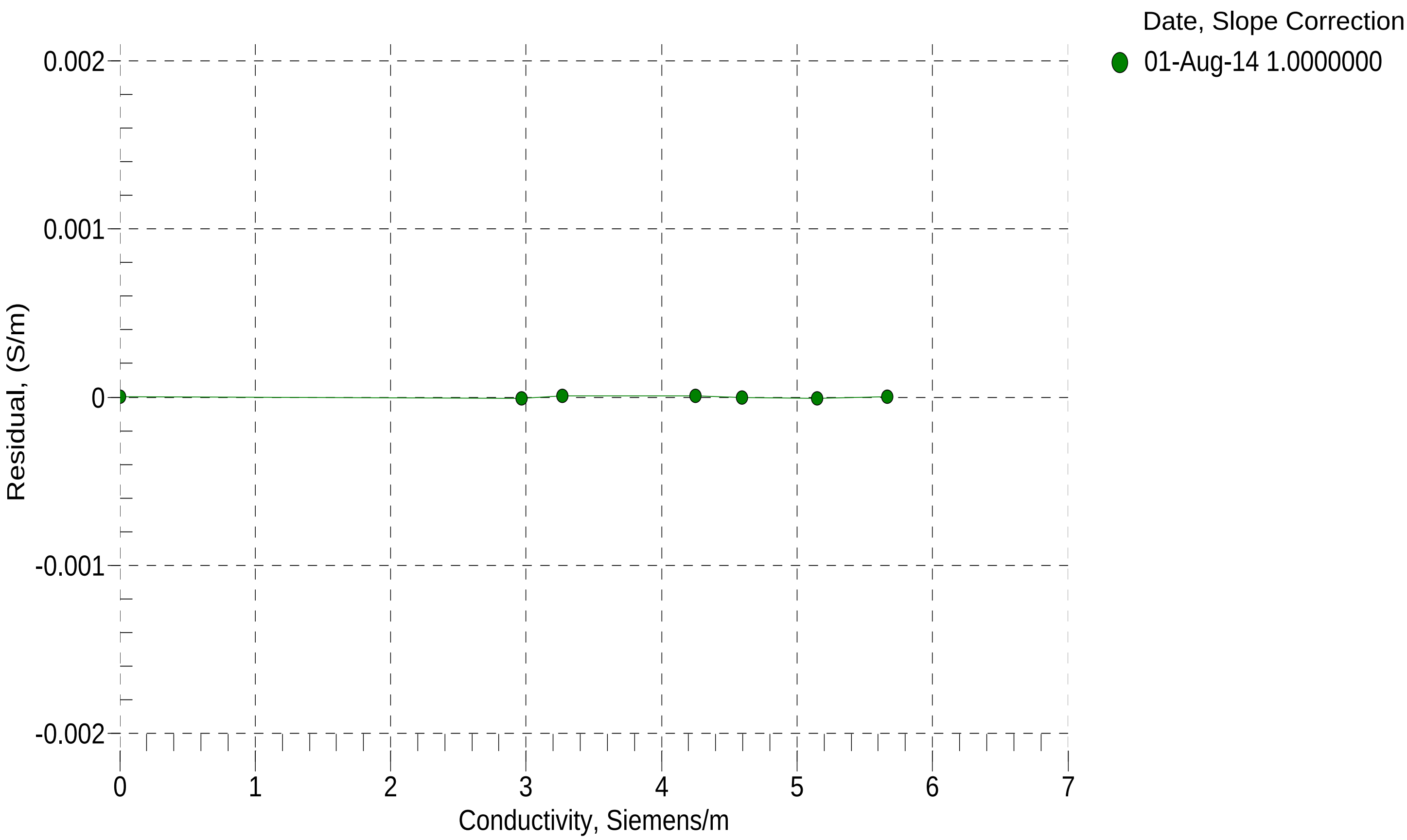
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2555.06	0.0000	0.00000
0.9999	34.6620	2.96402	5152.45	2.9640	-0.00001
4.5000	34.6420	3.26990	5348.66	3.2699	0.00001
15.0000	34.5995	4.24782	5931.81	4.2478	0.00001
18.5000	34.5906	4.59165	6123.38	4.5916	-0.00000
24.0000	34.5807	5.14744	6420.68	5.1474	-0.00001
29.0000	34.5717	5.66675	6686.20	5.6668	0.00000
32.5000	34.5689	6.03771	6869.36	6.0376	-0.00007

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

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

Residual = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 7516
CALIBRATION DATE: 25-Jul-14

SBE 19plus V2 PRESSURE CALIBRATION DATA
FSR: 870 psia S/N 4121114

COEFFICIENTS:

```
PA0 =      7.314919e-001
PA1 =      2.642565e-003
PA2 =      1.732304e-011
PTEMPA0 = -6.523207e+001
PTEMPA1 =  5.184727e+001
PTEMPA2 = -2.914367e-001

PTCA0 =  5.247629e+005
PTCA1 =  1.920978e+001
PTCA2 = -3.223458e-001
PTCB0 =  2.514787e+001
PTCB1 = -1.225000e-003
PTCB2 =  0.000000e+000
```

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FS
14.67	530302.0	1.7	14.67	-0.00
179.94	592732.0	1.7	179.91	-0.00
359.94	660678.0	1.7	359.90	-0.00
539.95	728575.0	1.7	539.93	-0.00
719.95	796402.0	1.7	719.93	-0.00
869.93	852874.0	1.7	869.92	-0.00
719.97	796425.0	1.7	719.99	0.00
539.98	728610.0	1.7	540.02	0.00
359.98	660716.0	1.7	360.00	0.00
179.97	592766.0	1.7	180.00	0.00
14.67	530311.0	1.7	14.69	0.00

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.91	530445.76
29.00	1.84	530445.98
24.00	1.74	530436.16
18.50	1.63	530409.06
15.00	1.56	530378.19
4.50	1.36	530234.61
1.00	1.29	530184.80

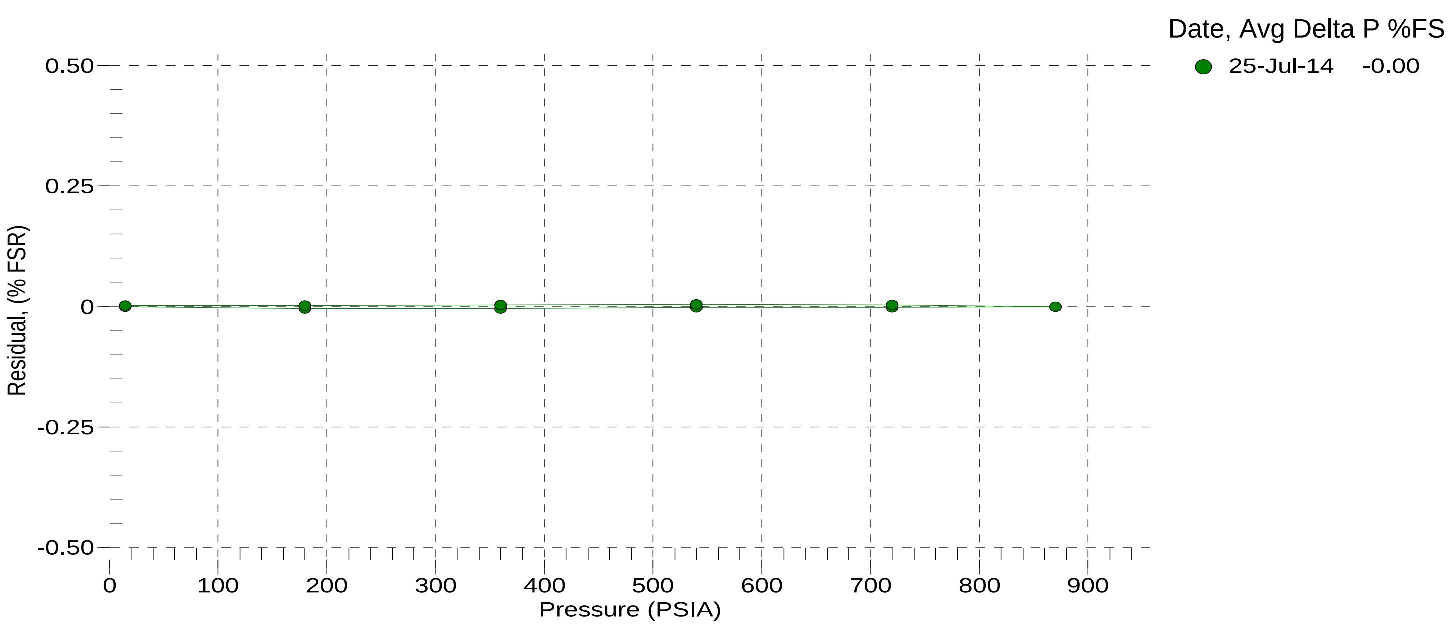
TEMP(ITS90)	SPAN(mV)
-5.00	25.15
35.00	25.11

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

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

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

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



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Pressure Test Certificate

Test Date: 07/24/14

Description: SBE-19Plus SeaCat Profiler

Sensor Information:

Model Number: 19P

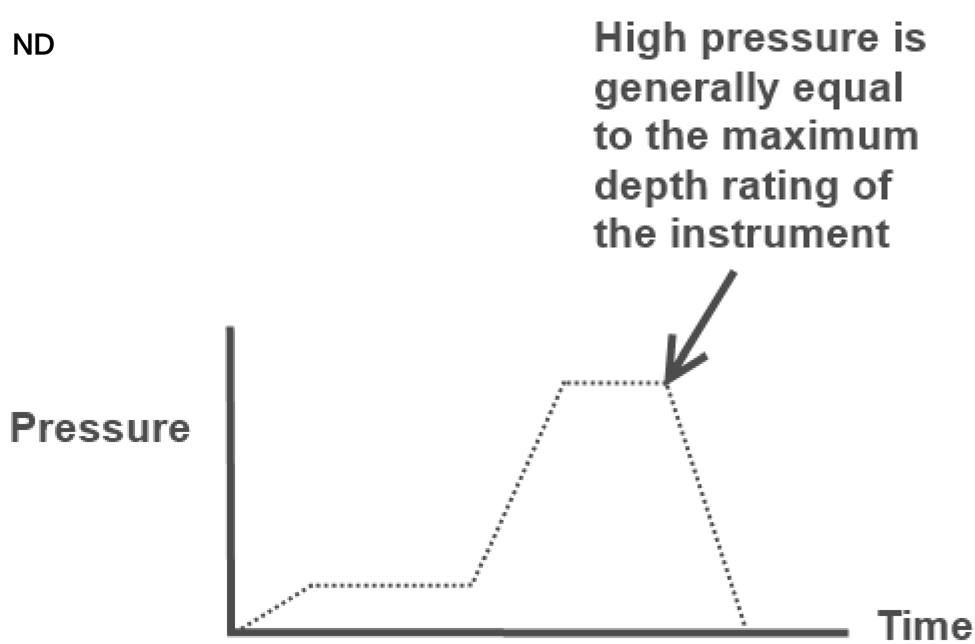
Serial Number: 7516

Pressure Test Protocol:

Low Pressure Test:	40	PSI	Held For: 15	Minutes
High Pressure Test:	870	PSI	Held For: 15	Minutes

Passed Test: Yes

Tested By: ND



Typical Test Profile

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SBE 5M SUBMERISIBLE PUMP CONFIGURATION SHEET

Serial Number:	**05-7533**		MRP PN:	**90623**
Pressure Rating:	**600m**		Test Date:	**03/19/2014**
Housing Type:	**Plastic**			

Maxon Motor Type

P/N 801606, Motor PN 20127 (Continuous Duty 9 VDC, 2000 RPM MAX)

Pump Specifications:

V_{IN} at 6.0V, no load, voltage across C2:	**6.10**	VDC	Current:	**6.63**	mA
V_{IN} at 9.0V, no load, voltage across C2:	**8.02**	VDC	Current:	**7.74**	mA
V_{IN} at 15.0V, no load, voltage across C2:	**8.02**	VDC	Current:	**7.72**	mA
Pump submerged, no load, V_{IN} 12VDC	**119.70**	mA			

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Pressure Test Certificate

Test Date: 3/19/2014

Description: SBE-5M Submersible Pump

Sensor Information:

Model Number: 5M

Serial Number: 7533

Pressure Information:

Pressure Sensor Rating (psia): none

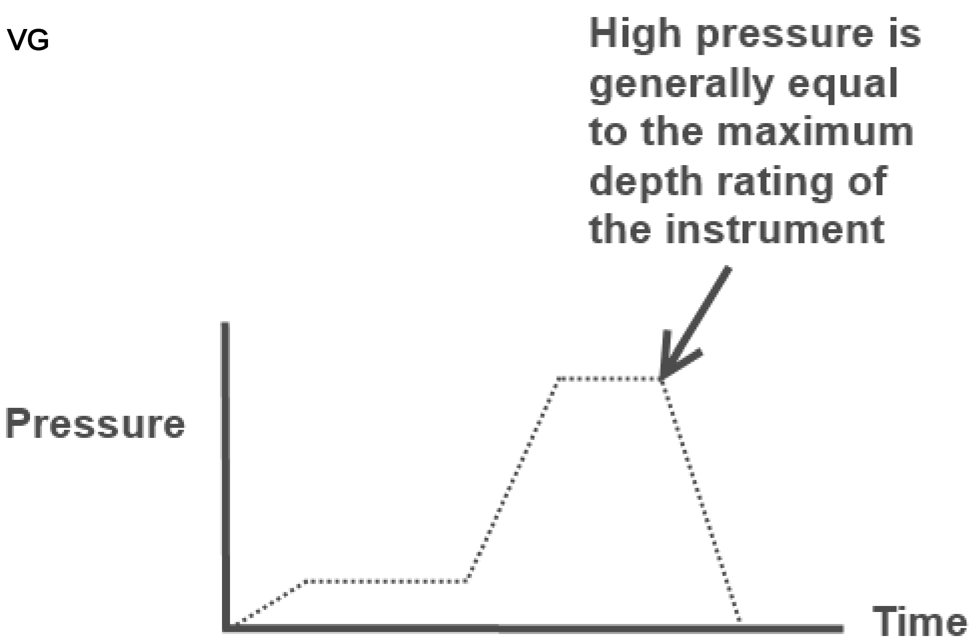
Housing Rating (psia): 870

Pressure Test Protocol:

Low Pressure Test:	40	PSI	Held For:	15	Minutes
High Pressure Test:	870	PSI	Held For:	15	Minutes

Passed Test: Yes

Tested By: VG



Typical Test Profile

3279

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SENSOR SERIAL NUMBER: 3279
CALIBRATION DATE: 13-Dec-14

SBE 19 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -4.12521393e+000
h = 4.92140574e-001
i = 1.24479128e-003
j = -2.96715879e-005

CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

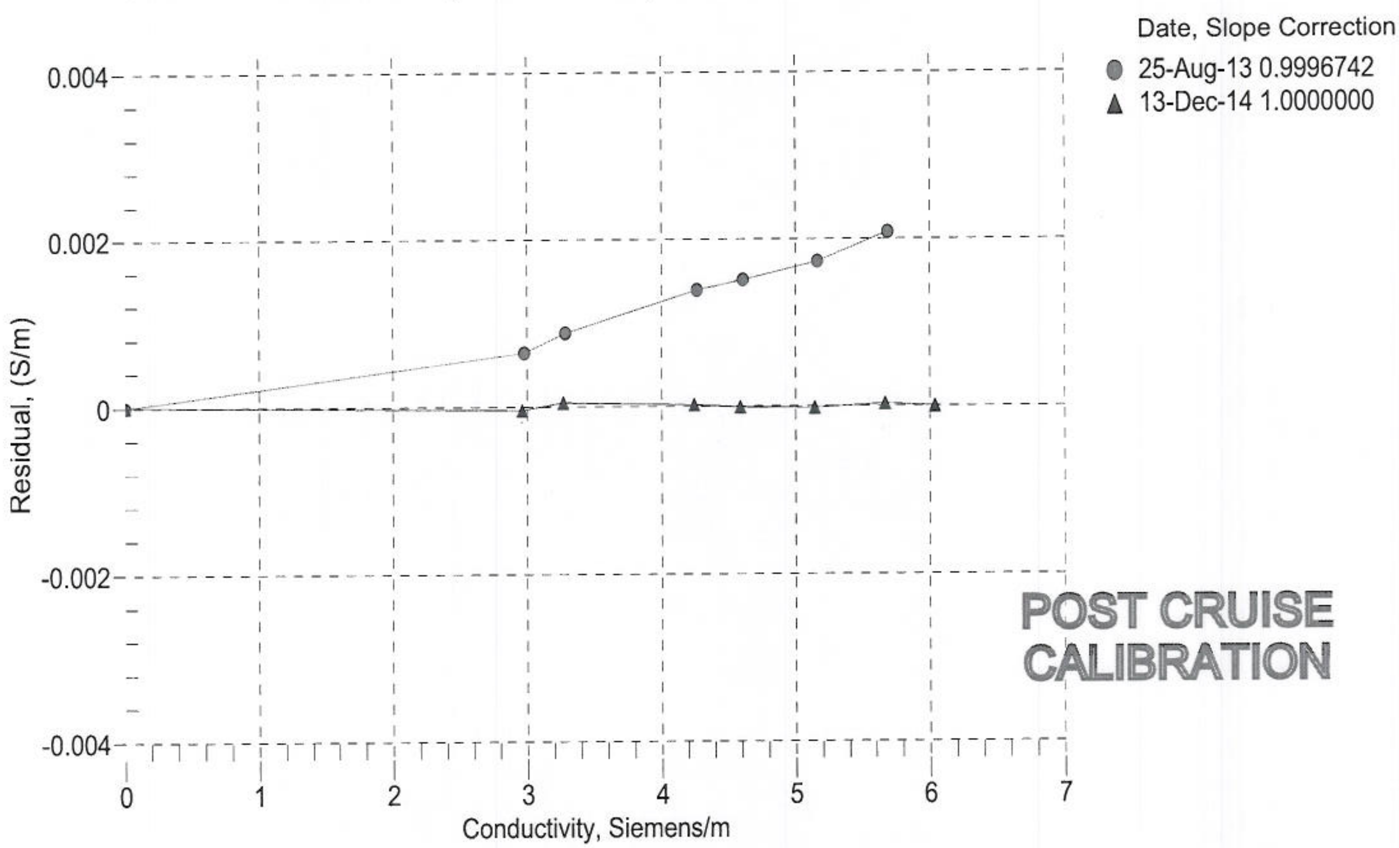
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88541	0.00000	0.00000
1.0000	34.6488	2.96301	8.21346	2.96297	-0.00004
4.5000	34.6281	3.26871	8.57517	3.26876	0.00005
15.0000	34.5835	4.24607	9.63946	4.24608	0.00001
18.5000	34.5723	4.58948	9.98617	4.58946	-0.00002
24.0000	34.5596	5.14464	10.52227	5.14462	-0.00003
29.0000	34.5506	5.66368	10.99966	5.66370	0.00003
32.5000	34.5441	6.03387	11.32766	6.03386	-0.00000

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

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

Residual = instrument conductivity - bath conductivity



POST CRUISE CALIBRATION

SBE
SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	C&C Technologies		
Job Number:	81747	Date of Report:	12/15/2014
Model Number	SBE 19	Serial Number:	1942377-3279

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

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

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 12/13/2014 Drift since last cal: -0.00060 PSU/month*

Comments:

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

Date: Drift since Last cal: PSU/month*

Comments:

**Measured at 3.0 S/m*

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

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SENSOR SERIAL NUMBER: 3279
CALIBRATION DATE: 13-Dec-14

SBE 19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

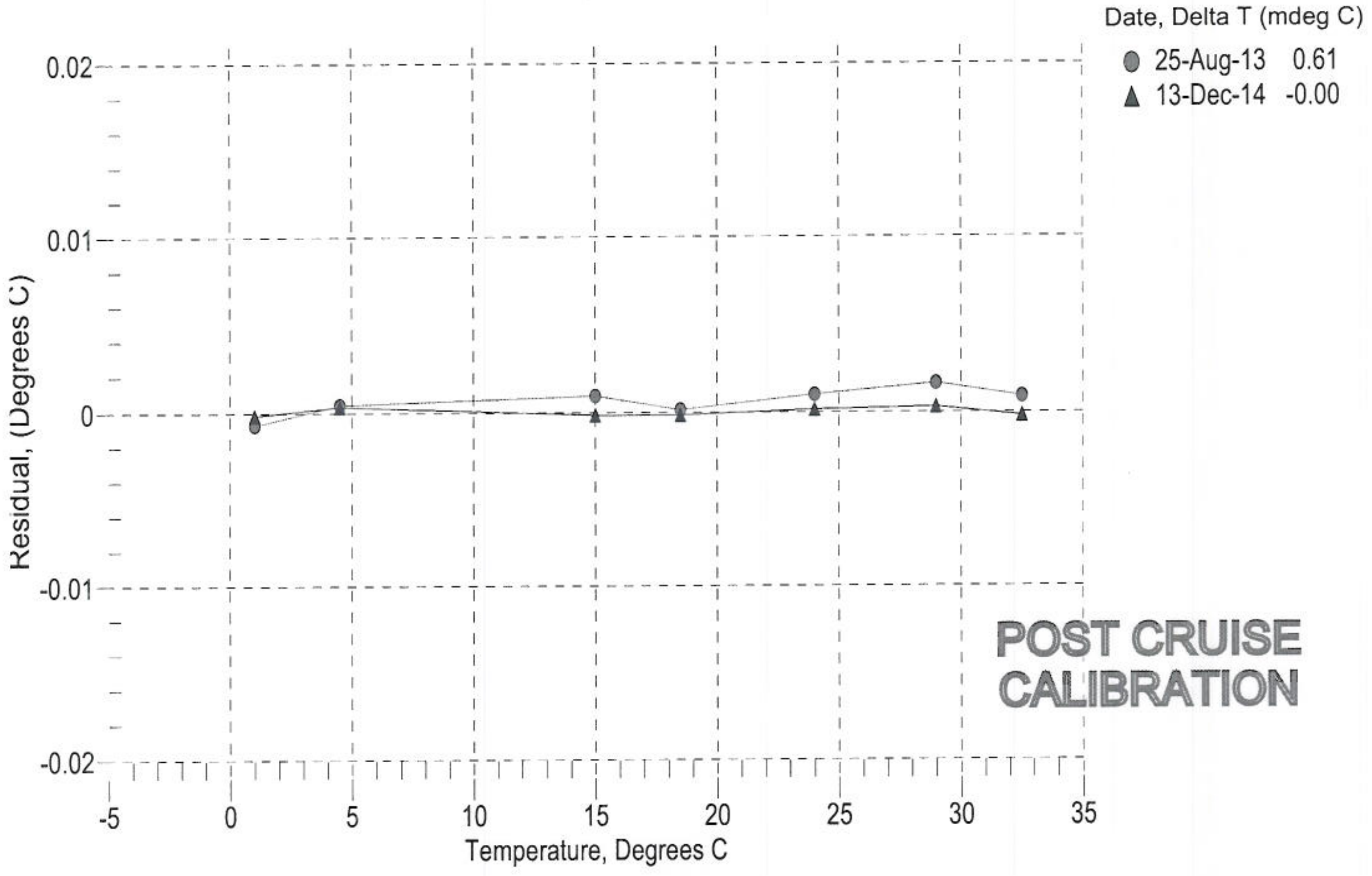
ITS-90 COEFFICIENTS:

```
g =  4.14883889e-003
h =  5.79830346e-004
i = -1.44827434e-007
j = -2.55980219e-006
f0 =  1000.0
```

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2379.947	0.9998	-0.00017
4.5000	2578.553	4.5003	0.00031
15.0000	3244.255	14.9998	-0.00018
18.5000	3490.681	18.4998	-0.00016
24.0000	3904.039	24.0001	0.00013
29.0000	4308.503	29.0003	0.00028
32.5000	4608.408	32.4998	-0.00021

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)

Residual = instrument temperature - bath temperature



SBE SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	C&C Technologies		
Job Number:	81747	**Date of Report:**	12/15/2014
Model Number	SBE 19	**Serial Number:**	1942377-3279

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

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

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 12/13/2014 Drift since last cal: -0.00047 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

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: 3279
CALIBRATION DATE: 25-Nov-14

SBE 19 PRESSURE CALIBRATION DATA
FSR: 6000 psia S/N 100368

DIGIQUARTZ COEFFICIENTS:

```
C1 =  -2.776819e+004
C2 =  -2.888680e-001
C3 =   8.049490e-003
D1 =   3.511900e-002
D2 =   0.000000e+000
T1 =   3.000895e+001
T2 =  -4.438660e-004
T3 =   4.031420e-006
T4 =   2.014690e-009
T5 =   0.000000e+000
```

AD590M, AD590B, SLOPE AND OFFSET:

```
AD590M =    0.00000e+000
AD590B =    0.00000e+000
Slope  =    0.99995
Offset =   -0.3168 (dbars)
```

PRESSURE (PSIA)	INST OUTPUT (Hz)	INST TEMP (C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.707	33341.40	22.6	15.277	14.817	0.110
1211.652	34050.60	22.7	1211.726	1211.203	-0.449
2408.569	34743.60	22.7	2408.795	2408.209	-0.360
3605.591	35421.20	22.7	3606.147	3605.497	-0.094
4802.532	36083.90	22.7	4803.104	4802.391	-0.141
5999.447	36732.90	22.8	6000.339	5999.563	0.116
4803.105	36084.40	22.8	4804.002	4803.288	0.183
3605.857	35421.50	22.8	3606.663	3606.013	0.156
2408.910	34744.00	22.8	2409.449	2408.862	-0.048
1212.022	34051.30	22.8	1212.876	1212.353	0.331
14.702	33341.50	22.8	15.357	14.897	0.195

Residual = corrected instrument pressure - reference pressure