NOAA FORM 76-35A

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

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey Hydrographic

Project No. OPR-S325-KR-13

Time Frame July – August 2013

LOCALITY

State ALASKA

General Locality Bering Sea

Sub Locality Approaches to Red Dog Mine

2013

CHIEF OF PARTY

MARTA KRYNYTZKY

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DATE

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NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION HYDROGRAPHIC TITLE SHEET	REGISTER NO. **H12520, H12521, H12522, H12523**
INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office	FIELD NO. **N / A**

State Alaska

General Locality Bering Sea

Locality Approaches to Red Dog Mine

Scale 1:40,000 Date of Survey July 19 to August 26, 2013

Instructions Dated April 3, 2013 Project No. OPR-S325-KR-13

Vessel *Qualifier 105*

Chief of party Marta Krynytzky

Surveyed by TERRASOND PERSONNEL (A. Orthmann, C. Priest, S. Shaw, J. Theis, K. Wade, M. Hildebrandt, S. Johnson, G. Cain, D. Seamount, T. Morino, ET. AL.)

Soundings taken by echosounder, hand lead, pole ECHOSOUNDER – (POLE MOUNTED)

Graphic record scaled by N/A

Graphic record checked by N/A

Protracted by N/A Automated plot by N/A

Verification by

Soundings in METERS at MLLW

REMARKS:

Contract No. DG133C-08-CQ-0005

ALL TIMES ARE RECORDED IN UTC

Hydrographic Survey:

TerraSond Limited
1617 South Industrial Way, Suite 3
Palmer, AK 99645

Tide Support:

JOA Surveys, LLC
2000 E. Dowling Rd., Suite 10
Anchorage, AK 99503

Data Acquisition and Processing Report

OPR-S325-KR-13

January 6th, 2014

Red Dog Mine Dock, Alaska

Vessels: ***Qualifier 105 and Q15 Skiff***

General Locality: ***Bering Sea, Alaska***

Sub Locality: ***H12520 – 7 NM NW of Red Dog Mine***

H12521 – Approaches to Red Dog Mine

H12522 – 6 NM South of Red Dog Mine

H12523 – 10 NM SW of Red Dog Mine

Lead Hydrographer: ***Marta Krynytzky***

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A. Equipment

A.1. Echosounder Systems

To collect sounding data, this project utilized a Reson Seabat 7101 Multibeam Echosounder (MBES) and an Odom Echotrac CV100 Single Beam Echosounder (SBES). Bottom imagery was acquired using an EdgeTech 4200 Side Scan Sonar (SSS) system.

A.1.1. Side Scan Sonar

One EdgeTech 4200-FS Side Scan Sonar (SSS) system was used on this survey.

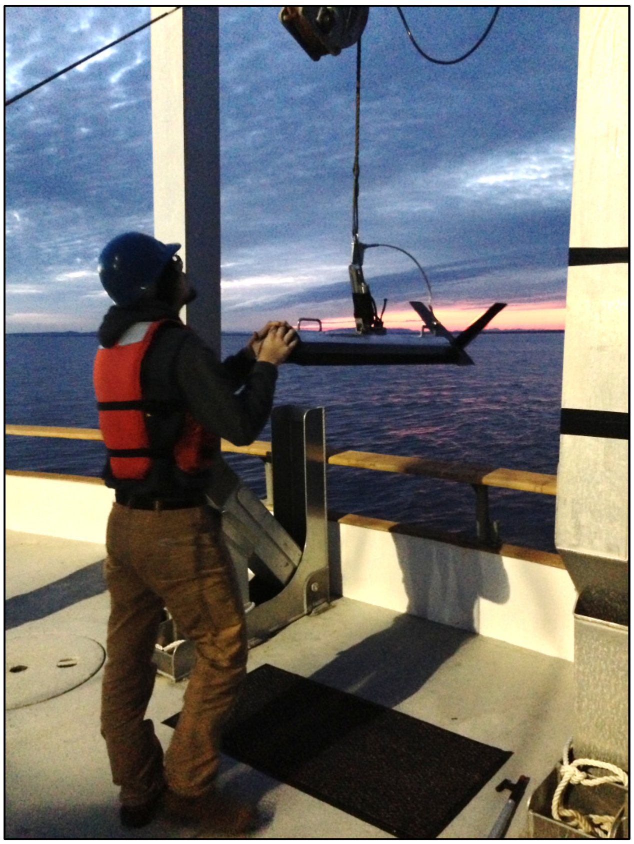


Figure 1 – Side scan towfish used for this survey being deployed from vessel A-frame.

The system consists of a stainless steel towfish, topside processor, and interconnecting cables. EdgeTech Discover served as the user interface and data acquisition software. For this survey the side scan sonar fish was towed behind the vessel. Cable out was measured by a cable counter system; Smart Sensor Cable Pay Out Indicator (SCC) manufactured by Hydrographic Consultants, Inc.

Range, gain, and other user-selectable settings were adjusted, as necessary, through Discover to maximize object detection capabilities. The system was configured to output data via Ethernet network connection to a Windows XP PC running Discover software, which logged the side scan data to .JSF format files.

The system was operated in "High Speed Mode," which utilized EdgeTech's "MultiPulse" (MP) feature. By placing two pings in the water simultaneously, MP allows NOAA object detection requirements to be met to speeds as high as 10 knots, though typical survey speeds were around 8 knots for this project.

SSS performance was verified with daily confidence checks with features captured in the sonar record. SSS confidence checks are available in Appendix II of this report.

See Table 1 for echosounder specifications.

EdgeTech 4200-FS	
Firmware Version	n/a
Sonar Operating Frequency	100 /400 kHz (400 kHz used)
Modulation	Full Spectrum Chirp frequency modulated pulse with amplitude and phase weighting
Operating Range (max)	120 kHz 500 meters p/side; 410 kHz 150 meters p/side
Towing Speed (max safe)	12 knots
Towing Speed *	4.8 knots in HDM, 9.6 knots in HSM
Output Power	120 kHz 4 joules, 410 kHz 2 joules
Pulse Length	120 kHz up to 20 ms, 410 kHz up to 10 ms
Resolution Across Track	120 kHz 8 cm, 410 kHz 2 cm
Resolution Along Track	120 kHz: 2,5m @ 200 meters range, 410 kHz: 0,5m @ 100 meters range
Horizontal Beam Width (HDM)	120 kHz - 0.64°, 410 kHz – 0.3°
Horizontal Beam Width (HSM)	120 kHz – 1.26°, 410 kHz – 0.4°
Resolution Across Track	120 kHz 8 cm, 410 kHz 2 cm
Resolution Along Track	120 kHz: 2,5m @ 200 meters range, 410 kHz: 0,5m @ 100 meters range
Vertical Beam Width	50°
Max Operating Depth	2000 m

Table 1 – EdgeTech 4200-FS side scan sonar technical specifications. *Indicates meets NOAA Shallow Water Survey Specifications with minimum 3 pings on a 1 meter target at 100 meter range scale.

A.1.2. Multibeam Echosounder

One Reson SeaBat 7101-ER system was used on this survey.

The Reson SeaBat 7101 is a digital multibeam echosounder (MBES), which utilizes Reson 7k Control Center software (running on a Windows 7 PC) to serve as the user interface. The 7101 is an upgraded 8101 unit, with improvements that include the ability to form additional beams.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through Reson 7k Control Center to maximize data quality. The system was configured to output bathymetric data via Ethernet network connection to QPS QINSy acquisition software, which logged .DB (database format) files. The system was also configured to output backscatter (multibeam "snippet") data, which was logged, but not processed. Prior to processing, DB files were exported to .XTF (extended Triton format).

Echosounder accuracy was checked by bar check methods on five separate occasions (on JD183, JD208, JD212, JD217, and JD236), with processed results comparing on average to 0.05 m (or better) of the bar depth. Six comparison lead lines were also taken (on JD198, JD206, two on JD208, JD217 and JD236), with agreement varying from 0.01 m to 0.624 m, results that were deemed acceptable given the conditions and variables surrounding lead line collection.

Additionally, the 7101 multibeam data was examined where it overlapped with single beam data collected by the skiff. The two data sets demonstrate good agreement, generally comparing to 0.05 m (or better).

Echosounder accuracy test results are available in Appendix II of this report.

See Table 2 for echosounder specifications.

Reson SeaBat 7101	
Firmware Version	n/a
Sonar Operating Frequency	240 kHz
Along Track Transmit Beamwidth	1.6° ± 0.3°
Across Track Receive Beamwidth	1.5°
Max Ping Rate	40 pings / s
Pulse Length	21 µsec to 225 µsec
Number of Beams	101, 239, or 511 (239 used)
Max Swath Angle	150°
Depth Range	1 – 500 m
Depth Resolution	1.25 cm

Table 2 – Reson SeaBat 7101 multibeam echosounder technical specifications.

A.1.3. Single Beam Echosounder

One Odom Echotrac CV100 system was used on this survey.

The Odom Echotrac CV100 is a digital imaging single beam echosounder (SBES), which utilizes Odom eChart software to serve as the user interface. The system was coupled to an Airmar SM200 (single-frequency, 200-kHz) transducer.

Power, gain, depth filters and other user-selectable settings were adjusted, as necessary, through eChart to maximize data quality. The system was configured to output bathymetric data via Ethernet network connection to a Windows XP PC running HYPACK software, which logged .RAW and .BIN format files.

Odom CV100s are all-digital units that do not create a paper record. In lieu of paper records, the .BIN files contain the bottom tracking information, which is converted and viewable in CARIS HIPS Single Beam Editor.

Echosounder accuracy was checked by bar check methods (on JD247), with processed echosounder results comparing on average to 0.02 m (or better) of the expected bar depth. A comparison lead line was also taken (on JD247), with processed depth comparing within 0.025 m (or better) of the lead line depth.

Additionally, the Odom CV100 single beam data was examined where it overlapped with the Reson 7101 multibeam data. The two data sets demonstrate good agreement, generally comparing to 0.05 m (or better).

Echosounder accuracy test results are available in Appendix II of this report.

See Table 3 for echosounder specifications.

Odom Echotrac CV100	
Firmware Version	4.09
Sonar Operating Frequency	100 – 750 kHz (200 kHz used)
Output Power	300 W RMS Max
Ping Rate	Up to 20 Hz
Resolution	0.01 m
Depth Range	0.3 – 600 m, depending on frequency and transducer

Table 3 – Odom Echotrac CV100 single beam echosounder technical specifications.

A.2. Vessels

All hydrographic data for this survey was acquired using the survey vessel *Qualifier 105* (*Q105*), and its skiff (*Q15*). The *Q15* skiff acquired only SBES data in the shallowest portions of the survey, while the *Q105* acquired all other data sets.

A.2.1. Qualifier 105

The *Q105,* owned and operated by Support Vessels of Alaska (SVA), was chartered as the primary survey platform for this survey. The *Q105* was operated on a 24/7 schedule for data acquisition, data processing, personnel housing, and equipment deployments.

The *Q105* is a 32 m aluminum hull vessel with a 9.1 m beam and a 1.8 m draft. The vessel is powered by three Detroit D-60 engines. AC electrical power was provided by a 103 KW generator.

Figure 2 – Q105 performing survey operations in the project area.

For this survey, the *Q105* was outfit with an Applanix POSMV 320 V5 to provide attitude and positioning, with IMU mounted at the vessel center of gravity (COG), and antennas on top of the vessel crow's nest. A Reson Seabat 7101 MBES transducer was pole-mounted on the port side, just aft of the main cabin. An EdgeTech 4200 SSS fish was towed from the vessel A-frame at the center of the vessel's stern. An Oceanscience Underway SV system was installed on the port stern to collect sound speed profiles. A Trimble 5700 GPS system was also installed for independent positioning checks. Calibrations and quality control checks were performed on all installed systems as described in Section B of this report. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.

The survey equipment on the *Q105* performed within normal parameters with no major issues encountered, except a mounting issue affecting roll calibrations, which is described in Section C of this report.

R/V *Q105* Survey Equipment

Description	Manufacturer	Model / Part	Serial Number(s)
Multibeam Echosounder	Reson	7101 7-P-1 Sonar Processor Unit	350706 18290413019
Surface Sound Velocity	AML Oceanographic (formerly Applied Microsystems)	MICRO-X with SV-XChange Sensor	203266 10239
Side Scan Sonar	EdgeTech	4200-FS (fish) 701-DL (processor)	37874 37705
Positioning System	POSMV	320 V5	5849
Motion and Heading	POSMV	IMU-200	783
Check GPS	Trimble	5700	0220320002
Underway SVP	Ocean Science	UnderwaySV400	n/a
Underway SVP-Probe	Valeport	Rapid SVT 200Bar	38871
Check SVP	AML Oceanographic (formerly Applied Microsystems)	SV Plus v2	3259 3279
Check SVP	Odom	Digibar	98478
RTK Signal Receiver	Pacific Crest	ADLP-2	12477612

Table 4 – Major survey equipment used aboard the R/V Q105.

A.2.2. *Q15* Skiff

The *Q15* skiff, also owned by SVA, was utilized for all SBES data acquisition. It is an open skiff with a length of approximately 4.5 m, a beam of 2 m, and a draft of 0.30 m. It is propelled by a single engine.

Figure 3 – Q15 Skiff

The *Q15* skiff was equipped with an Odom Echotrac CV100 SBES and a Trimble 5700 GPS receiver. Data logged with the Trimble 5700 was post-processed using simultaneous data logged at the nearby TerraSond Red Dog base station (REDD) to provide final positioning and heave corrections. Both the SBES transducer and the Trimble 5700 GPS antenna were pole-mounted near the stern of the vessel, as shown in Figure 3.

Skiff *Q15* Survey Equipment

Description	Manufacturer	Model / Part	Serial Number
GPS Positioning	Trimble	5700	220320056
Single Beam Echosounder	Odom	CV100	003505
Single Beam Transducer	Airmar	SM200/200	TR3501

Table 5 – Survey equipment used aboard the Skiff Q15.

A.3. Speed of Sound

Speed of sound data was collected while surveying on the *Q105* using an Ocean Science Underway SV system, which was equipped with a Valeport RapidSVT sensor. Odom Digibar Pro and AML SV+ sensors were used for comparison purposes. The Reson 7101 multibeam head was outfit with an AML Micro-X SV-XChange sensor to continually monitor surface sound speed. All sensors were factory calibrated prior to the start of survey operations.

Sound speed profiles were taken as deep as possible in order to capture sound speed through the entire water column. Due to the flat bathymetry in the project area and predictable speed of the vessel, most casts extended to near the seafloor.

Comparison casts were accomplished using the AML SV+ or Digibar sensors by lowering the probes manually to the seafloor.

Sound speed casts were on an interval of 2 hours during MBES operations aboard the *Q105*. The *Q15* skiff did not deploy a sound speed profiler, instead utilizing the nearest *Q105* cast (within 2 hours), which was possible since both vessels worked close to each other during skiff operations. Exceptions when they occurred are noted in the applicable Descriptive Report (DR).

In general, sound speed profiles were consistent with highly stratified and changing conditions, showing large variances (up to nearly 12 m/s) through the water column and between casts.

Confidence checks were accomplished by comparing the results obtained by the Underway SV Valeport probe to independent SVP probes on a weekly basis during survey operations (occurring on JD201, JD204, JD208, JD212, JD217, JD221, JD229, and JD236). Results (available in the DR's Separate II) were typically very good, especially when it was possible to collect the profiles simultaneously.

Refer to the CARIS HIPS .SVP file submitted with the deliverables for positions, collection times, and data. Copies of the manufacturer's calibration reports are included in the Appendix IV of this report. The instruments in Tables 6-10 were used to collect data for sound speed.

A.3.1. Sound Speed Sensors

Sound Speed Device	Manufacturer	Serial Numbers	Calibration Date
MICRO-X with SV-XChange Sensor	AML Oceanographic Sydney, British Columbia, Canada	203266 10239	4/21/2013 by AML Oceanographic
Underway SV	Valeport Limited Totnes, Devon, U.K.	38871	5/3/2013 by Valeport Limited
SV Plus (+) v2	AML Oceanographic Sydney, British Columbia, Canada	3279	5/3/2013 by AML Oceanographic
Digibar Pro	Odom Hydrographic Systems, Inc. Baton Rouge, Louisiana	98478 002992	3/28/2013 by Odom Hydrographic

Table 6 – Sound speed probes and calibration dates.

A.3.2. Sound Speed Sensor Technical Specifications

AML Oceanographic Micro-X (SV-XChange)	
SV Range	1375 – 1625 m/s
SV Precision	+/- 0.006 m/s
SV Accuracy	+/- 0.025 m/s
SV Resolution	0.001 m/s

Table 7 – AML Oceanographic SV-XChange specifications.

Valeport Rapid SVT (200Bar)	
SV Range	1375 – 1900m/s
SV Accuracy	±0.02m/s
SV Resolution	0.001m/s
Pressure Range	10, 50, 100, 200
Pressure Accuracy	±0.05% range
Pressure Resolution	0.001% range

Table 8 – Valeport Rapid SVT specifications.

Applied Microsystems SV Plus v2	
SV Precision	0.03 m/s
SV Accuracy	0.05 m/s
SV Resolution	0.015 m/s
Pressure Precision	0.03 % of full scale
Pressure Accuracy	0.05 % of full scale
Pressure Resolution	0.005 % of full scale

Table 9 – AML SV Plus v2 specifications.

Odom DigibarPro	
SV Accuracy	0.3 m/s
SV Resolution	0.1 m/s
Depth Sensor Accuracy	0.31 m

Table 10 – Odom Digibar Pro specifications.

A.4. Positioning and Attitude Systems

The *Q105* was configured with an Applanix POSMV 320 V5 system as the primary source of vessel positioning, motion, and heading. The POSMV system consists of two dual-frequency GNSS antennas and an inertial measurement unit (IMU) coupled to a topside processor.

For real-time GPS position corrections, the POSMV was interfaced with a Pacific Crest ADL radio, which received Real-Time Kinematic (RTK) corrections transmitted from the project base station established by the survey crew at the Red Dog dock. The POSMV was also configured to automatically utilize its internal WAAS (wide-area augmentation system) receiver when RTK corrections were unavailable.

Additionally, the POSMV was configured to record all raw data to .POS files over Ethernet, which were logged continuously during survey operations. As a backup, the unit also logged all raw data to .000 files directly to USB drives. These raw files enabled post-processing of the GPS and inertial data in Applanix POSPac MMS software in conjunction with simultaneous raw base station GPS to produce higher quality post-processed kinematic (PPK) position, motion, and heading. POS files also enabled application of delayed heave (TrueHeave) to all sounding data.

The POSMV also provided time synchronization for the acquisition systems. The unit output 1-PPS (pulse per second) and a ZDA data string to sync the Reson 7k Control Center software and QPS QINSy to UTC time, at a rate of 1 Hz.

Additionally, the POSMV was configured to output a GGA string to provide positions to EdgeTech Discover (for side scan positioning), TerraLOG software (general note keeping), and the Underway SV acquisition software (for sound speed profile time-tagging and positioning).

For positioning confidence checks on the *Q105*, a Trimble 5700 (T5700) with a Trimble Zephyr antenna was used. During survey operations, the T5700 was set to continuously log dual-frequency GPS data to a compact flash card at 10 Hz. The T5700 and POSMV positions were simultaneously displayed in the acquisition software; QPS QINSy, to continuously ensure the independent systems were producing similar results. Daily screengrabs of the comparison were taken, and are available in each DR Separate I.

The *Q15* skiff also utilized a T5700 for positioning. The skiff's T5700 was also configured to continuously log dual-frequency GPS data to compact flash card at 10 Hz, which was later post-processed to provide the skiff's final positioning and heave data.

It is important to note that final positions for both vessels were derived through post-processed kinematic (PPK) processing methods, which replaced positions generated in real-time entirely. Positioning confidence checks are available in Separate I of the DRs.

A.4.1. Position and Attitude System Technical Specifications

<table>
<tr><th colspan="3">POSMV 320 V5</th></tr>
<tr><td rowspan="2">DGPS Positioning</td><td>Positioning Accuracy</td><td>0.5 – 2 m</td></tr>
<tr><td>Roll, Pitch Accuracy</td><td>0.02 degrees</td></tr>
<tr><td rowspan="2">Kinematic Surveying</td><td>Positioning Accuracy</td><td>Horizontal: +/- (8 mm + 1 ppm x baseline length)
Vertical: +/- (15 mm + 1 ppm x baseline length)</td></tr>
<tr><td>Roll, Pitch Accuracy</td><td>0.01 degrees (1 sigma)</td></tr>
<tr><td colspan="2">Heave Accuracy</td><td>Realtime Heave: 5 cm or 5%
TrueHeave: 2 cm or 2%
(whichever is greater) for periods of 20 s or less</td></tr>
<tr><td colspan="2">Heading Accuracy</td><td>0.02 degrees (1 sigma, 2 m baseline)</td></tr>
<tr><td colspan="2">Velocity Accuracy</td><td>0.03 m/s horizontal</td></tr>
</table>

Table 11 – Applanix POSMV 320 V5 technical specifications.

Trimble 5700		
Code Differential GPS Positioning	Horizontal Positioning Accuracy	± 0.25 m + 1 ppm RMS
	Vertical Positioning Accuracy	± 0.50 m + 1 ppm RMS
Kinematic Surveying	Horizontal Positioning Accuracy	± 10 mm + 1 ppm RMS
	Vertical Positioning Accuracy	± 20 mm + 1 ppm RMS

Table 12 – Trimble 5700 technical specifications.

A.5. Dynamic Draft Corrections

Dynamic draft corrections were determined using PPK GPS methods for all vessels by way of squat settlement calibrations. Corrections were determined for a range that covered normal survey speeds and engine RPMs. Raw data logged for each vessel's primary positioning system (POSMV for *Q105* and T5700 for the *Q15* skiff), along with data from the project base station, were utilized in this process. See Section C for more information and results.

A.6. GPS Base Stations

One GPS base station was installed to support survey operations. The station was installed on the conveyor structure at the Red Dog port facility, coincident with the NOAA NWLON tide station. This position was centrally located in the survey area and allowed for a maximum baseline of 30 kilometers, though typically much less.

The base station consisted of a Trimble NetRS GPS receiver with Zephyr Geodetic antenna interfaced with Pacific Crest ADL radio. Two 12V gel cell batteries interfaced to an AC float charger provided power for the base, a configuration that allowed base station operation to continue in the event of AC power failures.

The GPS antenna was firmly mounted above the conveyor structure's roofline, with little or no masking. The receiver was configured to log dual-frequency GPS data to internal flash memory at a rate of 1 Hz and additionally set to broadcast "CMR+" (Trimble format) corrections over the ADL radio. A satellite internet system was also installed, which enabled access to the station over the internet for QC and data retrieval.

Station ID	GPS Receiver	Antenna	Rate	RTK Broadcast	Additional Equipment
REDD	Trimble NetRS SN# 444924148 Firmware V1.3.2	Trimble Zephyr Geodetic (TRM41249) SN# 12469585	1 Hz	CMR+	Pacific Crest ADL radio Starband Nova 1500 Satellite Internet Dish and Modem

Table 13 – RTK base station equipment, power and download configurations.

The *Q105* received the RTK CMR+ signal via a Pacific Crest ADL radio, which provided the correction message to the vessel POSMV, allowing it to compute an RTK solution. Signal reception was highly variable throughout the project area, and signal loss was common.

When signal loss occurred, the POSMV automatically defaulted to WAAS corrections. The Pacific Crest ADL radios used on the project were new radios, purchased to comply with FCC broadcast regulations that went into effect in 2013. However, on this project, the radios provided disappointing range and consistency as compared to the older PDL radios commonly used on previous NOAA projects. However, all real-time positions (RTK or WAAS) were replaced with PPK positioning following post-processing.

The base station data was downloaded via internet onboard the *Q105* at least twice per day, in order to post-process the previous shift's POS data. Daily checks of proper operation of the NETRS (including satellite tracking, power levels, and logging status) were also made. A webcam at the base station site was also examined to check for any site issues. Confidence checks on the stability of the base station mount and repeatability of the position solution were accomplished at least weekly by upload of 24-hour data series to NGS OPUS (Online Positioning User Service), which always returned results comparing to 0.013 m (or better) of the original position. See Section B of this report for more information regarding base station position confidence checks.

A.6.1. Base Station Equipment Technical Specifications

Trimble Net RS	
Accuracy (Static)	Horizontal 5 mm + 1 ppm RMS Vertical 10 mm + 1 ppm RMS
Output Standard Used	CMR+
Update Rate (both RTK and logging)	1 Hz

Table 14 – Trimble Net RS specifications.

A.7. Tide Gauges

A.7.1. NWLON Gauges

The NWLON tide gauge, Red Dog Dock (949-1094), was utilized for this project.

A.7.2. Subordinate Stations

No subordinate tide stations were required or installed for this project.

A.7.3. Bottom Mounted Pressure Gauges

Bottom mounted pressure gauges (BMPGs) were deployed offshore in the survey area for tide zoning purposes. For this survey, Sea-Bird SBE 26plus Wave and Tide Recorder submersible tide gauges ("Seabirds") were utilized.

Four separate deployments were accomplished over the course of the project, using two separate Seabird units. 14-day data collection intervals were planned for each deployment site, with actual collection periods ranging from 12-15 days. The deployment locations were strategically chosen prior to survey operations commencing to bracket the survey area and provide time and range corrections at the points most distant from the NWLON tide station for refining the project tide zones.

Each Seabird was synced to UTC and set to log at a 6-minute interval using a 180 second averaging period. The Seabird was mounted in a specially fabricated mooring (with approximately 250 lbs of weight) and gently lowered to the bottom at the deployment location by the *Q105*. Following the 12-16 day deployment period, the Seabird was pulled and the logged data was downloaded. Barometric pressure downloaded from the NOAA Red Dog weather station provided atmospheric pressure corrections.

All Seabird tide gauges were factory calibrated prior to the start of the survey season.

Refer to the HVCR for detailed information regarding the calibration, installation and data processing procedures used for these stations.

A.7.4. Tide Gauge Technical Specifications

Sea-Bird SBE 26plus Wave & Tide Recorder	
Pressure Sensor Accuracy	0.01% of full scale
Pressure Resolution	0.2 mm for 1-minute integration
Repeatability	0.005% of full scale

Table 15 – Sea-Bird SBE 26plus specifications.

A.8. Software Used

A.8.1. Acquisition Software

The *Q105* was outfitted with a quad-core PC running Windows XP or Windows 7 for data acquisition and log keeping. On the *Q15* skiff, a dual-core laptop running Windows XP was used for these purposes. A summary of the principal software installed and used on these systems during data collection follows:

- QPS QINSy hydrographic data acquisition software was used on the *Q105* for navigation, and to log the multibeam and attitude data to DB format files. QINSy was also used to export XTF format files from each DB prior to processing.
- EdgeTech Discover acquisition software was used on the *Q105* to interface with the EdgeTech 4200 side scan sonar, and log all SSS data to JSF format files.

- Reson 7k Control Center served as the interface with the Reson Seabat 7101 multibeam system, allowing the system to be tuned and operated.
- HYPACK hydrographic data acquisition software was used on the *Q15* skiff for navigation, and to log the SBES and positioning data to RAW (and BIN) format files.
- Odom eChart served as the interface with the Odom Echotrac CV100 echosounder on the *Q15* skiff during SBES operations. It also displayed the digital bottom track trace and waveform to assist the operator with ensuring proper bottom tracking.
- Trimble Configuration Toolbox was used, as necessary, to configure common options in the T5700 receivers prior to data acquisition by the vessel.
- Hyperterminal and/or Putty were used to communicate with the AML SV+ sound profilers. This software allowed the technician to change settings on the profiler as well as download the data to a text file to be used by processing.
- Sea-Bird Seasoft was used to configure the Sea-Bird tide gauges prior to deployment, and to download and convert the data after retrieval.
- POSMV POSView was used as the interface with the POSMV. The software was used for initial configuration and GAMS (GPS Azimuth Measurement Subsystem) calibration, and on a daily basis for real-time QC of the POSMV navigation and attitude solutions. The software was also used to continuously log "POS" files during survey operations. The POS file contained the raw accelerometer and GNSS data necessary for PPK. The POS file also contained TrueHeave records, which were loaded into the survey lines in processing.
- TerraLog, an in-house software package, was used to keep digital logsheets for all echosounder, POSMV, and sound speed files.
- Xtreme Cable Counter, an in-house software package, was interfaced with the SSS cable counter and used to continuously log time-tagged cable out to text files, and to provide cable-out values to Discover for direct incorporation into the SSS JSF files.

Program Name	Version	Date	Primary Function
QPS QINSy	8.10	2013	Multibeam acquisition suite and navigation
EdgeTech Discover	8.24	2012	Side scan sonar interface and acquisition
Reson 7k Control Center	SUI4.0.0.7	2013	Multibeam interface
Oceanscience RapidSVLog	n/a	n/a	Underway SV interface
HYPACK	13.0.0.6	2013	Single beam acquisition suite and navigation
Odom eChart	1.4.0	2010	Single beam echosounder interface
Trimble Configuration Toolbox	6.9.0.2	2010	Trimble 5700 interface
HyperTerminal / Putty	0.60	2007	Configuration and download of AML SV Plus v2 and Odom Digibar sound speed sensors
Sea-Bird Seasoft	2.0	2011	Configuration and data download for Sea-Bird SBE26 Plus tide gauges
Applanix POSView	7.41	2013	POSMV configuration, monitoring and logging
TerraLog	1.1.0.6	2013	Log keeping
Xtreme Cable Counter	3.1	2013	Log SSS cable out, output cable out to Discover

Table 16 – Software used for data acquisition.

A.8.2. Processing and Reporting Software

Processing and reporting was done on quad-core PCs running Windows 7 Professional. A summary of the primary software installed and used on these systems to complete planning, processing, and reporting tasks follows:

- CARIS HIPS and SIPS was used extensively as the primary data processing system. CARIS HIPS was used to apply all necessary corrections to soundings including corrections for motion, sound speed and tide. CARIS HIPS was used to clean and review all soundings and to generate the final BASE surfaces.
- CARIS Notebook, configured for NOAA Extended Attributes version 5.3.2, was used to create the S-57 deliverables. Survey extents were imported, edited, and assigned attributes and exported to S-57 (or CARIS HOB) format.
- Chesapeake SonarWiz was used to correct, process, and review all SSS data and select contacts.

- ESRI ArcGIS was used for line planning pre-plots during survey operations to assist with tracking of work completed, generation of progress sketches, and during reporting for chartlet creation and other documentation.
- Applanix POSPac 6.2 was used extensively to produce post-processed kinematic (PPK) data. Both the MMS and POSGNSS modules were utilized. MMS was used to post-process POSMV data from the *Q105*, while POSGNSS was used to post-process T5700 data from the *Q15* skiff.
- TerraLog, an in-house multi-purpose software package, was used to process sound speed profiles and keep track of processing work completed on lines, drafts, depth checks, PPK files, and others.

Program Name	Version	Date	Primary Function
CARIS HIPS and SIPS	7.1.2 8.1.2	2013 2013	Multibeam and Single Beam data processing Side Scan Sonar deliverables
CARIS Notebook	3.1.1	2011	Feature attribution and creation of S-57 deliverables
Chesapeake SonarWiz 5	5 v 5.06.0017	2013	Side scan sonar processing
Geographic Calculator	SP 1	2013	Combine smaller side scan sonar mosaics into sheet-wide images
ESRI ArcGIS	9.3.1 10.1	2009 2012	Desktop mapping software
Applanix POSPac MMS	6.2	2013	Post-processing kinematic data from POSMV
Applanix POSPac POSGNSS	5.3	2013	Post-processing kinematic data from T5700
Microsoft Office	2010	2010	Logsheets, reports, and various processing tasks
TerraLog	1.1.0.6	2013	Keeping notes, reporting, process SVP casts
HeaveXtractor	2013	2013	Extract heave from PPK data for *Q15* skiff
Microsoft Infopath	2013	2013	Populate DR XML schemas
Altova XMLSpy	2014	2013	Edit DR XMLs

Table 17 – Software used during processing and reporting.

A.9. Bottom Samples

The *Q105* collected all bottom samples for this survey.

At planned locations, a Van Veen style grab sampler was lowered and a bottom sample collected. Aboard the vessel, the sample was examined and its S-57 (SBDARE object) attributes noted along with time and position in a spreadsheet logsheet.

The logsheet was later imported by processing into CARIS Notebook software for producing the S-57 deliverable. A table with bottom sample locations is available in each DR, Appendix V: Supplemental Survey Records and Correspondence.

A.10. Shoreline Verification

Shoreline verification requirements were not extensive for this survey, consisting only of the Red Dog conveyor structure. Fixes on the dock position were taken during *Q15* skiff operations, to be later imported and attributed in CARIS Notebook during creation of the S57 FFF (final feature file) deliverables.

B. Quality Control

B.1. Overview

The traceability and integrity of the echosounder data, position, and other supporting data was maintained as it was moved from the collection phase through processing. Consistency in file naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

CARIS HIPS and SIPS 7.1 was used for bathymetric data processing tasks on this project. CARIS HIPS was designed to ensure that all edits, adjustments and computations performed with the data followed a specific order and were saved separately from the raw data to maintain the integrity of the original data.

Chesapeake SonarWiz 5 was used for side scan sonar data processing, including contact selection. SonarWiz is designed to preserve the highest possible resolution from the raw data, and provides a number of tools for performing data corrections, adjustments, bottom imagery visualization, and contact selection. SonarWiz was also used to export processed SSS data to XTF format in order to view the data in CARIS SIPS (8.1).

Quality control checks were performed throughout the survey on all survey equipment and survey results. The following sections outline the quality control efforts used throughout this project in the context of the procedures used, from acquisition through processing and reporting.

B.2. Data Collection

B.2.1. QPS QINSy

QINSy data acquisition software was used to log all multibeam data and to provide general navigation for survey line tracking. The software features a number of quality assurance tools, which were taken advantage of during this survey.

Using the raw echosounder depth data, QINSy generated a real-time digital terrain model (DTM) during data logging that was tide and draft corrected. The DTM was displayed as a layer in the QINSy “Map” view. The vessel position was plotted on top of the DTM along with other common data types including shape files containing survey lines and boundaries, nautical charts, and waypoints, as necessary. Note that the DTM was only used as a field quality assurance tool and was not used during subsequent data processing. Tide and offset corrections applied to the DTM and other real-time displays had no effect on the raw data logged by QINSy and later imported into CARIS HIPS. Final tide and offset corrections were applied in CARIS HIPS.

In addition to the DTM and standard navigation information, QINSy was configured with various tabular and graphical displays that allowed the survey crew to monitor data quality in real-time. Alarms were setup to alert the survey crew immediately to certain quality-critical situations. These included:

- Simultaneous display of independent Trimble T5700 position on the navigation window as real-time position reality checks
- Alarm for loss of ZDA timing sync or positioning data from POSMV
- Alarm for loss of attitude or positioning data from POSMV
- Alarm for loss of sonar input

B.2.2. EdgeTech Discover (SSS)

Discover data acquisition software was used to log all SSS data. Discover presented the SSS data in a scrolling waterfall display so that data quality could be continually monitored, and enable the operator to log the SSS data to EdgeTech JSF format.

JSF format preserves the full data quality of the SSS data time series, with no down-sampling common with other formats such as XTF. Gain and bottom tracking adjustments were applied in Discover, but were for display purposes and did not affect recorded data – final gain and bottom tracking adjustments, as well as layback calculations, were done in Chesapeake SonarWiz.

In addition to the scrolling waterfall display, Discover presented tabular information on system status so the operator could check for proper operation. These included status of the GGA positioning string (from the POSMV system), cable-out, logging status, and more. Altitude of towfish above the seafloor was also displayed, which enabled the operator to ensure the towfish was always flown at 8% to 20% of the range scale in use, per HSSD requirements.

Throughout the survey, the SSS was operated to maximize the detection abilities and meet object detection requirements. Data quality displayed in Discover provided real-time feedback for determination on line spacing adjustments, vessel speed, vessel direction, or occasionally for ceasing operations altogether when weather conditions were too detrimental for data quality.

B.2.3. Cable Out

Cable out was measured by a cable counter system, a Smart Sensor Cable Pay Out Indicator (SCC) manufactured by Hydrographic Consultants, Inc. The system featured a real-time display of cable out, which was determined by measuring revolutions of the sheave wheel as towfish payout cable passed over it.

Cable out value accuracy was initially checked by measuring tape, and then re-confirmed throughout the survey by examining alignment of features on adjacent (opposite heading) lines, which depended on accurate cable out for layback computations.

The SCC also featured a serial output, allowing cable out values to be parsed and displayed in other software packages. On July 25th (JD206) an in-house program, Xtreme Cable Counter (XCC) was deployed to parse the cable out string. XCC time-tagged and logged cable out data to text file, and also formatted the string so it would be readable by EdgeTech Discover.

Cable-out text files written by XCC were used for comparison purposes and as a backup recording of the cable out. These included continuously written files (with the current cable out at a rate of 1 Hz) and "changes-only" files, which logged only when the software detected a cable out change. As XCC was not capable of outputting to EdgeTech Discover until JD206, only lines on JD206 and onwards have cable out written directly to the JSF. Lines prior to JD206 had cable out manually noted on a line-by-line basis.

XCC also featured an on-screen display utilized for quality control purposes. Current cable out value, along with input and output status, was continually updated on screen allowing the operator to ensure proper operation. An alarm function with cable-out or cable-in velocity alerted the operator to any unplanned cable movements detected by the cable counter.

B.2.4. HYPACK

HYPACK data acquisition software was used to log all single beam data and to provide general navigation for survey line tracking on the *Q15* skiff. The software features a number of quality assurance tools, which were utilized during this survey.

Using the raw echosounder depth data, HYPACK generated a real-time digital terrain model (DTM) during data logging. The DTM was displayed as a layer in the HYPACK "Navigation" view. The *Q15* skiff vessel position was plotted on top of the DTM along with other background data which included shape files containing the pre-planned survey lines and survey boundaries, as well as the nautical chart. GeoTIFs created from the *Q105* multibeam data were also displayed to ensure overlap between the two datasets for QC purposes.

Note that the DTM was only used as a field quality assurance tool and was not used during subsequent data processing. Tide and offset corrections applied to the DTM and other real-time displays had no effect on the raw data logged by HYPACK and later imported into CARIS HIPS. Final tide and offset corrections were applied in CARIS HIPS.

In addition to the DTM and standard navigation information, HYPACK was configured with various tabular and graphical displays that allowed the survey crew to monitor data quality in real-time. Alarms were setup to alert the survey crew immediately to certain quality-critical situations. These included an alarm for loss of ZDA time synchronization and sonar input status.

It should be noted that HYPACK automatically breaks and restarts RAW file logging at the Julian day rollover. This process takes 2-3 seconds during which no bathymetric data is recorded. Therefore, lines run over the Julian day change (which occurred at 4 pm local time) may have a small along-track gap. These small gaps are rare, deemed insignificant, and re-ran only when necessary to better delineate a feature.

B.2.5. Draft Measurements

On the *Q105*, vessel static draft was measured on average every two to three days during survey operations, as well as events causing potential significant change in draft such as fueling, and adjusting ballast tanks. With the vessel at rest, a calibrated measure-down pole or tape was used to measure the distance from the waterline to the measure-down point on the vessel gunwale. The measurement was taken on both sides of the vessel. On the *Q15* skiff, draft was measured directly from the skiff reference point on the aft port-side transom to the waterline at least once per skiff survey shift.

Draft values were checked to ensure they fell within the normal range for the survey vessel, and time-tagged and logged in the TerraLog software comments for later inclusion in the CARIS HIPS Vessel File (HVF) by processing (included with the survey deliverables).

B.2.6. Sound Speed Measurements

Sound speed profiles or “casts” were collected normally at two-hour intervals on the *Q105*. Analysis of the sound speed variance in the survey area and frequent SVP-artifact evident in the multibeam data showed that the frequent profiles were necessary as there was often dramatic difference between profiles in this stratified environment.

Casts were not collected for the *Q15* skiff. Instead, during SVP correction of skiff data, the nearest *Q105* cast in distance and time (within two hours) was used. This was possible because both vessels worked nearby whenever the skiff was collecting data.

Casts were taken from the *Q105* using an Oceanscience UnderwaySV system, which utilized a Valeport SV sensor. When deployed, the sensor freefalls through the water column and the fall is arrested when a manual break is applied by the operator at the UnderwaySV winch, before the sensor hits the bottom. The sensor is then reeled into the vessel, and the stored profile data downloaded wirelessly by UnderwaySV software.

Prior to survey operations commencing, the system was sea-trialed to determine the rate of descent at various survey speeds. It was determined that at 8 knots, the typical survey speed for the *Q105*, the sensor dropped through the water column at 3 m/s. Therefore, during casts, the operator would allow the probe to freefall for a specified time interval based on the depth (for example, 10 seconds if a 30 m cast was required).

Downloaded sound speed profiles were automatically assigned position and UTC timestamps by the UnderwaySV software, which was interfaced with a GGA position/time string from the POSMV. These fields were then carried through to the CARIS SVP files during processing in TerraSond’s TerraLog software. Automatic time and position stamps helped to greatly reduce the possibility of assigning incorrect time or positions to profiles. Note that TerraLog did not natively support the UnderwaySV format; therefore, an in-house software program (UnderwaySV Converter) was utilized to convert the UnderwaySV files to a TerraLog supported format ("MVP"), which maintained position and timestamps.

During weekly SVP comparisons, Odom Digibar and AML SV+ sensors were deployed by hand. During these deployments, the sound speed sensor was held at the surface for approximately one minute to achieve temperature equilibrium before being lowered slowly to the bottom (typically no more than 1 meter/second) and raised by hand in the same fashion. When back aboard, the sensor was downloaded and the profile examined to ensure a good profile was acquired. If a profile was not acquired, or contained obvious problems, another profile was collected.

The sound speed file was entered into TerraLog, which automatically co-referenced the filename with a geo-tag and a timestamp.

B.2.7. Logsheets

TerraLog, an in-house software package, was utilized during survey operations for log keeping during both acquisition and processing phases.

TerraLog was designed to replace Excel-based logsheets for common log keeping tasks. Its primary purpose is to simplify both acquisition and processing logsheet entries, provide a more seamless and consistent flow of user-entered log data from acquisition to processing, and output standardized logsheets in PDF format. Since TerraLog automatically time- and geo- tags (with GGA input) events, it largely eliminates errors associated with manually entered time and position. On this survey, TerraLog was configured to receive a GGA data string from the POSMV, enabling the software to geo-tag all events.

On-board the vessel, events pertinent to surveying, including start/stop of lines, start/stop of POS files, surveyors' initials, weather conditions, draft and sound speed casts, were entered into TerraLog, which recorded events to a SQL database file. It should be noted that although TerraLog time-tagged events like start of line and end of line, it had no automatic synchronization capabilities with the acquisition software, therefore, it relied on operator entry which means a small time difference (usually on the order of seconds) is common between the TerraLog entry and the actual data file start and end. However, for the purpose of log keeping, the time difference was deemed to be of no importance. Additionally, the acquisition software (both Discover and QINSy) would automatically split files when they became too large – occasionally resulting in two files for the same line – though only one line entry appears in TerraLog.

The following common events, with their time and position when applicable, were recorded by the survey crew:

- Generic line information including line name
- Generic POS file information including approximate start and stop times
- RTK base station in use and status

- Static draft measurements
- Sound speed cast events
- Sea and wind state, especially when adversely affecting operations
- Comments on any unusual observations or problems
- Start and end of line cable out for side scan operations

Onboard the *Q105*, the SQL database was simultaneously accessible by acquisition and processing personnel. Following acquisition of a line, data processing personnel would examine acquisition's comments and take the raw data through the processing workflow, tracking edits and corrections in TerraLog in context of the readily accessible acquisition-recorded information. Task completion and details of common processing tasks tracked in TerraLog included:

- Common CARIS HIPS processes including conversion, SVP correction, tide correction, SBET and TrueHeave application, TPU computation, merge, cleaning, and general processing comments
- POS file processing including base station selection and processing methods
- SVP file processing

Figure 4 is an example of the TerraLog line processing interface.

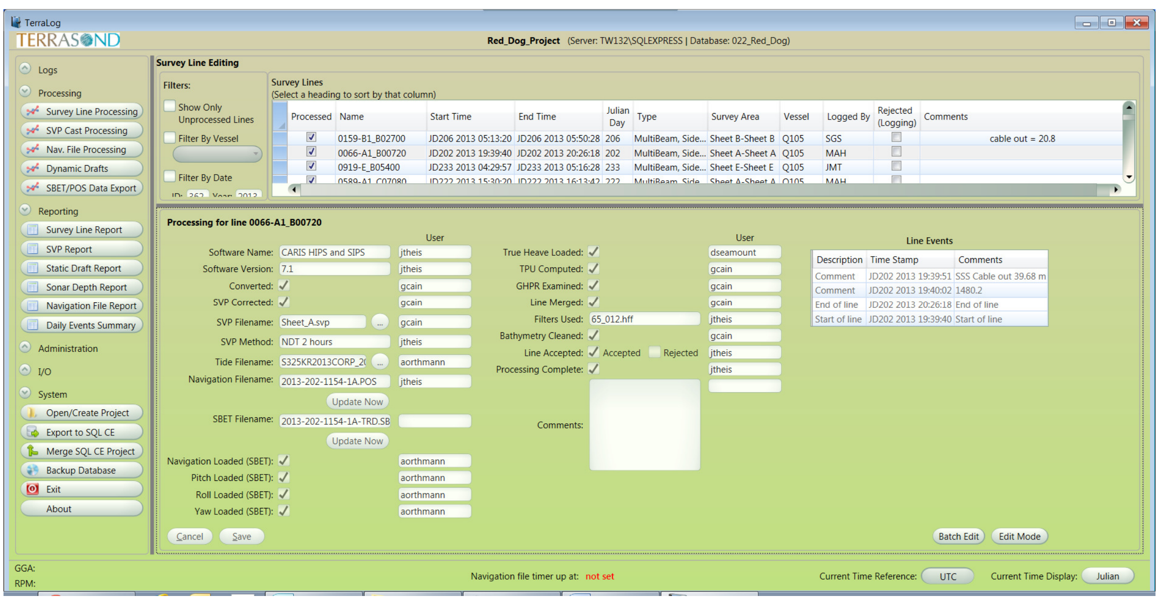


Figure 4 – TerraLog interface for line processing.

It should be noted that TerraLog was only used on the *Q105*, it was not available on the *Q15* skiff. Notes taken on the *Q15* were entered into HYPACK comments and later extracted and entered into TerraLog during processing.

Following processing, logsheets were exported from TerraLog to PDF. Logsheets include logs for lines, draft measurements, sound speed profiles, depth checks, navigation file processing, and daily events. The PDFs are available in the DRs, *Separate I: Acquisition & Processing Logs*.

B.2.8. Base Station Deployment

Due to the lack of DGPS coverage in the area, and to enable PPK processing, one base station was installed for the project. The specific equipment utilized was described in Section A of this report.

In order to maximize base station data quality, care was taken to choose an optimum base station location that would cover the survey area. The station was established on the Red Dog dock, with GPS antenna mounted at the top of the conveyor superstructure and electronics housed in the NOAA NWLON tide station house, based on the following criteria:

- Little or no GPS satellite masking
- Dock structure was higher than the surrounding terrain, eliminating any potential line of site issues for RTK radio broadcast
- Proximity to the survey area – largest baseline was 30 kilometers, though most of the area was much less
- Location at the dock allowed for relatively easy access from the survey vessel for inspection and troubleshooting purposes
- 120V AC power available, minimizing complication of add-on power systems
- Clear line of site for satellite internet access antenna

During deployment, the GPS antenna was leveled and secured to the top of the conveyor belt structure with sufficient clearance from the building and roof to enable a clear view of the sky and prevent satellite masking. Battery voltage, logging status and other important parameters were logged.

During the survey, proper operation was checked remotely via the station's satellite internet link at least twice daily. Real-time checks included battery voltage, logging status, and confirmation of satellite tracking. Data was also downloaded at least twice daily, converted to Rinex format, and used to process the prior day's vessel GPS data – a process which also served as a check on data integrity, as any issues with base station data quality or coverage would manifest itself as positioning problems during processing.

As a confidence check on antenna stability, an OPUS solution was derived at least once weekly from a 24-hour data set and compared to the initial 24-hour OPUS solution. Results were excellent with all subsequent measurements comparing to within 0.013 m (or better) of the initial position.

It is important to note that some survey data was collected when the Red Dog dock base station (REDD) was not in operation. For these days (JD200 and JD237), vessel positioning data was post-processed using the FAA CORS site (site ID OTZ1) in Kotzebue. This was necessary because the *Q105* arrived on-site and began to collect survey lines before the dock could be accessed to install the base station at the start of the project, and again at the end of the project when it was necessary to acquire additional lines after demobilizing the base station. Despite the approximately 100 KM baseline to OTZ1, positioning error on the affected data was well within horizontal specifications at 1 m (or better). Vessel position confidence checks, which compared the position of vessel data when post-processed separately using the two base stations (OTZ1 and REDD), also consistently returned results that compared horizontally to 2 m (or better).

The base station confidence checks are available with the project HVCR. Vessel position confidence checks are available in Separate I of the DRs.

B.2.9. File Naming and Initial File Handling

A file naming convention was established prior to survey commencement for all raw files created in acquisition. Files were named in a consistent manner with attributes that identified the originating vessel, survey sheet, and Julian day.

The file naming convention assisted with data management and quality control in processing. Data was more easily filed in its correct location in the directory structure and more readily located later when needed. The file naming system was also designed to reduce the chance of duplicate file names in the project.

Table 18 lists raw data files commonly created in acquisition and transferred to data processing.

Type	Description		Example / Format
Raw MBES DB and XTF	Mainscheme MBES Line		**0001-A1_B00900.db**
			0001-A1_B00900.XTF
			Index-Sheet/Vessel_Lineset/LineNumber
	Test / Check / Lead Line / Bar Check		**0001-Y1_B00900.db**
			0001-Y1_B00900.XTF
			Index-Sheet/Vessel_Lineset/LineNumber
Raw JSF	Side Scan Files from Discover		**0001-A1_B00900.JSF**
			Index-Sheet/Vessel_Lineset/LineNumber
SSS processed XTFs	Processed Side Scan Files exported from SonarWiz		**0001-A1_B00900.XTF**
			Index-Sheet/Vessel_Lineset/LineNumber
RAW and BIN	HYPACK Files: Bathy Data		Year/Vessel/Day/Time
	Line Type	**Prefix**	**Example**
	All	n/a	**2013SK2220008.RAW**
SVP	Text File from Digibar or AML		**1A-2013-190-1400.DIGI**
			1A-2013-190-1400.AML
			VesselSheet-Year-JD-Time.instrument
HEX	Raw File from Seabird Tide Gauge		*Location-SerialNumber-Year-StartDay-EndDay*
			A3-SN1221-2013-145-1522.HEX
T01	Trimble 5700 Binary File (navigation)		
	Vessel	**Receiver SN**	**00562200.T01**
	Q15 Skiff	0056	*ReceiverSN/JD/FileSequenceNumber*
T00	Trimble NetRS Binary File (base)		
	Station	**ID**	**RedDog201307201600a.T00**
	Red Dog Dock	REDD	*Station /Date/FileStartTime*
POS	Raw Positioning Data (.000 file) from POSMV		**2013-177-1713-1A.POS**
			Year-JD-StartTime-VesselSheet

Table 18 – Common raw data files.

Files that were logged over Julian day rollovers were named (and filed) for the day in which logging began. This was adhered to even if the majority of the file was logged in the “new” day. This was a common occurrence since Julian day midnight occurred at 16:00 local time during prime daylight hours.

During data collection, the raw data files were logged to a local hard drive in a logical directory structure on the acquisition PCs. At the end of each line (or after a full shift for *Q15* skiff operations) the data was copied to network share on the vessel server that was available to the processors. Data processors then moved the data files to their permanent storage location on the server, where the data was backed-up and processing began. At the end of the project, when the *Q105* was de-mobed, the field server containing all data was physically transferred to the TerraSond office in Palmer where processing and reporting continued.

B.3. Bathymetric (MBES & SBES) Data Processing

Initial data processing was carried out in the field on the *Q105*. Final data processing and reporting was completed at TerraSond's Palmer, Alaska office.

Following transfer from the acquisition, raw bathymetric data was converted, cleaned and preliminary tide and GPS corrections were applied in accordance with standard TerraSond processing procedures, customized as necessary for this survey. This was normally accomplished in real-time, directly after each line was acquired, providing rapid coverage and quality determination.

Following the completion of field operations and prior to deliverable creation, final data processing was completed in the Palmer office. This consisted of a review of all collected data, final cleaning and designating soundings, and application of final correctors.

Checks and data corrections applied by data processors were recorded to database file using the TerraLog interface. Log files were then output to PDF. These are available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.1. Conversion into CARIS HIPS and Waterline Offset

CARIS HIPS was the primary software used for bathymetric processing for this project. The MBES XTF exported from QINSy (*Q105* only) and the SBES RAW files written by HYPACK (*Q15* skiff only) were imported into CARIS HIPS using the conversion wizard module. During conversion, CARIS HIPS created a directory structure organized by project, vessel and Julian day.

During conversion of SBES files, 1500 m/s was entered as the sound speed to match the value set in the Odom CV100s by acquisition, which allowed CARIS HIPS to convert depths in the RAW file to travel time for later sound speed correction. The SBES BIN files, containing the digital trace data, were also carried over to the line directories at this time.

The CARIS HIPS vessel definition file (HVF) for each vessel was updated with a new waterline value prior to sound speed correction. Port and starboard measure-downs recorded in TerraLog were averaged and reduced to the vessel's reference point using the surveyed vessel offsets to determine the static draft. This value was entered as a new waterline value in each vessel's HVF and checked to confirm the values fell within the normal range for the vessel. The static draft PDF report exported from TerraLog is available in each DR, *Separate I: Acquisition and Processing Logs.*

B.3.2. Load TrueHeave (*Q105* only)

On the *Q105*, which was equipped with a POSMV, TrueHeave (also known as "delayed heave") was logged continually during survey operations to POS file. In processing, CARIS HIPS' "Load TrueHeave" utility was utilized to load all multibeam lines with TrueHeave, which imported the records into each survey line. The TrueHeave records, whenever present, were utilized by CARIS HIPS by default for heave correction.

B.3.3. PPK Heave (*Q15* skiff only)

On the *Q15* skiff only, which was outfit with a dual-frequency GPS system instead of a heave sensor, heave correction were accomplished by extracting the heave component from post-processed kinematic (PPK) GPS altitudes.

During survey operations, GPS data was continually logged on the vessel at a rate of 10 Hz to ensure enough altitude data points existed to capture the full heave period from waves or swells. The data was post-processed in POSPac POSGNSS with concurrent base station data from the nearby TerraSond base station at the Red Dog dock to produce PPK navigation files in text format.

HeaveXtractor was used to extract heave data at 10 Hz from the navigation files. HeaveXtractor is an in-house software utility that uses a high-pass filter (20-second moving average) cycled over each altitude, centered on the time of the data point for the averaging period. The filter result was subtracted from the data point, resulting in a residual value which consisted of the heave component of the altitude. Longer term effects of dynamic draft and tide were removed through this process. The result is heave experienced at the vessel's Trimble antenna (which was co-located with the vessel RP and transducer), centered on zero.

HeaveXtractor included a number of quality control tools. These included a check for overlapping navigation files, a check to ensure the output files overlapped the CARIS line files completely, internal data integrity (spikes or noise or non-zero average heave) and data consistency.

The utility wrote text files that contained the original PPK data, plus the moving average value and residual heave. These files were loaded into all *Q15* skiff survey lines using CARIS' HIPS Generic Data Parser (GDP). The lines were subsequently re-SVP'd and re-merged to apply the correctors.

Before and after comparisons of the *Q15* skiff data were accomplished, with excellent results apparent following PPK Heave application. This method was also successfully used on the 2012 Nushagak River surveys with identical equipment.

B.3.4. Sound Speed Corrections

Sound speed profiles (casts) were processed using TerraLog, an in-house software package. During entry of the cast in acquisition, the software assigned the cast a timestamp according to the average time recording in the SVP file, as well as a geographic position. If the raw SVP file contained a position and time-tag (as UnderwaySV files logged on the *Q105* on this project did), TerraLog utilized it instead.

During processing, TerraLog separated the profile into it's up and down components and graphed the data points, allowing obvious erroneous points to be rejected by data processing personnel. Once checked and cleaned, the software exported the combined (average of up and down components) profile to CARIS HIPS .SVP format at a regular 0.10 m interval. The output was checked for incorrect timestamps and positions, and appended to the appropriate master CARIS HIPS .SVP file based on vessel and survey sheet.

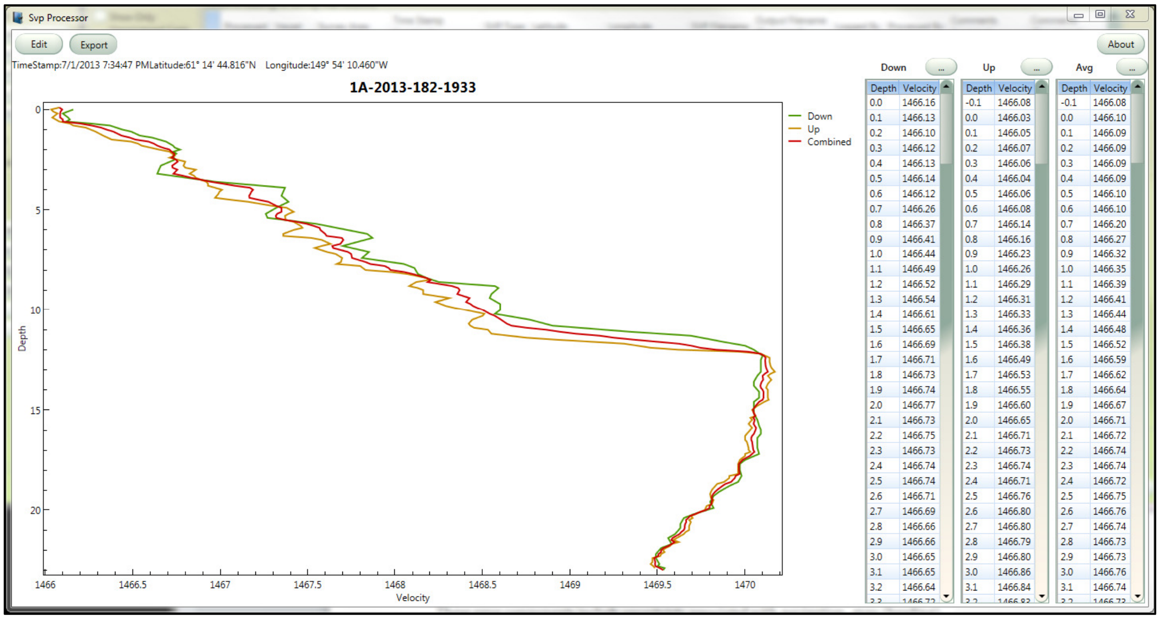


Figure 5 – Example SVP profile editing interface in TerraLog.

As TerraLog did not natively support the raw UnderwaySV files, the UnderwaySV files were reformatted to a file type readable by TerraLog. Initially, files were reformatted manually in Excel to "Digi" type, modeled on the Odom Digibar. However, a utility was written during survey operations (UnderwaySV Converter) which automatically converted the UnderwaySV files to "MVP" type, modeled on the MVP-200 system. MVP type had the advantage of including the Geographic position originally written to the raw file by the UnderwaySV software.

Each line was corrected for sound speed using CARIS HIPS "Sound Velocity Correction" utility. "Nearest in distance within time" was selected for the profile selection method. For the time constraint, two hours was used. The value was chosen to match the cast interval done in acquisition. Deviations to the two-hour interval, when they occurred, are described in the corresponding DR. Each line logsheet is also marked with the correction method, typically coded as "NDT 2" (for nearest-in-distance within two hours).

B.3.5. Total Propagated Uncertainty

After sound speed correction, CARIS HIPS was used to compute total propagated uncertainty (TPU). The CARIS HIPS TPU calculation assigned a horizontal and vertical error estimate to each sounding based on the combined error of all component measurements.

These error components include uncertainty associated with navigation, gyro (heading), heave, tide, latency, sensor offsets and individual sonar model characteristics. Stored in the HVF, these error sources were obtained from manufacturer specifications, determined during the vessel survey (sensor offsets), or while running operational tests (patch test, squat settlement). Table 19 describes the TPU values entered in the HVF. Note all values entered are at 1-sigma, per CARIS guidance, while CARIS reports TPU at 2-sigma.

HVF TPU Entry	*Q105* Error Entry	*Q15* Skiff Error Entry	Source
Sonar Type	Reson Seabat 7101 (239 beams)	Odom Echotrac CV	Entry in HVF for Swath1 (sonar model). Uses the sonar parameters from the CARIS devicemodels.xml file to model sonar error based on manufacturer-provided estimates
Gyro	0.02°	0	*Q105*: http://www.caris.com/tpu/gyro_tbl.cfm (Applanix POSMV 320 -- 2m baseline) *Q15* Skiff: Gyro was n/a for skiff
Heave	5% or 0.05m	5% or 0.1m	*Q105*: http://www.caris.com/tpu/heave_tbl.cfm (Applanix POSMV 320 -- whichever is higher) *Q15* Skiff: Maximum std dev of PPK heights (whichever is higher)
Roll and Pitch	0.010°	5°	*Q105*: http://www.caris.com/tpu/roll_tbl.cfm (Applanix POSMV 320 -- RTK) *Q15* Skiff: Estimated std dev of applied fixed pitch correction
Navigation	0.1 m	0.1 m	PPK processing results reports indicate RMS positioning errors better than 0.10 m on average
Timing – (all systems)	0.01 sec.	0.1 sec	Estimated overall synchronization error. Sensors not applicable for the *Q15* skiff have an entry of '0'
Offset X	0.05 m	0.05 m	*Q105*: Accuracy estimate of the X offset of the transducer acoustic center relative to the vessel RP *Q15* Skiff: The points were co-located on skiff but an error value is entered to allow for estimated position deviations due to pitch and roll
Offset Y	0.02 m	0.05 m	Same as above
Offset Z	0.02 m	0.04 m	Standard deviation of bar check results
Vessel Speed	2 knots	2 knots	Estimated maximum current experienced in survey area
Loading	0.02 m	0.02 m	Estimated change in vessel draft due to loading changes experienced between draft measurements
Draft	0.02 m	0.02 m	Estimated accuracy of static draft measurements
Delta Draft	0.02 m	0.02 m	Standard deviation of squat-settlement test results
MRU Align StdDev Gyro, Roll/Pitch	0.1°	0	*Q105*: Estimate of accuracy of patch test results for the applicable sensors *Q15* Skiff: Gyro, pitch, and roll sensors are n/a for the skiff

Table 19 – TPU values used.

Other parameters affecting TPU computation:

- For "MRU to Trans" offsets under "TPU values," the offset from the POSMV IMU (T5700 antenna on *Q15* skiff) to the sonar was entered.
- For "Nav to Trans" offsets, once again, the offset from the POSMV IMU (T5700 antenna on *Q15* skiff) to the sonar was entered.
- SMRMSG (smoothed RMS) error data was loaded into all *Q105* lines using CARIS HIPS "Load Error Data" function. SMRMSG files, produced by Applanix POSPac 6.2 MMS as part of the PPK process, contain error estimates that are of higher accuracy than the fixed estimates in the HVF. SMRMSG files were applied to all *Q105* lines at a rate of 1 Hz for position, vertical, roll, pitch, and gyro. During TPU computation the Uncertainty Source was selected as "Error Data," which had the effect of using the SMRMSG data instead of the HVF settings listed for the mentioned sensors. SMRMSG files were not generated for *Q15* skiff data, which relies on the fixed error estimates from the HVF.
- The tide zone ZDF (zone definition file) for the project contains error estimates for each tide zone and gauge. This ZDF was loaded in CARIS HIPS with the Compute Errors option enabled. During TPU computation these values were utilized by HIPS to estimate tidal error. Error estimates for the zones ranged from 0.012 m to 0.032 m. The error estimate for water level measurements at the gauge was 0.012 m. The ZDF and gauge files are included with the CARIS survey deliverables. Note that values for tide error were left at zero during the "Compute TPU" process, as CARIS HIPS ignores these values and uses the tide error loaded into each line instead.
- For estimated sound speed error, a value which varied by survey sheet was entered. These values, which ranged from 1.565 to 2.426 m/s, were derived from an analysis of the variance between subsequent sound speed casts.
- For surface sound speed error, 0.025 was entered for multibeam data (*Q105* only) as the manufacturer specified accuracy of the surface sound speed probe. A value of '0' was entered for SBES data since no surface probe was used on the *Q15* skiff.

B.3.6. Post-Processed Kinematic GPS

All final positions for this project were post-processed.

The project was not located within USCG DGPS coverage. A real-time kinematic (RTK) GPS base station (described in Section A.6 in this report) was established to transmit corrections to the survey vessel, enabling accurate 3D positioning in real-time via radio broadcast. However, the RTK radio reception was still susceptible to frequent interruption and interference. Therefore, post-processed kinematic (PPK) GPS methods were utilized for final positions.

PPK processing for this project utilized Applanix POSPac software (both MMS and POSGNSS modules). POSPac MMS made use of the dual-frequency 1 Hz GPS data logged at the project base station (Rinex format, converted from .T00), the known position of the base station established by NGS OPUS, and the raw positioning data logged on-board the vessels to produce post-processed positioning files. These PPK files (SBET format for *Q105*, text format for the *Q15* skiff) were loaded into all lines in processing, which replaced navigation logged in real-time. For *Q105* data, the process also produced the SMRMSG file, which contained root mean square (RMS) error estimates for the post-processed solution, which was loaded and applied as described previously in this report.

To process *Q105* POS files to produce an SBET, a POSPac MMS project was first established using the POS file requiring processing as the source name. Base station data was converted from the native Trimble T00 format to Rinex using the POSPac “Convert to Rinex” utility and imported into the project, followed by the POS file.

Following successful importation of the base and POS data, the base station position was set to the known ITRF position established by OPUS using an initial 24-hour data set. For this survey, a base station antenna height of 0 meters was used because the ARP of the antenna was the survey reference point for the base station.

Next, the GNSS-Inertial Processor was run. “IN-Fusion Single Baseline” was selected as the GNSS processing mode using the project base station REDD. This performed the actual PPK processing step.

To ensure quality positioning, the QC plots produced by POSPac were reviewed for spikes, or abnormalities, following successful completion of processing. SBET altitude and smoothed performance metrics for north, east, and down position error RMS were reviewed.

Finally, SBETs were exported from POSPac. The option to produce “Custom Smoothed BET” was used to produce an SBET in the NAD83(2011) reference frame. This made it so all final positions were NAD83. The custom SBETs were then applied in CARIS HIPS. The flow chart in Figure 6 is a generalized overview of the POSPac workflow used on this project.

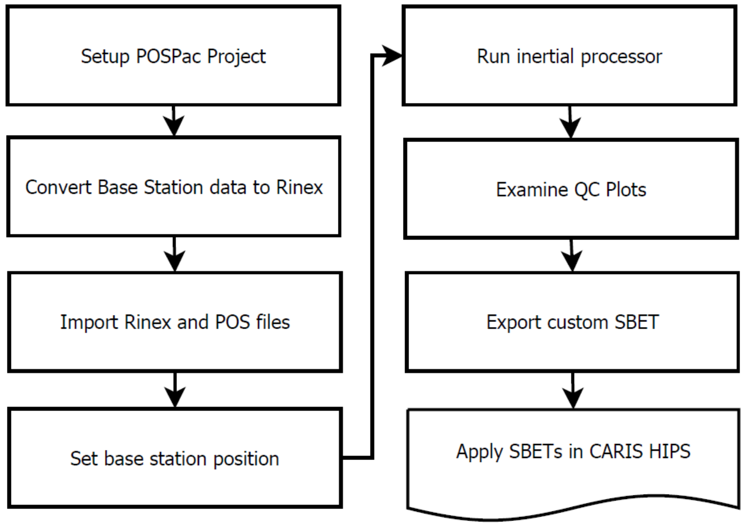


Figure 6 – Flow chart overview of POSPac workflow used on this project.

Q15 skiff T5700 data was post-processed in a nearly identical fashion, except POSPac's POSGNSS module was utilized instead, and a text file was produced in place of an SBET. All PPK navigation files (SBET and text) that were applied to the data are included with the survey deliverables.

B.3.7. Load Attitude / Navigation Data

For *Q105* multibeam data only, SBETs were loaded into all lines using CARIS HIPS "Load Navigation/Attitude Data" utility. During the loading process, the options to import post-processed navigation (at 0.1 second interval), gyro, pitch, roll, and GPS height (at 0.02 second interval) were selected.

For *Q15* skiff SBES data only, the PPK text files were loaded using CARIS HIPS Generic Data Parser utility. This step was done concurrent with the loading of PPK Heave, which was described earlier in this report.

In this process, each line's original (real-time) navigation and GPS Height records were overwritten with the information in the PPK files. For *Q105* multibeam lines, motion and gyro from the SBET were also loaded, replacing the real-time values. The name of the PPK file applied to each survey line was noted by the data processors in the data processing logsheet.

It is important to note that this process replaced all real-time navigation and attitude originally converted from QINSy XTF file or HYPACK RAW file with PPK navigation, project-wide without exception.

B.3.8. Load Tide and Merge

CARIS HIPS "Load Tide" function was used to load all lines with discrete tide zone data. The zone definition file (ZDF) "S325KR2013CORP_20131125.zdf" was selected. This file referenced a file for the Red Dog Dock tide station ("9491094.tid") that contained 6-

minute tide data on MLLW. The option to "Compute Errors" was enabled, which allowed CARIS HIPS to compute estimates for tidal error for each line based on the error parameters defined in the ZDF. The CARIS HIPS "Merge" function was used to apply the tide corrections.

Refer to the project HVCR for more information regarding the derivation of the ZDF.

B.3.9. Navigation and Attitude Sensor Checks

Navigation data was reviewed using CARIS HIPS Navigation Editor. The review consisted of a visual inspection of plotted fixes noting any gaps in the data or unusual jumps in vessel position.

Attitude data was reviewed in CARIS HIPS Attitude Editor. This involved checking for gaps or spikes in the gyro, pitch, roll and heave sensor fields.

Significant gaps or spikes in records, which were extremely rare, were reviewed by the Lead Hydrographer and a determination was made whether interpolation was possible, or if rejection and rerun would be required.

Checks done on the sensors were tracked in TerraLog; processing results are recorded there. Exported logsheets are available in the DR, *Separate 1: Acquisition and Processing Logs*.

B.3.10. Multibeam Swath Filtering

Prior to manual review and cleaning, all multibeam data was filtered using CARIS HIPS "Filter Select Lines" function.

In this process, all beams greater than 65 degrees from nadir (port and starboard) were automatically rejected. Additionally, all soundings with a quality flag of 0, 1, or 2, were also rejected regardless of their angle from nadir. This left only high quality soundings within 65 degrees of nadir, and removed the majority of erroneous soundings, which assisted with manual cleaning. This also removed the data most susceptible to sound speed and motion artifact errors.

In some cases, especially when sound speed refraction error caused the edges of multibeam swathes to curve outside of allowable error specifications, beams were rejected at values less than 65 degrees. 55 and 45 degree filters were occasionally necessary to reject soundings particularly affected by sound speed refraction error.

As a set-line spacing survey with 200% concurrent side scan coverage, complete coverage was not required; therefore, filtering was applied without regard to the effects of along-track gaps between adjacent survey lines.

Filter settings were initially saved to a HIPS filter file (HFF). The HFF was selected for subsequent filtering. The HFFs are included with the CARIS deliverables, and the file used for each survey line was noted in the line logsheet by processing.

B.3.11. Multibeam Editing

Initial field cleaning of multibeam data was done using CARIS HIPS Swath Editor. Soundings were examined for spikes or other abnormalities, and obvious erroneous soundings were rejected. Cleaning status was tracked in the processing section of TerraLog, along with the processors' comments or notes, if any.

Final cleaning was done in CARIS HIPS Subset Mode, following application of final corrections (including tides).

In CARIS HIPS, a 4 m resolution CUBE surface was first generated based on CUBE parameters meeting the requirements in the 2013 Hydrographic Surveys Specifications and Deliverables (HSSD). The CUBE surface, which was loaded as a reference layer, was then examined in subset mode simultaneous with the contributing soundings.

To prevent unnecessary and excess rejection of soundings, requirements in the HSSD were adhered to during the subset editing process. Specifically, only soundings which caused the CUBE surface to error from the obvious seafloor position by an amount greater than the allowable TVU (total vertical uncertainty) at that depth were rejected. As a set-line spacing survey with minimal to no overlap in many areas, this made it necessary to manually reject many sound speed refraction "tails" and outer beam motion artifact. It is important to note that this surface-focused approach leaves many noisy, accepted soundings that can exceed the TVU allowance, however, the final deliverable is the surface (not the soundings), which meets TVU specifications.

Designated soundings, which flagged shoalest soundings on features that were not well modeled by the 4 m CUBE surface, were also picked during this process. As specified in the HSSD, the shoalest sounding on features were designated only when the difference between the CUBE surface and reliable shoaler sounding(s) was more than one-half the maximum allowable TVU at that depth (for depths under 20 m), or greater than the TVU at that depth (for depths over 20 m). Additionally, if a sounding on a feature was within 80 m (2 mm at survey scale) of a shoaler part of the surface (or a shoaler designated sounding), it was not designated. Note that side scan contacts were not always designated – frequently the contacts, though apparent in the multibeam data, did not meet the HSSD criteria for designation.

For editing consistency, the data was reviewed in subset with set visualization parameters. Data was examined looking along-track through the data, which is standard practice for examining bathymetry in subset. The subset view slice length was constrained to approximately 10-12 lines, width was constrained to 60-80 m, and vertical exaggeration in the subset window was manually set so that the vertical scale graticule displayed in increments of 0.20 m. Subset tiles were used to track editing progress, with care taken to ensure all data was examined.

Following editing, the "Depth" and "Shoal" layers of the CUBE surface were examined. These layers readily portrayed extreme fliers, which were subsequently loaded into subset and rejected to ensure they did not affect the final CUBE surface.

B.3.12. Single Beam Editing

Single beam data, which was collected by the *Q15* skiff, was manually cleaned using CARIS HIPS Single Beam Editor. Erroneous soundings exceeding the error tolerances outlined in the HSSD (deviating by more than one-half of the TVU for the depth) were rejected.

The soundings were examined for spikes or other abnormalities. During this process the bottom trace data (stored in the BIN file recorded by HYPACK) was used as background data in Single Beam Editor to ensure the soundings accurately portrayed the bottom. The digital bottom greatly assisted in determination of noise from real bottom.

Note that in the version of CARIS HIPS used on this project, the alignment of soundings to the digital trace frequently shows a vertical shift. This is due to the fact that CARIS HIPS does not correct the trace position for the effects of sound speed and offsets from the HVF, while the soundings have been corrected. However, the trace still served as a useful tool when editing soundings.

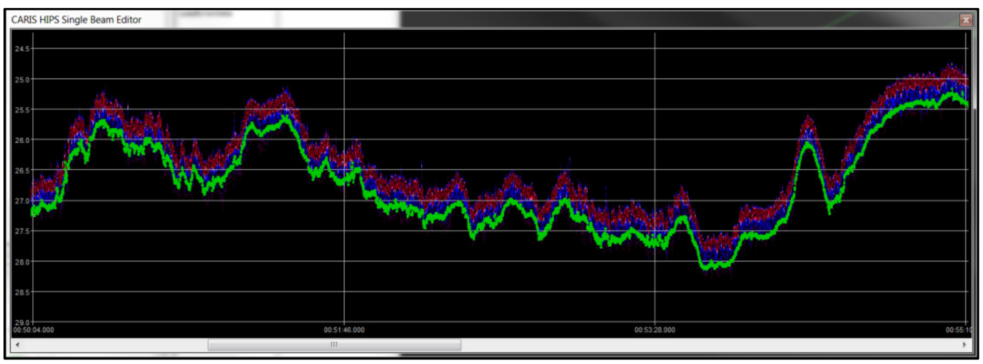


Figure 7 – Example of sounding (green) and digital trace data (magenta and blue) in CARIS HIPS Singlebeam Editor.

As a final check on the SBES data for gross fliers, all SBES data was loaded into CARIS HIPS Subset mode and reviewed with the 2D slice set parallel to each line. Auto-exaggeration was turned on, and any remaining gross fliers were rejected.

Subset mode was also used to systematically examine the data for matchup with crosslines and overlapping multibeam lines.

B.3.13. Dynamic Draft Corrections

Dynamic draft corrections were computed and applied for this survey. Corrections were applied to all soundings by way of a speed-based correction table entered into the HVF for each vessel. The speed-based corrections were determined by squat-settlement test methods. Refer to Section C for results.

B.3.14. Final BASE Surfaces and Feature Files

The final depth information for this survey is submitted as a collection of BASE surfaces (CARIS HIPS 7.1 CSAR format), which best represent the seafloor at the time of survey.

Surfaces were created at 4 m resolution per the HSSD requirements for set-line spacing surveys (with 200% concurrent side scan coverage), as CUBE BASE surfaces. "Density and Locale" was chosen as the disambiguity method and NOAA CUBE parameter .XML based on 4 m resolution selected as the advanced CUBE parameters. These parameters are included with the CARIS HIPS digital data deliverables.

Each surface was finalized prior to submittal. During this process, final uncertainty was determined using the "Greater of the two" (Uncertainty or Std. Dev. at 95% C.I.) option. Designated soundings were applied, which forced the final surfaces to honor these soundings.

A data set containing a single S-57 file (in CARIS HIPS .HOB format) and supporting files was submitted in conjunction with each survey. The S-57 file contains information on objects not represented in the depth grid, including meta-data objects. Each feature object includes the mandatory S-57 attributes (including NOAA version 5.3.2 extended attributes) that may be useful for chart compilation.

B.3.15. Crossline Analysis

The crossline analysis was conducted using CARIS HIPS "QC Report" routine. Each crossline was selected and run through the process, which calculated the difference between each accepted crossline sounding and a 4 m resolution QC BASE surface created from the mainscheme data. Although crosslines are included in the final BASE surfaces, they were not included in the QC BASE surfaces so as to not bias the results.

Differences in depth were grouped by beam number and statistics computed, which included the percentage of soundings with differences from the BASE surface falling within IHO Order 1. When at least 95% of the soundings exceed IHO Order 1, the crossline was considered to "pass," but when less than 95% of the soundings compare within IHO Order 1, the crossline was considered to "fail." For this project, no beams failed.

A discussion concerning the methodology of crossline selection, as well as a summary of results, is available in the DRs. The crossline reports are included in the DRs, *Separate II.*

B.3.16. Bathymetric Processing Flow Diagram

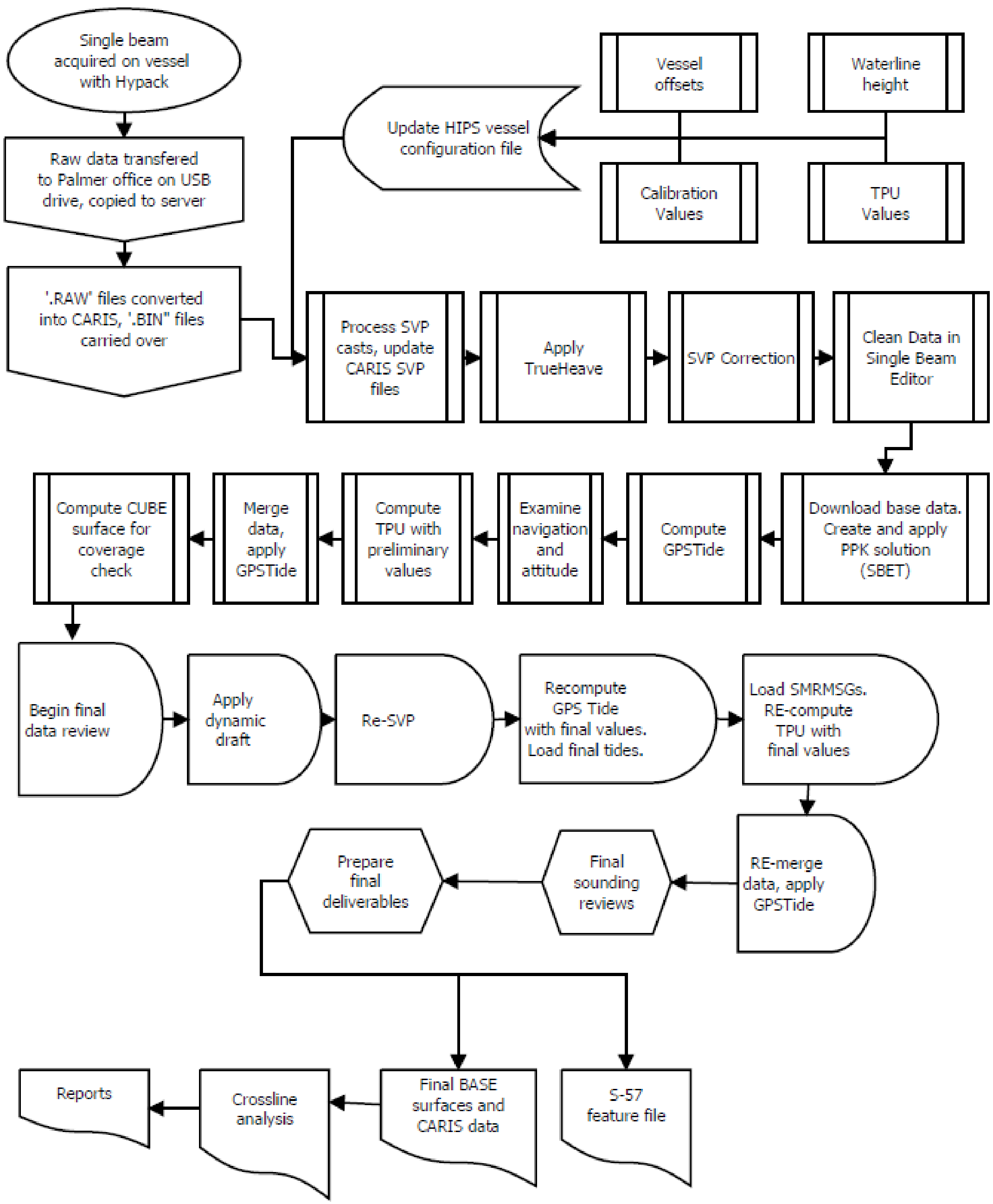


Figure 8 – Flow chart showing general processing workflow.

B.4. Side Scan Data Processing

Side scan data was processed in Chesapeake SonarWiz processing software. SonarWiz is a comprehensive side scan processing package that includes the capability to apply all necessary data adjustments while also providing useful data visualization tools to assist with contact selection. SonarWiz is also equipped with various data review and quality control tools, and preserves the full data quality of the side scan time series without unnecessary downsampling.

Data that was logged in raw EdgeTech JSF format by Discover software was imported directly into SonarWiz to begin processing.

Work completed in SonarWiz was tracked line-by-line in a SSS Processing Log, which is included with each project DR.

B.4.1. SSS Navigation Editor

Navigation data was reviewed in the SonarWiz ZEdit utility. ZEdit is similar in form and functionality to CARIS HIPS' Navigation Editor. Rare manual edits (rejection of erroneous navigation) were done when necessary. Figure 9 is an example screen grab from ZEdit.

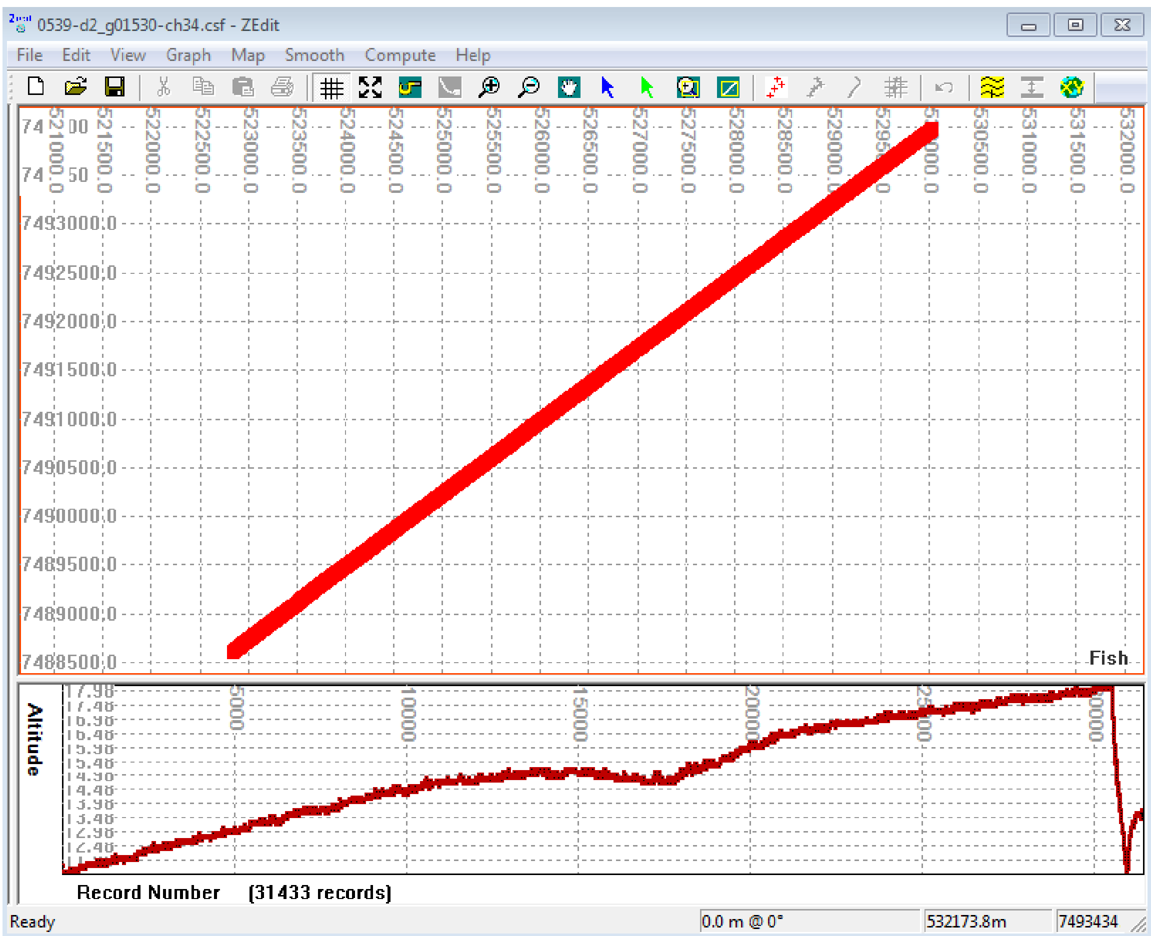


Figure 9 – SonarWiz ZEdit utility interface.

B.4.2. SSS Bottom Tracking

All SSS data was bottom tracked in SonarWiz. Bottom tracking eliminates the irrelevant water column data from the record so as to enable correction for slant range and application of time variable gains. The "Auto bottom tracking" was used, whereby SonarWiz automatically detected the intersection of the water column and the seafloor based on user-entered blanking, threshold, and duration settings.

Blanking was set to one meter, determining the point at which SonarWiz began to detect the bottom and eliminating the possibility of tracking bottom within one meter of the sonar. Threshold settings, determined by best fit trials, ranged from 18 to 24, which adjusted the sensitivity to signal strength of the automatic bottom tracking algorithm. Duration was set to '3,' which helped to eliminate spikes as the algorithm was forced to see at least three samples exceeding the threshold before tracking the bottom.

After auto bottom tracking was completed, the results were reviewed and manually edited where necessary.

Next, an offset of 0.25 meters was made to the bottom tracking. This shifted the bottom track result horizontally by 0.25 m on each channel, effectively removing the small portion of the seafloor at nadir where side scan data is of poorest quality. With 200% coverage, data at nadir is covered in the outer beams of the adjacent line. Additionally, the near-nadir area was fully ensonified by the multibeam sonar system. Removing near-nadir SSS data reduced the 'zipper' effect in the data without compromising data coverage or object detection capabilities.

B.4.3. Automatic Gain Control

Automatic Gain Control (AGC) was applied in SonarWiz to all side scan data. AGC signal processing corrects for differences in the amplitude of a reflected signal due to the angle of incidence and the propagation distance. AGC has the effect of normalizing the across-track gradient banding (dark to light moving outwards from nadir) in the imagery.

B.4.4. Tow Point Offset and Layback

SonarWiz was used to compute the position of the towfish. During this process, SonarWiz utilized the known offset from vessel RP to the tow point (the sheave on the vessel A-frame in tow position), sheave height, and layback. Vessel course made good (CMG) was used as the towfish heading source.

Layback was applied as a percentage of the cable out. To determine the optimal percentage, a set of adjacent reciprocal lines with a large feature was used to determine the percent that best aligned the features. The resulting percentage (85%) was then used as the starting point on all lines, but was adjusted slightly when necessary to bring features on adjacent lines into better alignment. The percentage was found to require only small changes for this project, and values ranging from 85% to 95% yielding good positioning results (with features generally aligned to within 2 m on reciprocal lines). The layback percentage used for each sheet and any exceptions are noted in the DRs.

For days previous to July 25th (JD206) cable out was manually noted in TerraLog by acquisition and then manually entered into SonarWiz at the appropriate timestamps. On JD206 the side scan acquisition software (Discover) was interfaced with the serial output from the cable counter (through the XCC software described previously in this report) and subsequently logged cable out (at a rate of 1 Hz) directly into the raw JSF files. SonarWiz subsequently imported the cable out values during conversion, making manual entry of cable out after JD206 unnecessary. The side scan processing logs in Separate I of the DRs detail which lines have manually entered cable out and which have cable out logged in the JSF.

B.4.5. Slant Range Correction

All lines were slant range corrected with a sound velocity of 1500 m/s in SonarWiz. During this standard automated process common to all SSS processing software, sonar data was repositioned across-track to compensate for the compression of data in the near-sonar region.

B.4.6. Data Review and Contact Selection

Following application of corrections, all lines were reviewed for data quality and contact selection. The SonarWiz Digitizing View allows detailed examination of individual lines in which the user can switch on/off slant range correction to view the water column if desired, which is similar to CARIS SIPS side scan editor.

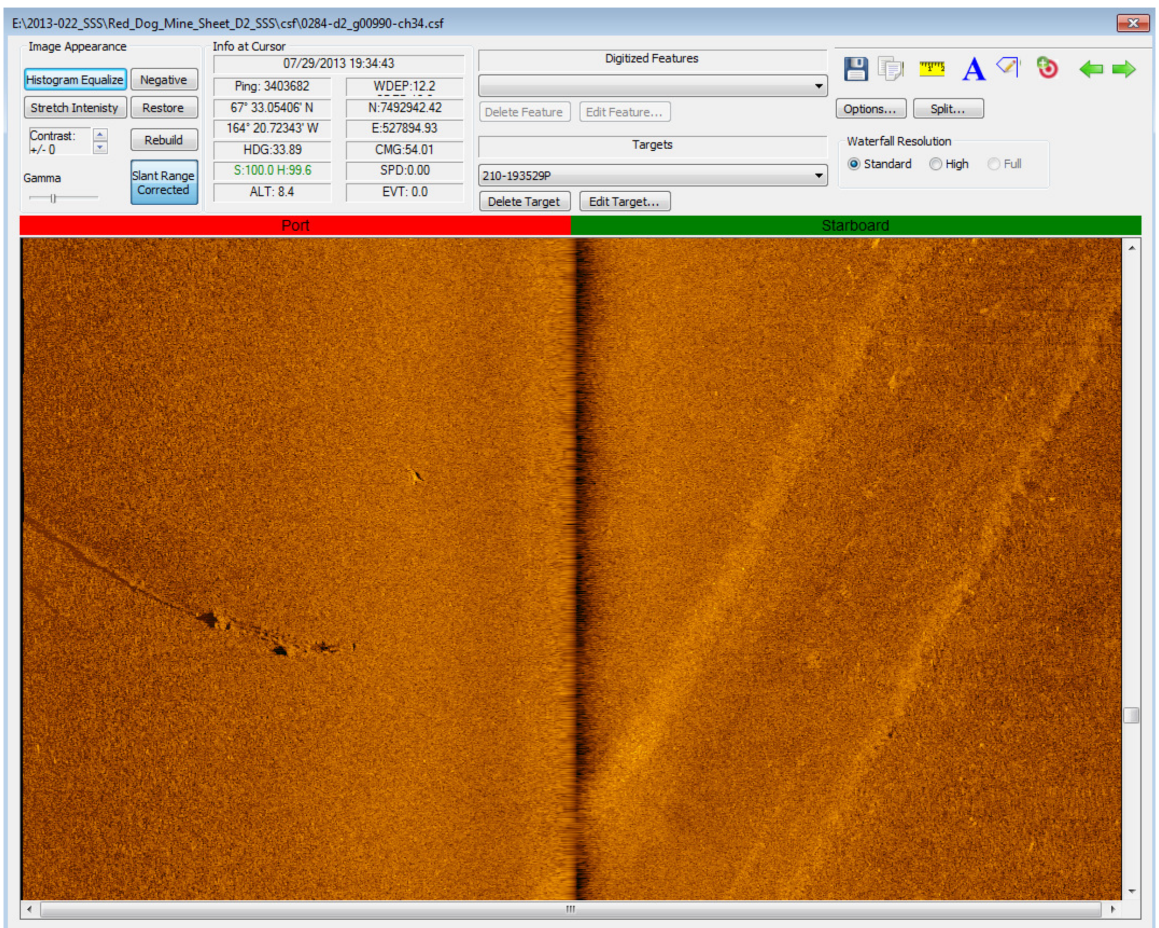


Figure 10 – SonarWiz Digitizing View.

Possible contacts were flagged and measured for height in the SonarWiz contact editor. In the contact editor, shadow length was measured to provide an estimate of object height above the seafloor. Contacts with heights of one meter (or greater) were deemed "significant" per the HSSD and flagged for multibeam development. With the realization that contact heights from side scan imagery are less accurate than measured heights from multibeam, contacts with heights of 0.75 m (or greater) were typically also flagged for multibeam development. This helped ensure marginal contacts were also developed, in case their actual height exceeded 1 m.

When picking contacts, SonarWiz exported a JPG image with the contact name for each contact. These images are available in the S57 multimedia folder.

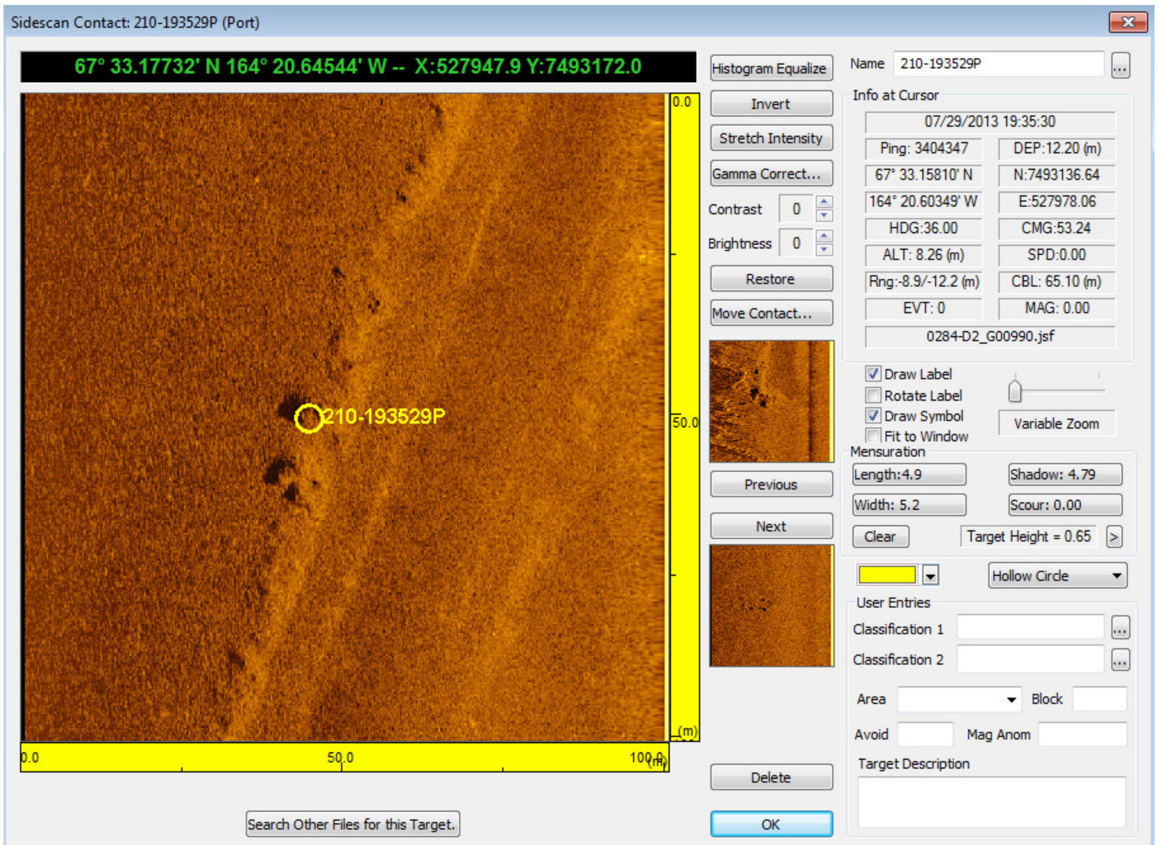


Figure 11 – SonarWiz Contact Editor.

B.4.7. SSS Final Review for Coverage and Contacts

All lines were reviewed for contacts at least twice. All lines were first reviewed immediately after data acquisition and processing, normally within two hours of acquisition. To ensure possible contacts were not missed, all lines were reviewed at least one additional time by a senior processor prior to departing the field.

B.4.8. Contact Development

Following side scan data collection, all significant contacts (object heights near or exceeding 1 meter) were fully developed with multibeam. During this process, multibeam data was acquired in a multi-line pattern centered on the object position, ensuring high-quality nadir beams passed over the potential object, and data density met the "Object Detection" requirements described in the HSSD.

Occasionally, potential features were observed in the multibeam data that did not have a correlating SSS contact. These typically consisted of sounding groups near nadir, which was on the very outer edge of the side scan range from each pass and, therefore, possibly not readily observable in the SSS record. Also, as a set-line spacing survey, these features typically did not have concurrent coverage from an adjacent multibeam line. When these doubtful features were observed, they were also flagged and developed, usually resulting in no feature found at the position. However, in some cases minor features were revealed at the positions.

B.4.9. Mosaic and Coverage Report Generation

Two methods were used to confirm the 200% coverage requirement for the survey was met.

In the field, SonarWiz was utilized to provide coverage reports. Coverage reports output a geo-referenced image with color codes for coverage. Green indicated areas that have 200% (or greater) coverage and red indicated areas that had 100% coverage. Areas not meeting the 200% coverage requirement according to the SonarWiz coverage reports were addressed in the field when possible. An example of the SonarWiz coverage report is shown in Figure 12.

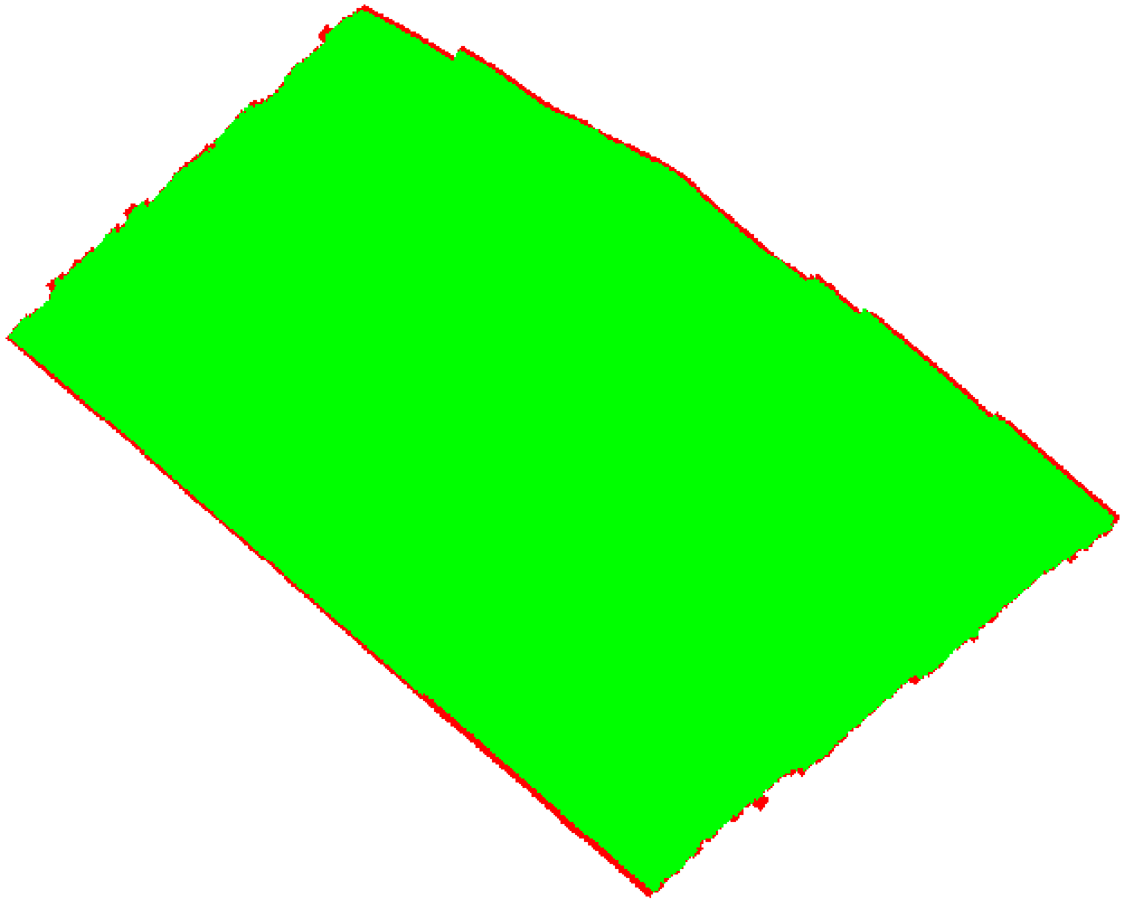


Figure 12 – Example of SonarWiz Coverage Report; green indicates 200% (or greater) coverage and red indicates 100% coverage.

To demonstrate coverage in accordance with the HSSD, after completion of final processing, two separate 100% coverage greyscale GeoTif images were exported from SonarWiz at 1 meter resolution. Every other (alternating) line was used in the export to create the 100% coverages. When file sizes were too large for exported files, smaller areas were first exported to GeoTIF and then merged using Bluemarble software to provide one file per 100% coverage for each sheet.

The 100% coverage GeoTifs, as well as the SonarWiz coverage report GeoTIFs, are provided with the survey deliverables.

B.4.10. Side Scan Sonar Contact Correlation and S57 Presentation

After the application of SSS corrections and processing, all contacts were exported to text file (CSV format), including contact name, contact position, acquisition time, measured height, length, width, image name, and other contact details. The CSV was imported into CARIS Notebook where contact correlation with multibeam was performed, and contacts were attributed with NOAA extended attributes. Contact images produced by SonarWiz were placed in the Notebook Multimedia folder, provided with the survey deliverables.

Significant contacts were correlated with multibeam data. Multibeam data was examined in the vicinity of the SSS position for features. If a feature was verified by MBES and found to be significant (greater than 1 m in height), it was designated when it met HSSD designation criteria and attributed as a sounding (SOUNDG) object in the S57 SSS contact feature file (included with the survey deliverables), using the multibeam position and depth. Note that these features do not appear in the final feature file (FFF) because the final surfaces already represent the least depth on objects.

Insignificant contacts (generally less than 1 m in height) were normally not correlated with multibeam data. Insignificant contacts in close proximity to each other were examined and correlated with each other where appropriate. However, insignificant contacts frequently met the HSSD requirements for designated soundings and were therefore designated during the multibeam editing process, described previously in this report.

SSS contacts (including significant, insignificant, and disproven) were attributed as "CSYMB" objects and are available for review in the SSS contact feature file, with contact images in the accompanying Multimedia folder.

B.4.11. CARIS SIPS Readable Files

To fulfill HSSD requirements of providing side scan in a format readable by CARIS SIPS, fully processed 16 bit XTFs were exported from SonarWiz and imported into CARIS 8.1. Exported XTFs contain only final fish position (as computed by SonarWiz), thus, the CARIS HVF contains no position offsets and the XTFs contain no cable out or layback values. Note that CARIS HIPS and SIPS 8.1 was used for import of side scan data instead of CARIS HIPS and SIPS 7.1 (which was used for bathymetric data processing as described in other sections) because of its ability to display 16-bit side scan data, a capability not available in 7.1.

To convert into CARIS, the XTF Converter was used. Navigation type was selected as "Geographic," and "Ping Header: Sensor" selected as the navigation source for Ship Navigation. The "Convert Side Scan" option was enabled, with the option to convert channels 3 and 4. "Attitude Packets" was selected as the source of gyro data, and no layback was imported (since positions in the XTF were already towfish positions). Ship and sensor position are identical in the XTF as SonarWiz only exports the towfish position into both XTF data fields.

In CARIS SIPS 8.1, small gaps, spikes, and duplicates in the navigation trackline are apparent. These gaps and duplications are not present in the SonarWiz data and are produced during the SonarWiz export to XTF process. To reduce the effect of the missing or duplicate navigation points in SIPS, navigation was smoothed using the Set Interpolation function in CARIS. Interpolation was set to the Tight Bezier Curve. This minor interpolation positively affected the quality of data displayed in CARIS SIPS, though navigation spikes or abnormalities might remain in the SIPS data set.

It is important to note that ALL side scan processing was done in Chesepeake SonarWiz. Only conversion and basic navigation smoothing was performed in CARIS SIPS. For quality control purposes, a handful of contacts were compared in SIPS versus contacts in

SonarWiz to ensure positioning carried through (with good results). Otherwise, the SIPS data set was not extensively examined and differences in imagery and navigation quality and/or positioning versus the SonarWiz results are likely. Additionally, despite using CARIS HIPS and SIPS 8.1 for the side scan data (with its improved ability to deal with 16-bit side scan data), it was apparent the imagery quality in SIPS is not as high as imagery quality in SonarWiz. It is recommended that the side scan data in SIPS format be used for reference only. Figures 13 and 14 demonstrate a feature viewed in SonarWiz versus the same feature in CARIS SIPS.

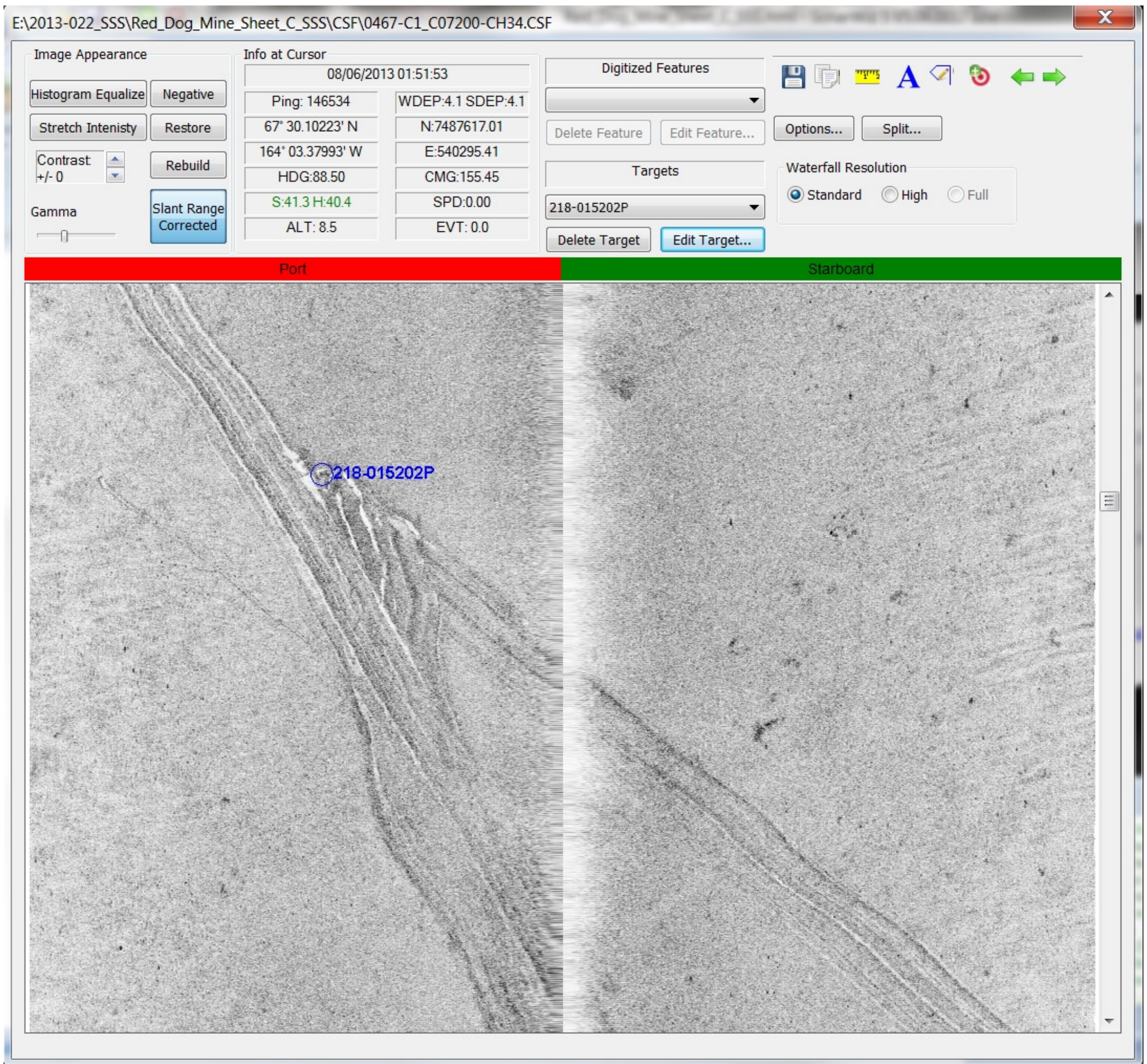


Figure 13 – Feature in SonarWiz.

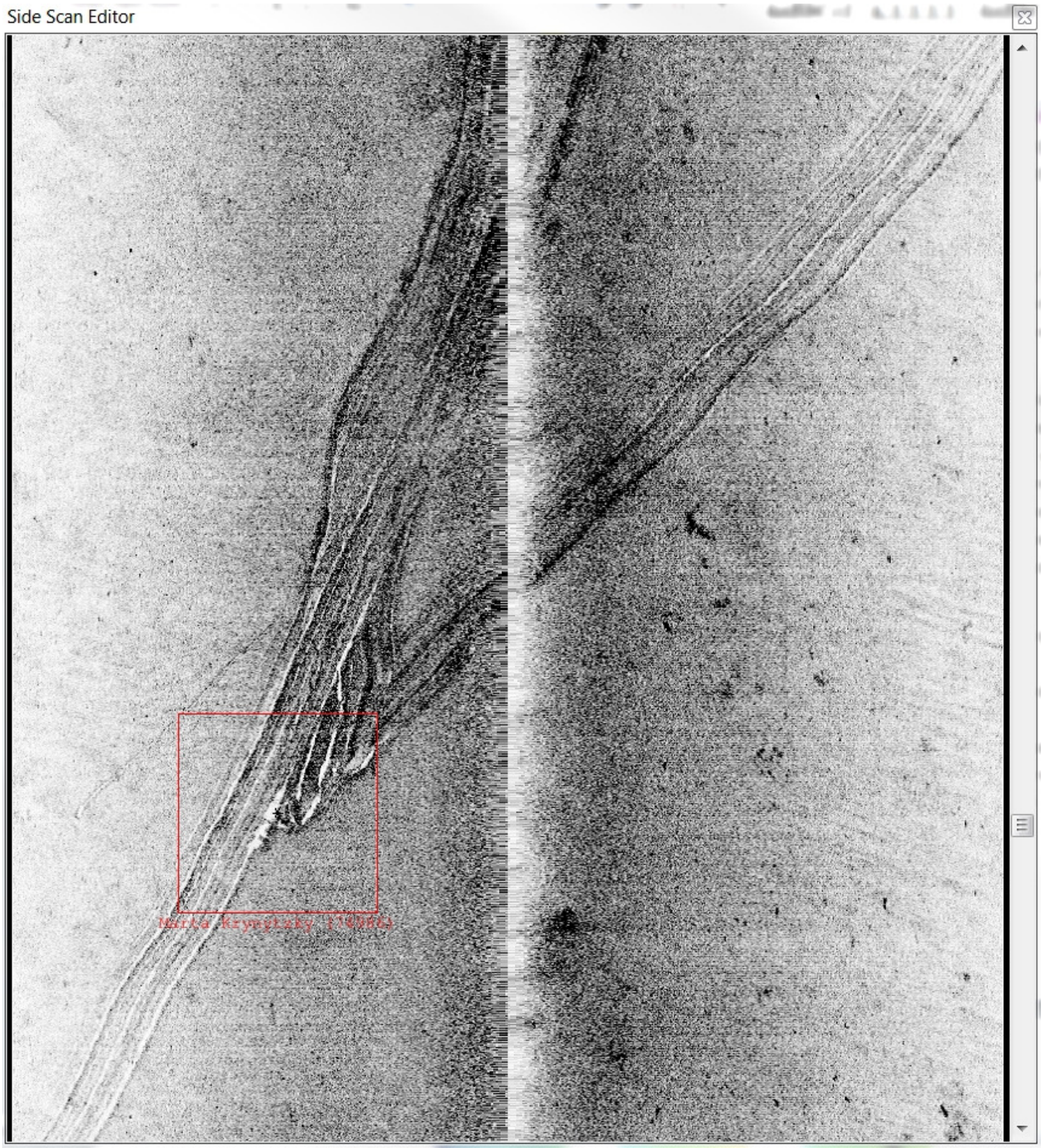


Figure 14 – Same feature viewed in CARIS SIPS (8.1). Feature appears flipped vertically compared to SonarWiz as the two software packages display using different along-track view perspectives.

B.4.12. SSS Processing Flow Diagram

The following is an overview of the SSS processing flow used on this project.

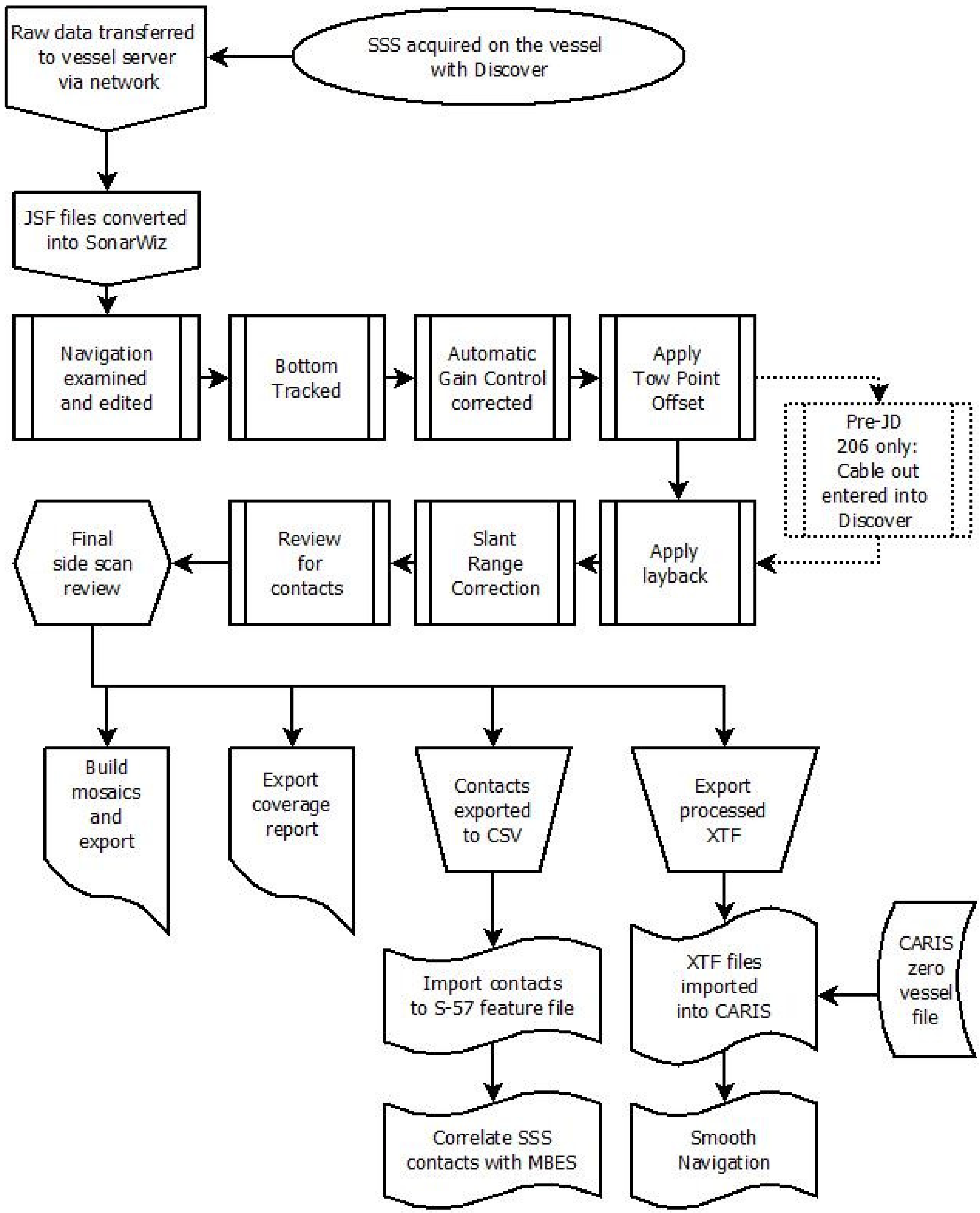


Figure 15 – Flow chart showing the side scan sonar processing workflow.

B.5. Confidence Checks

In addition to daily QC steps undertaken as part of the acquisition and processing procedures outlined in the above sections, formal confidence checks were also completed throughout the survey.

Table 20 summarizes the formal confidence checks. Planned intervals (for example, the weekly SVP comparison) were not always achieved on schedule due to weather or operational considerations. However, the planned confidence check was accomplished as soon as possible when conditions allowed.

Confidence Check	Purpose	Planned Frequency
Depth Checks (Bar and/or Lead Line)	Check depth accuracy Determine and refine Z offsets	Weekly
Echosounder Comparison (Multiple Vessels)	Overall check of consistency of survey systems.	No planned frequency; examine intersections of *Q105* and *Q15* skiff data
SVP Comparison	Check SVP sensors for consistency	Weekly
Side Scan Sonar Confidence Checks	Verify image quality and the ability to detect objects on the seafloor	Daily
Base Station Position Check	Ensure stable and repeatable base station position	Weekly
Vessel Position Confidence Check – Alternate Base Station	Check for accurate and consistent vessel positioning regardless of base station used (project base versus CORS)	Weekly
Vessel Position Confidence Check – Independent GPS	Check for accurate and consistent vessel positioning with independent GPS source	Daily, real-time check
Staff Shots	Check of tide gauge stability	Once per project (not required for the NWLON station)
ERS – Discrete Tides Comparison	Compare ERS survey to discrete tide zone survey	N/A for this survey; ERS was not utilized

Table 20 – Summary of confidence checks.

B.5.1. Bar Checks

For this survey, bar checks were utilized to determine and refine sonar Z offsets, and to check the relative accuracy of the echosounder and processing systems. These were planned to occur on a weekly basis, though it was not always possible to complete these on schedule as it required being alongside a dock. Therefore, these were accomplished whenever alongside either Red Dog dock (for base station maintenance), or when performing crew transfers in Kotzebue. One was also performed following vessel mobilization in Homer, Alaska. A total of five were accomplished for the *Q105* (on JD183, JD208, JD212, JD217, and JD236). One was completed on the *Q15* skiff (on JD247) post-project in Homer.

To perform the bar check, a rectangular aluminum grate, roughly one meter by one meter, was hung by steel cable from guide points on the vessel's gunwale. The steel cable was marked at an interval of 1 m from the bar, measured by tape. A sound speed profile was collected and the average velocity entered into the echosounder, and static draft was measured.

With QINSy (for *Q105* MBES) or HYPACK (for *Q15* skiff SBES) logging and the sonar tuned to track the bar instead of the bottom, the bar was lowered by 1 m increments directly below the transducer while bar depth and time were noted in the log. Bar check maximum depth, which ranged from 2 to 8 m on this survey, was determined by ability to maintain a sonar lock on the bar (which was highly current-dependent), as well as depth at the test location.

The bar depth was read relative to the waterline for later comparison to the CARIS HIPS results, as well as relative to the gunwale measure-down points for determining and re-confirming the acoustic center offset. Results obtained from CARIS HIPS always compared to better than 0.05 m on average of the actual bar depth for the MBES system, and 0.02 m for the SBES system.

In addition to serving as depth confidence checks, bar checks were critical to establish acoustic center offsets on the Odom single beam system. Odom single beam systems have an acoustic center position that can vary from the transducer face due to electronic delays between the processor, transducer and interconnecting cable. Odom refers to this offset from the transducer face as the "index value." Once determined for a particular layout, however, the value remains fixed.

Bar check logs are available in Appendix II of this report.

B.5.2. Lead Lines

Lead line checks were utilized to check the absolute accuracy of the echosounder and processing systems. These were planned to occur on a weekly basis, though it was not always possible to complete these on schedule. These were usually undertaken when alongside a dock, concurrent with a bar check.

Lead lines were accomplished by lowering a calibrated measuring tape outfit with a 2 lb. weight to the seafloor and noting the waterline level on the tape. This was done on both sides of the vessel in-line with the echosounder transducer and averaged to help account for any slope and obtain a best-estimate of the depth at the transducer, which was roughly centered on the vessel.

A sound speed profile and static draft was taken near in time to the lead line check, and QINSy recorded the echosounder data during the test. Later in processing, the CARIS HIPS computed depth was compared to the recorded depth in a lead line log.

For this project, lead lines proved very difficult to obtain accurately, even near slack tide at a dock, and often don't compare well with the echosounder data as a result. Both the Red Dog dock and Kotzebue dock (where the majority was collected) have distinct slopes, which made it difficult to obtain representative lead line depth.

On the *Q105*, six comparison lead lines were taken (on JD198, JD206, two on JD208, JD217 and JD236), with agreement varying from 0.01 m to 0.624 m, results that were deemed acceptable given the conditions and variables surrounding lead line collection. On the *Q15* skiff, a lead line was taken (on JD247), with processed depth comparing within 0.025 m (or better) of the lead line depth.

Lead line logs are available in Appendix II of this report.

B.5.3. Echosounder Comparison

No formal, direct comparisons of *Q15* skiff SBES and *Q105* MBES were undertaken. However, during acquisition, care was taken to ensure the two data sets had significant overlap.

The overlap zone was examined in CARIS subset mode, where the two show good agreement, usually comparing to 0.05 m (or better). Good agreement between the two vessels – each with completely independent sonar and positioning systems – helps demonstrate the lack of any large systematic biases in data collected for both vessels.

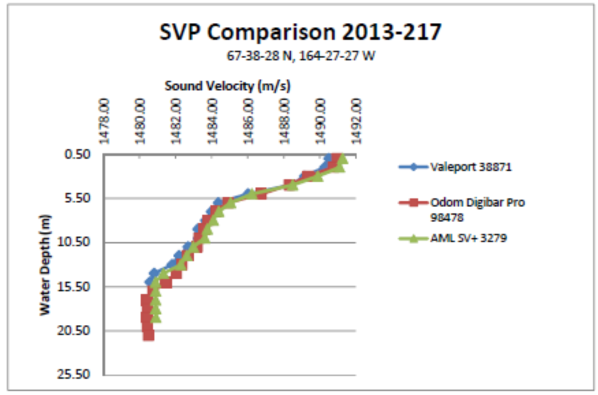
B.5.4. SVP Comparison

SVP comparisons were utilized to check the accuracy and consistency of the sound velocity probe data. In the test, data from the primary sound speed profiler was compared to at least one other independent, calibrated sound speed profiler. These comparisons were planned to occur on a weekly basis though operational concerns frequently caused their postponement.

To perform the test, a spare profiler probe was used to collect a cast coincident with the primary probe. Usually, all probes were lowered at the same time, though occasionally it was necessary to collect the profiles separately (though close in time). The data from both probes underwent standard processing and were compared depth-by-depth in an SVP comparison logsheet (see Figure 16). Results of the comparisons were good, with sound speed at all depths usually comparing to better then 1 m/s, though some show greater variance that is attributable to change over the slight differences in times of acquisition of the profiles.

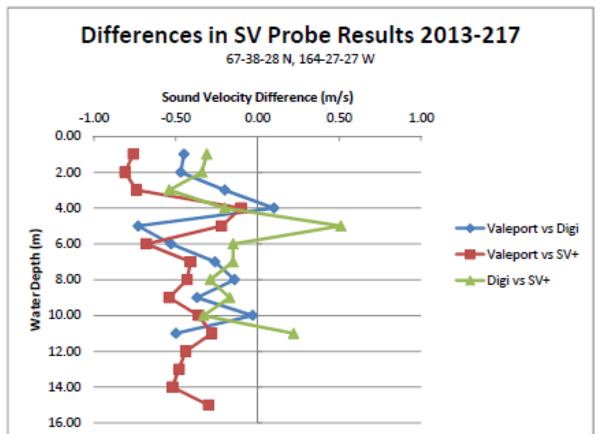
SVP comparison results are available in *Separate II* of the DRs.

SV Probe Results			
S/N	Valeport 38871	AML SV+ 3279	Odom Digibar Pro 98478
Date/time:	2013-217 17:37:20	2013-217 17:35:08	2013-217 17:37:26
Depth	Sound Velocity (m/s)		
1.00	1490.50	1491.26	1490.95
2.00	1490.28	1491.09	1490.75
3.00	1489.15	1489.89	1489.35
4.00	1488.40	1488.50	1488.30
5.00	1486.02	1486.24	1486.75
6.00	1484.38	1485.06	1484.91
7.00	1483.99	1484.40	1484.25
8.00	1483.66	1484.09	1483.80
9.00	1483.23	1483.77	1483.60
10.00	1483.27	1483.63	1483.30
11.00	1482.70	1482.98	1483.20
12.00	1482.19	1482.63	1482.70
13.00	1481.81	1482.29	1482.35
14.00	1480.82	1481.34	1482.05
15.00	1480.59	1480.89	1481.48
16.00		1480.90	1480.75
17.00		1480.90	1480.40
18.00		1480.91	1480.44
19.00		1480.92	1480.40
20.00			1480.45
21.00			1480.50



(Figure 1- Sound velocity from each Sound velocity Probe)

Statistics on the SV Probe results			
	Difference in Sound Velocity (m/s)		
Depth	Valeport vs Digi	Valeport vs SV+	Digi vs SV+
1.00	-0.45	-0.76	-0.31
2.00	-0.47	-0.81	-0.34
3.00	-0.20	-0.74	-0.54
4.00	0.10	-0.10	-0.20
5.00	-0.73	-0.22	0.51
6.00	-0.53	-0.68	-0.15
7.00	-0.26	-0.41	-0.15
8.00	-0.14	-0.43	-0.29
9.00	-0.37	-0.54	-0.17
10.00	-0.03	-0.36	-0.33
11.00	-0.50	-0.28	0.22
12.00	-0.51	-0.44	0.07
13.00	-0.54	-0.48	0.06
14.00	-1.23	-0.52	0.71
15.00	-0.89	-0.30	0.59
16.00			-0.15
17.00			-0.50
18.00			-0.47
19.00			-0.52
20.00			



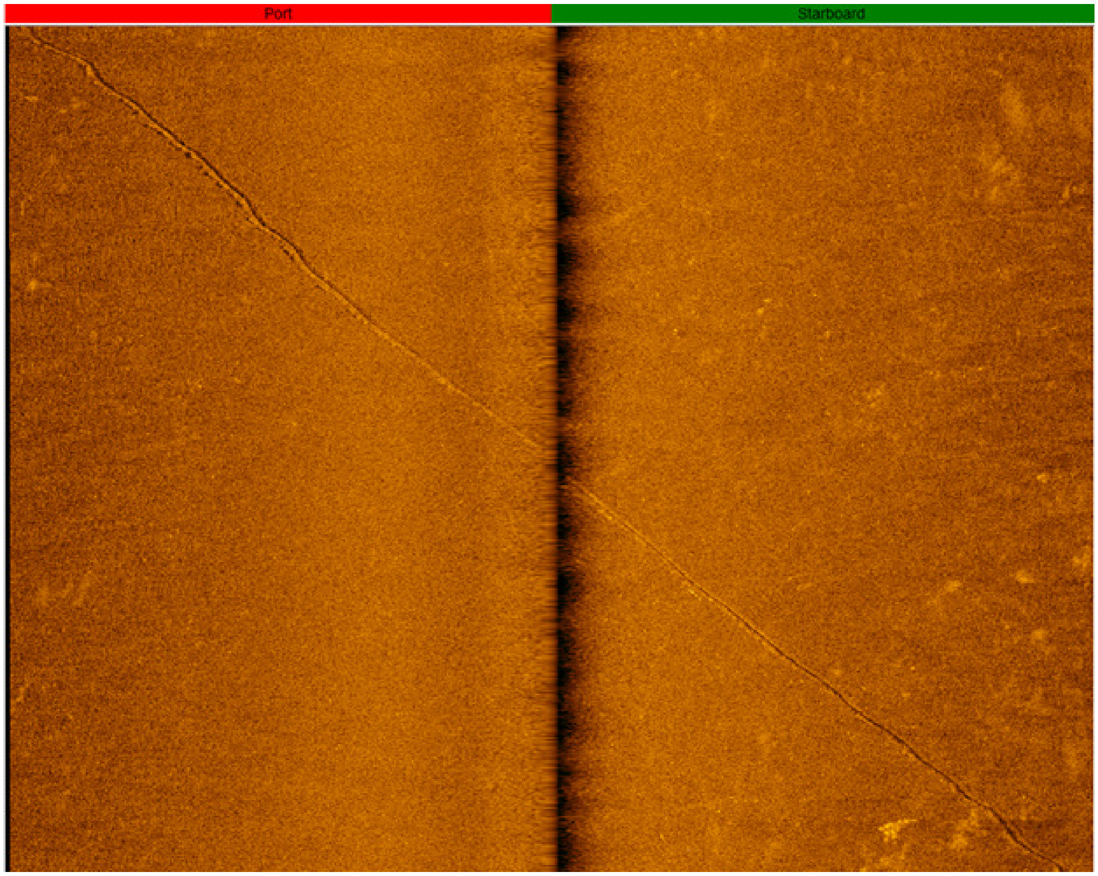
(Figure 2- Differences between the Maximum and Minimum Sound Velocity of the casts)

Figure 16 – Example of typical SVP comparison results. JD217 SVP comparison using three separate sound speed profilers.

B.5.5. Side Scan Sonar Daily Confidence Checks

Side scan sonar confidence checks were captured daily. At least once per day, during the sonar data review for contacts, at least one feature was captured as a check to confirm the system was functioning properly. Effort was made to capture a feature that crossed across the entire range scale of each sonar channel (port and starboard). Features were measured and recorded in the SSS Daily Confidence Check form. An example is shown in Figure 17. The SSS confidence checks are available in Appendix II.

Sidescan Sonar Daily Confidence Check



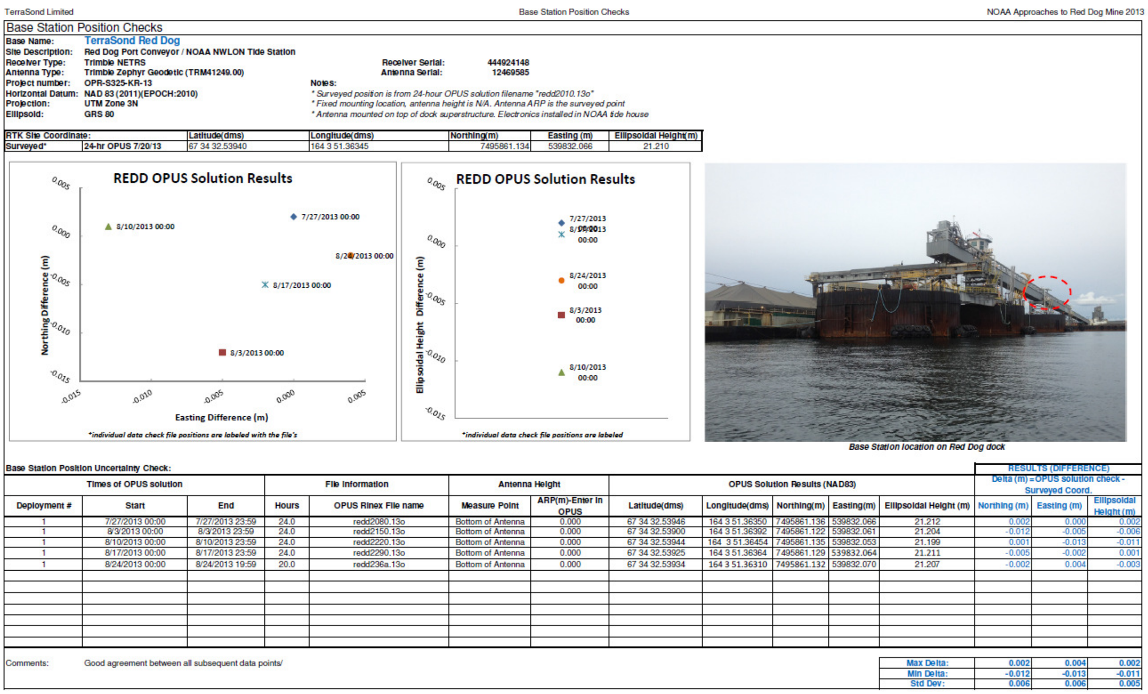
Port Channel		Starboard Channel	
Information		**Information**	
Line Name:	0145-B1_B02070	**Line Name:**	0145-B1_B02070
Latitude:	67 33.94002	**Latitude:**	67 33.94002
Longitude:	164 16.44998	**Longitude:**	164 16.44998
Date:	07/24/2013 (JD205)	**Date:**	07/24/2013 (JD205)
Time:	19:45:55	**Time:**	19:45:55
Dimensions		**Dimensions**	
Height:	N/A	**Height:**	N/A
Length:	296.431 meters	**Length:**	296.431 meters
Width:	1.604 meters	**Width:**	1.604 meters
Comments: Feature found across both channels.		**Comments:** Feature found across both channels.	

Figure 17 – Example of side scan sonar daily confidence check from JD205.

B.5.6. Base Station Position Checks

Position of the base station was established using NOAA NGS OPUS (Online Positioning User Service) by upload of the first 24-hour GPS static session from the base station deployment. This position became the accepted, surveyed position.

As a confidence check on antenna stability and to ensure repeatability, an OPUS solution was derived at least once weekly from a 24-hour data set and compared to the surveyed position. Results were excellent with all subsequent measurements comparing to within 0.013 m (or better) of the initial position. The base station confidence check logsheet is available with the project HVCR.


TerraSond Limited — Base Station Position Checks — NOAA Approaches to Red Dog Mine 2013

Base Station Position Checks

Base Name: TerraSond Red Dog
Site Description: Red Dog Port Conveyor / NOAA NWLON Tide Station
Receiver Type: Trimble NETRS — Receiver Serial: 444924148
Antenna Type: Trimble Zephyr Geodetic (TRM41249.00) — Antenna Serial: 12469585
Project number: OPR-S325-KR-13
Horizontal Datum: NAD 83 (2011)(EPOCH:2010)
Projection: UTM Zone 3N
Ellipsoid: GRS 80

Notes:
* Surveyed position is from 24-hour OPUS solution filename "redd2010.13o"
* Fixed mounting location, antenna height is N/A. Antenna ARP is the surveyed point
* Antenna mounted on top of dock superstructure. Electronics installed in NOAA tide house

RTK Site Coordinate:		Latitude(dms)	Longitude(dms)	Northing(m)	Easting (m)	Ellipsoidal Height(m)
Surveyed*	24-hr OPUS 7/20/13	67 34 32.53940	164 3 51.36345	7495861.134	539832.066	21.210

Base Station location on Red Dog dock

Base Station Position Uncertainty Check:

Times of OPUS solution				File Information	Antenna Height		OPUS Solution Results (NAD83)					RESULTS (DIFFERENCE) Delta (m) = OPUS solution check - Surveyed Coord.		
Deployment #	Start	End	Hours	OPUS Rinex File name	Measure Point	ARP(m)-Enter in OPUS	Latitude(dms)	Longitude(dms)	Northing(m)	Easting(m)	Ellipsoidal Height (m)	Northing (m)	Easting (m)	Ellipsoidal Height (m)
1	7/27/2013 00:00	7/27/2013 23:59	24.0	redd2080.13o	Bottom of Antenna	0.000	67 34 32.53946	164 3 51.36350	7495861.136	539832.066	21.212	0.002	0.000	0.002
1	8/3/2013 00:00	8/3/2013 23:59	24.0	redd2150.13o	Bottom of Antenna	0.000	67 34 32.53900	164 3 51.36392	7495861.122	539832.061	21.204	-0.012	-0.005	-0.006
1	8/10/2013 00:00	8/10/2013 23:59	24.0	redd2220.13o	Bottom of Antenna	0.000	67 34 32.53944	164 3 51.36454	7495861.135	539832.053	21.199	0.001	-0.013	-0.011
1	8/17/2013 00:00	8/17/2013 23:59	24.0	redd2290.13o	Bottom of Antenna	0.000	67 34 32.53925	164 3 51.36364	7495861.129	539832.064	21.211	-0.005	-0.002	0.001
1	8/24/2013 00:00	8/24/2013 19:59	20.0	redd236a.13o	Bottom of Antenna	0.000	67 34 32.53934	164 3 51.36310	7495861.132	539832.070	21.207	-0.002	0.004	-0.003
											Max Delta:	0.002	0.004	0.002
											Min Delta:	-0.012	-0.013	-0.011
											Std Dev:	0.006	0.006	0.005

Comments: Good agreement between all subsequent data points/

Figure 18 – Example Base Station Position Check logsheet.

B.5.7. Vessel Positioning Confidence Checks – Alternate Base Station

To ensure that vessel positioning was accurate and consistent, regardless of the base station in use – and as independent check of vessel positioning – vessel position confidence checks were undertaken. These were accomplished on a weekly basis, occurring on JD208, JD215, JD222, JD229, and JD236.

To complete this check for each vessel, a random POS file was selected and post-processed as normal with the project base station (REDD). The POS file was then re-processed with the nearest continuously operating reference station (CORS) site, and the results differenced with POSPac MMS's "Navdif" utility.

A difference plot was produced, which was recorded on a vessel positioning confidence form along with the comparison parameters and observations. For this project, the FAA WAAS site in Kotzebue (site ID OTZ, 100 kilometer distance from REDD) was used as the CORS site.

Results were excellent, with average differences agreeing to 0.2 m (or better). Results deviated up to 2 meters on occasion, which is still well within position specifications and considered good given the distance from the survey area to OTZ. The vessel positioning confidence check logs are available in *Separate I* of the DRs.

Vessel Positioning Confidence Check

(Comparison of PPK vessel position results using primary and alternate base station)

POS file: 2013-222-0132-1A **Date:** August 10th, 2013 (JD222) **Vessel:** Q105

Base Stations Used

Base Station ID	Operating Agency	Location	Function	Data Rate Used	Min. Baseline Distance (m)	Max. Baseline Distance (m)
REDD	TerraSond	Red Dog Dock	Project Primary	1 Second	100	19,050
OTZ1	FAA	Kotzebue	CORS Check	30 Second	99,500	117,800

Table 1 - Base stations used for comparison

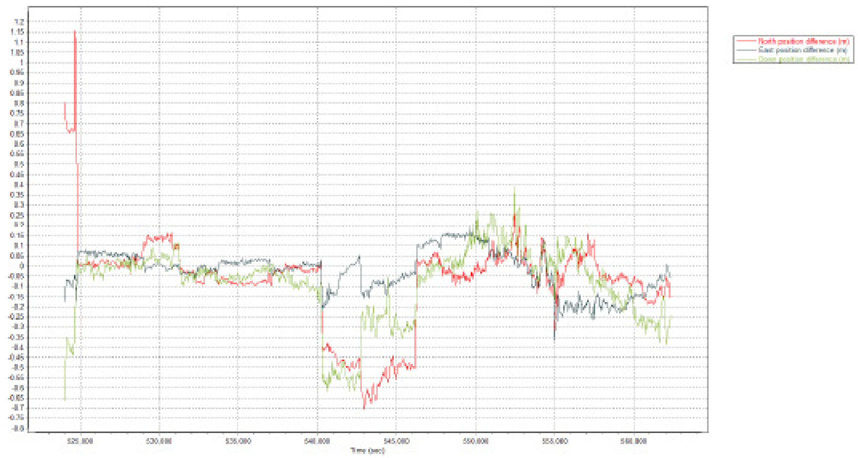


Figure 1 – POSPac MMS North, East, and Down position difference plot

Result Statistics

Position	Min. Difference (m)	Max. Difference (m)	Mean Difference (m)
North	-0.71	1.15	0.00
East	-0.37	0.16	-0.10
Down	-0.66	0.39	-0.05

Table 2 - Approximate minimum, maximum and mean differences

Comments: Good agreement overall, spike at beginning likely due to higher than usual PDOP when vessel was alongside Red Dog dock.

Figure 19 – Example of Vessel Positioning Confidence Check (alternate base station) from JD222.

B.5.8. Vessel Positioning Confidence Checks – Independent GPS

Checks of the primary position (from the Applanix POSMV) and an independent GPS source (a Trimble 5700, or T5700) were accomplished in real-time.

QPS QINSy was configured to draw a scatterplot comparison of the two position sources. The scatterplot was examined and a screen grab taken of the plot at least once daily. No abnormalities were observed during this project, with the positions usually comparing within 2 meters horizontally. Screengrabs of the scatterplots were saved daily, and are available in Separate I of the DRs.

B.5.9. Tide Station Staff Shots

Though not required in the tides SOW for the NWLON tide station, three hours of staff shots were taken on August 24th (JD236) as a check on gauge stability.

Standard leveling procedures and a lead line were used to determine the difference in elevation between a tide station benchmark and the water surface. A lead line was lowered to the water surface and a reading was taken at a temporary bench mark near one of the published tide station benchmarks. During the visit, three hours of observations were collected, at a 6-minute interval that started on the hour. The staff shot readings were timed to coincide with data collected by the Red Dog dock tide gauge.

Results were logged on a staff shot form which was sent by email, within 24-hours of collection, to TerraSond's tide subcontractor, JOA. See the HVCR for more information concerning tide operations and JOA's tide station reports (included with HVCR), which include the staff shot forms.

Note that JOA Surveys, which is contracted separately by NOAA to maintain the NWLON site, also performed staff shots at the site after completion of this project.

C. Corrections to Echo Soundings

The following methods were used to determine, evaluate and apply corrections to instruments and soundings.

C.1. Vessel Offsets

Sensor locations were established with a pre-season survey of the vessels using conventional survey instruments. Acoustic center offsets were determined through bar check method for the MBES and SBES systems.

A center reference point (CRP), or point from which all offsets were referenced, was selected for each vessel.

For the *Q105*, the top-center of the POSMV IMU, which was mounted at the vessels estimated center of gravity, was used as the CRP. For the *Q15* skiff, the CRP was located on the port side stern transom near the SBES mounting pole.

On the *Q105*, the primary POSMV GPS antenna to POSMV IMU offset was applied automatically during data collection (and subsequent post-processing) so that all positions and motion data were computed for the vessel CRP, while the remaining offsets were applied by way of the CARIS HIPS Vessel File (HVF).

It is important to note that X and Y offsets are entered only under the SV1 sensor in the HVF, while the Z offset is entered under both Swath1 and SV1. This configuration was intentionally done to prevent double application of the X and Y offsets (though this does not double-apply the Z offset), per consultation with CARIS. This configuration is specific to XTFs produced from Reson 7xxx series sonars.

All offsets received checks including reality tests by survey tape and bar check. Offset uncertainties varied, and are described previously in the TPU section of this report.

Vessel outlines and offset descriptions are provided in Figures 20 and 21, and Tables 21 and 22.

C.1.1. *Q105* Vessel Offsets

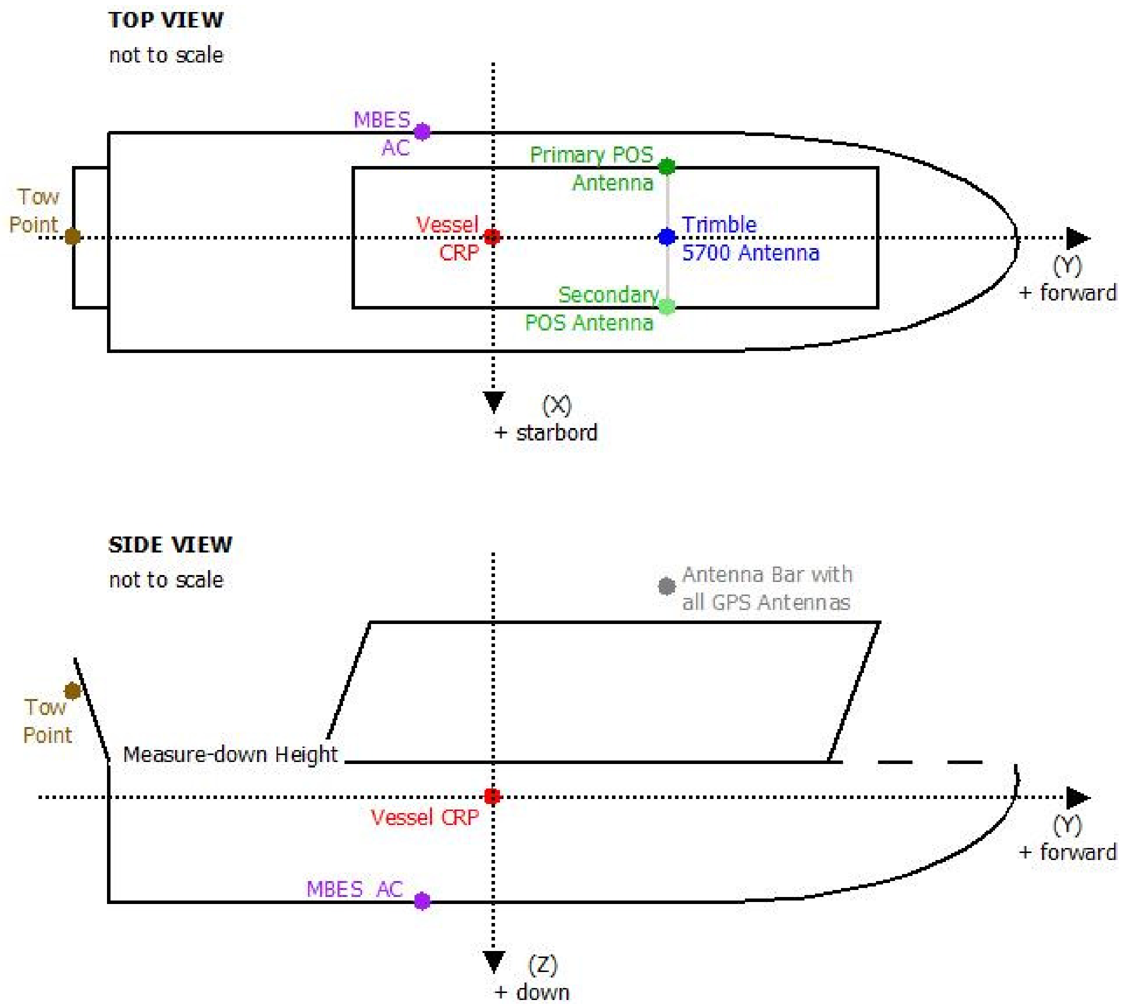


Figure 20 – Q105 vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
MBES Acoustic Center	-4.178	-3.380	+1.160	Z value determined by bar check
POS MV Primary GPS Antenna	-0.998	+5.083	-13.903	
POS MV Secondary GPS Antenna	+1.02	+5.093	-13.905	
POS MV IMU Reference Point	0.000	0.000	0.000	
Trimble 5700 (Zephyr) Antenna	+0.002	+5.088	-13.904	
Stern Tow Point	0.000	-14.94	4.00*	A frame in tow position. Z dimension is an approximation of the tow point to water surface.
Draft Measure-down Point (port side)	-	-	-2.551	
Draft Measure-down Point (stbd side)	-	-	-2.551	

Table 21 – R/V Q105 offset measurements from CRP, determined by vessel survey.

C.1.2. *Q15* Skiff Vessel Offsets

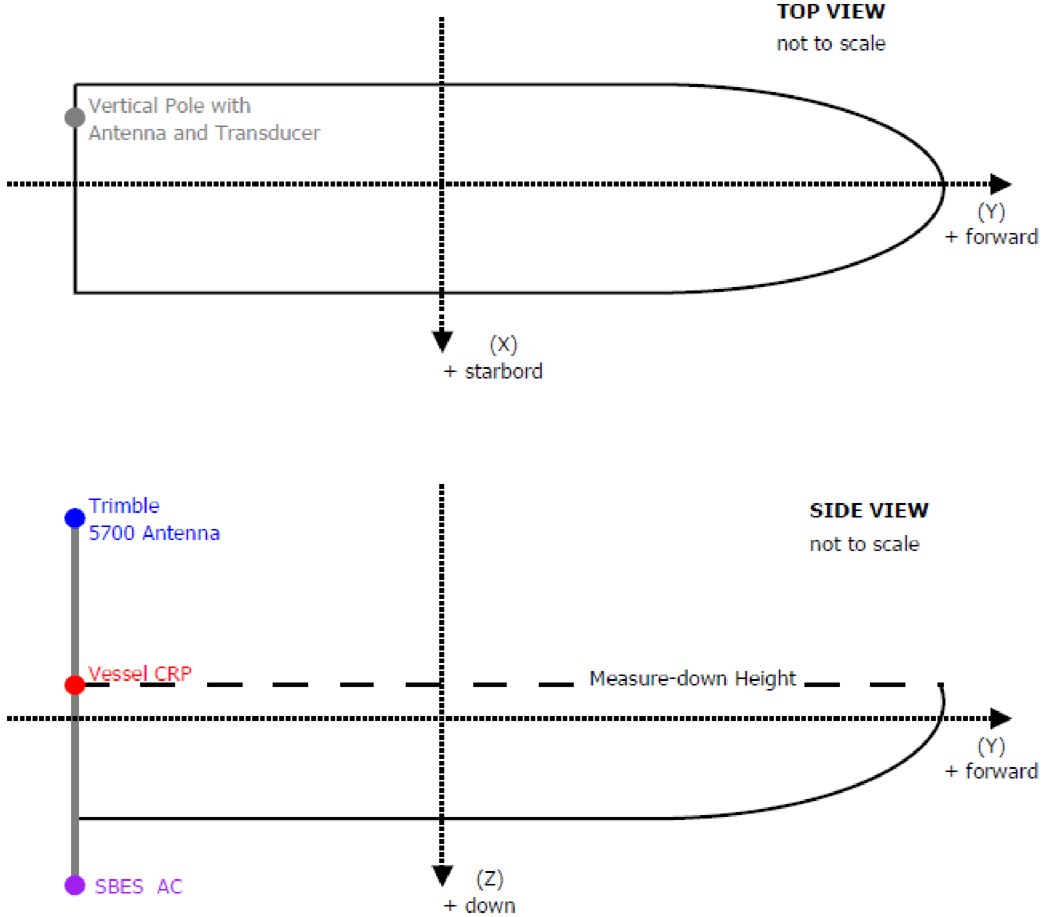


Figure 21 – Skiff Q15 vessel survey showing relative positions of installed survey equipment.

Equipment	X (m) (+ stbd)	Y (m) (+ fwd)	Z (m) (+ down)	Comments
VBES Acoustic Center	0.000	0.000	0.835	Z value determined by bar check
Trimble 5700 (Zephyr) Antenna	0.000	0.000	-1.680	
Draft Measure-down Point (stern)	-	-	0.000	Measure-down point is also the CRP

Table 22 – Skiff Q15 offset measurements from CRP.

C.1.3. Attitude and Positioning

As described in previous sections of this report, primary positioning, heave, roll, pitch and heading data were measured on the *Q105* with an Applanix POSMV 320 V5 system. The system was configured to output attitude and position for the top-center of the system's IMU. The POSMV output positioning data to QINSy as standard NMEA strings via RS-232 serial cable. During survey operations, raw POSMV data was continually recorded to a POS file, which was post-processed to improve position and attitude accuracy, and used to apply TrueHeave data.

A GAMS (GPS azimuth measurement subsystem) calibration was done to maximize the heading accuracy of the system. The results are shown in the Table 23.

Date (JD)	A-B Ant Separation (m)	Baseline Vector (m)		
		X (+ stbd)	Y (+ fwd)	Z (+ down)
2013-199	1.999	1.998	0.031	-0.053

Table 23 – POSMV GAMS calibration results.

Positioning data for *Q15* skiff were measured with a Trimble 5700 (T5700) dual-frequency GPS. Vessel heave was also recorded by the T5700, which was extracted and applied to the soundings for heave compensation as described previously in this report. The T5700 was configured to output GGA (GPS position) and ZDA (time synchronization) messages as standard NMEA strings via RS-232 serial cable to HYPACK. Additionally, during survey operations, the T5700 logged raw data to compact flash data card at 10 Hz, enabling post-processing of the positions and extraction of heave records in processing.

Note that since the data was SBES, pitch and roll were not required or logged on the *Q15* skiff, though a fixed pitch correction was later applied (see next section; C.1.4). A heading sensor was also not necessary because the transducer and the navigation antenna were co-located in X and Y.

Refer to Section B of this document for descriptions of uncertainties associated with each system.

C.1.4. Fixed Pitch Correction to *Q15* Skiff Data

Though the *Q15* skiff was not outfit with a pitch sensor, it was necessary to apply a pitch correction to skiff data. A constant pitch correction of -6.25 degrees was applied through the CARIS HIPS GDP to all skiff lines. The value was determined as a best average correction following multiple iterations of crossline comparisons, with values greater or less than -6.25 returning higher standard deviations on crossline comparisons. Uncertainty is estimated at a relatively high +/- 5 degrees due to the constantly changing pitch of the skiff.

When surveying, the skiff operated in a consistently bow-up fashion (i.e. not on step), causing the transducer to angle forwards. This had the result, without the pitch corrector, of causing soundings to be deeper overall than actual, except when going upslope when soundings would show shoaler than actual. The effect of the error (pre-correction) was on the order of 0.10 m. After application of the pitch correction factor, this effect was largely eliminated, resulting in better matchup with itself as well as *Q105* MBES data.

C.1.5. Calibration / Patch Tests

On the *Q105*, patch tests were performed to determine latency, pitch, roll and yaw offsets between the POSMV and the Reson multibeam systems. Results were then applied as fixed correctors for all multibeam data through the HVF.

The tests were done over part of the survey area which had relatively large feature. A test was performed near the start of the project to establish initial values, and again near the end of the project to re-check the values. Values were consistent between the patch tests, though roll showed small variations between tests as described in Section C.1.7.

On the *Q15* skiff, a calibration was performed to determine latency between the Trimble 5700 and the Odom echosounder systems. The test was done over part of the survey area near the Red Dog dock, which had a combination of slope and abrupt bottom changes.

The calibration test data for each vessel is available for review with the CARIS HIPS deliverables in the Calibrations project.

C.1.6. Latency, Pitch, and Roll

The *Q15* skiff, which was outfit with only a SBES system, received a latency check only. The *Q105*, which was outfit with a multibeam system, received full patch tests for all sensors.

To determine latency, a survey line was run twice – in the same direction – at low and high speeds over the feature. The data was examined in CARIS HIPS Calibration mode. Any horizontal offset of the features indicated latency between the positioning and sounding systems. A correction (in seconds) that improved the matchup was determined and entered into the HVF.

Note that the timing correction was entered into the HVF for the Swath1 sensor instead of the navigation sensor, which resulted in the correction being applied to all positioning and attitude data (not just navigation). This was desirable because latency, determined with the POSMV, is system-wide and, therefore, affects all output data. The sign of the value found also needed to be reversed since the correction was being added to the Swath1 sonar times instead of the navigation sensor.

To determine pitch offset, a third line was run back over the feature at low speed in the same direction as the first line. The first and third lines were examined for feature alignment. Any remaining horizontal offsets of bottom features in this line set following latency correction indicated the pitch offset between the attitude and sounding systems. The value which best compensated for the pitch misalignment was entered into the HVF.

Yaw offset was then determined, following the corrections for latency and pitch. Survey lines run in opposite directions with outer beams overlapping the feature were examined. Any remaining horizontal offset of corresponding beams indicated a yaw offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

Roll offset was also determined on the *Q105*. The same survey line run twice over flat bottom topography, in opposite directions, was examined. Any vertical offset of outer beams indicated a roll offset between the sounder and motion sensor reference frames. A value that improved matchup was determined and entered into the HVF.

Note that the roll offset determined by patch tests were found to vary slightly over the course of the project. This is discussed in the next section; C.1.7.

Refer to Section B of this report for uncertainties associated with patch test results. Table 24 summarizes the results.

Vessel	Patch Test Date	Latency Results (seconds)	Pitch Results (degrees)	Yaw Results (degrees)	Roll Results (degrees)
Q105	2013-204* 2013-230	-0.010	1.175	1.500	-0.595
Q15 Skiff	2013-219	0.000	n/a	n/a	n/a
*JD204 patch test results were pre-dated in the HVF to JD198					

Table 24 – Calibration test results.

C.1.7. Adjustments to *Q105* Roll Calibrations

A small variable roll offset (0.00 to -0.110 degrees from original value) was discovered during field operations in the multibeam data on the *Q105*. The issue was apparent as an across-track misalignment when adjacent multibeam lines were viewed in CARIS Subset Mode, causing the bottom that should be flat to vary by up to 0.20 m from port to starboard. The offset was variable, but stable over short periods of time (hours to days), indicating a movement to a new, temporary steady state instead of time synchronization or other potential problems which would show greater frequency of change.

The issue was investigated in the field, though no obvious cause was discovered. It is possible the multibeam pole's hydraulic pack, which supplied constant pressure at 3000 PSI to keep the arm firmly in place against the hull, actually had slightly variable pressure. Another possibility is that the hull at the arm-hull contact point would flex slightly depending on conditions including temperature or the amount of pressure applied.

Efforts were made in acquisition and processing to minimize the error caused by the misalignment. During acquisition, the mount was closely monitored and examined to investigate the cause. Short "roll check" lines were run almost daily after discovery of the issue, along a survey line in the opposite direction. These lines were compared in calibration mode and an adjustment was entered into the HVF file. Additionally, in processing, sequential lines were systematically examined in CARIS Calibration Editor and roll adjustments that best aligned the lines determined.

Correctors were placed into the HVF under the “Roll” sensor. The corrections were applied during sound speed correction and served as fine adjustments on the -0.595 roll value, initially determined by patch test. Following application of the corrections, the incidence of the roll misalignment was reduced overall or eliminated in many places, though negative effects of up to 0.20 m are still periodically visible in the final data set. Despite the error, the data is well within specifications as evidenced by crossline comparison results.

C.2. Speed of Sound Corrections

Sound speed profile data for OPR-S325-KR-13 was collected using an Underway SV. An Odom Digibar and/or AML SV Plus sensor was used for comparison casts. All profilers were factory calibrated prior to commencement of survey operations.

Profiles were collected by acquisition normally on a 2-hour interval. They were processed in TerraSond’s TerraLog software, which produced a CARIS HIPS-compatible format at 0.1 m depth intervals. The output was appended to the master CARIS HIPS .SVP file by survey area.

Sound speed corrections were applied in processing to the raw sounding data through CARIS HIPS “Sound Velocity Correction” utility. The correction method selected was nearest in distance within 2-hours. Deviations, when they occurred, are described in the appropriate DR. The profile selection method was also noted on the line logsheets.

Refer to Section B of this report for more information on acquisition and processing methodology and uncertainties. Refer to the project DRs, *Separate II* for sound speed comparisons. Refer to Appendix IV of this report for calibration reports. Individual profile data can be found in the CARIS HIPS .SVP file submitted with the digital CARIS HIPS data for the survey.

C.3. Static Draft

Static draft measurements were regularly made on each vessel. Measurements were taken on average every 2-3 days on the *Q105*, when conditions allowed. Measurements were taken every survey shift on the *Q15* skiff. Static draft was determined by measuring from a surveyed measure-down point to the water level with the vessel at rest. The measure-down values were recorded in TerraLog.

For the *Q105*, TerraLog averaged the port and starboard measure-downs and reduced the result to the vessel’s CRP using the surveyed offset value for the CRP to measure-down point. This produced the CRP to waterline offset, which was entered as a new waterline value in the CARIS HIPS HVF, and checked to confirm the value fell within the normal range for the vessel. On the *Q15* skiff, it was possible to measure directly from the CRP to the waterline.

The waterline correction was applied to the soundings by CARIS HIPS during sound velocity correction.

Refer to Section B for uncertainties associated with static draft measurements. Static draft tables are available in the HVF with the CARIS HIPS deliverables. Logsheets exported from TerraLog are available with the project DRs, in Separate I.

C.4. Dynamic Draft Corrections

Dynamic draft corrections were determined by means of a squat settlement test. PPK GPS methods were used to produce and extract the GPS altitudes from the test. Corrections were determined for a range that covered normal engine RPMs and vessel speeds.

C.4.1. Squat Settlement Test Procedure

During the squat settlement test, the vessel logged raw POSMV attitude and positioning data to the POS file (*Q105*), or raw positioning data from the T5700 (*Q15* skiff), while the nearby shore base station (REDD) logged dual-frequency GPS data at 1 Hz. A survey line was run in each direction, at incrementing engine RPM/speed. Between each line set, as well as at the start and end of the test, a “static” was collected whereby the vessel would sit with engines in idle and log for a minimum of 2-minutes. The survey crew would note the time and speed of each event.

The POS (or T5700) file was post-processed concurrent with the nearby base station data in Applanix POSPac software to produce the PPK 3D positioning data, which was brought into Excel. Using the event notes, the positioning data was separated and grouped according to RPM/speed range, or static. Each range was averaged to remove heave and motion. A polynomial equation was computed which best fit the static periods, then used to remove the tide component from each altitude. The residual result was the difference from static or dynamic draft. Finally, the results were averaged for each direction to eliminate any affect from the current, wind or other factors.

The table of corrections for dynamic draft as a function of speed was compiled from this data, and applied as a speed-to-draft table entered into the HVF. For this survey, it was deemed acceptable to apply speed-based instead of RPM-based corrections, because current rarely exceeded 2 knots in the area.

C.4.2. R/V *Q105* Dynamic Draft Results

A squat settlement test was completed on the *Q105* on July 26-27th, 2013 (JD207-208). Speed values between 6.2 knots (3.2 m/s) and 10.2 knots (5.3 m/s), which were below and above the minimum and maximum speeds commonly used during survey operations, were tested. The results are shown in Table 25.

Speed (m/s)	Dynamic Draft (m) (positive down)
3.190	0.017
3.395	0.016
3.601	0.021
3.807	0.031
4.013	0.043
4.218	0.055
4.424	0.066
4.630	0.073
4.836	0.073
5.042	0.065
5.247	0.046

Table 25 – R/V Q105 settlement results.

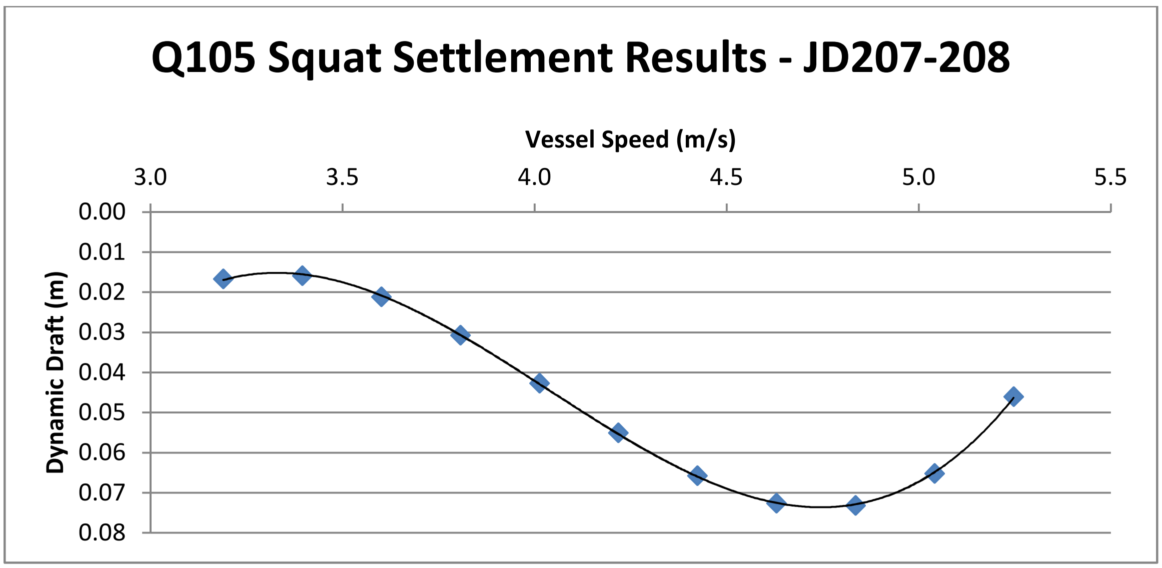


Figure 22 – Q105 settlement results. Vertical units are meters, positive down.

C.4.3. Skiff *Q15* Dynamic Draft Results

A squat settlement test was completed on the *Q15* skiff on August 11-12th, 2013 (JD223-224). Speed values between 4.4 kts (2.3 m/s) and 10 kts (5.1 m/s), which were below and above the minimum and maximum speeds commonly used during survey operations, were tested. The results are shown in Table 26.

Speed (m/s)	Dynamic Draft (m) (positive down)
2.289	0.058
2.469	0.075
2.752	0.103
2.855	0.116
2.932	0.146
3.164	0.168
3.575	0.200
3.833	0.228
5.144	0.228

Table 26 – Skiff Q15 settlement results.

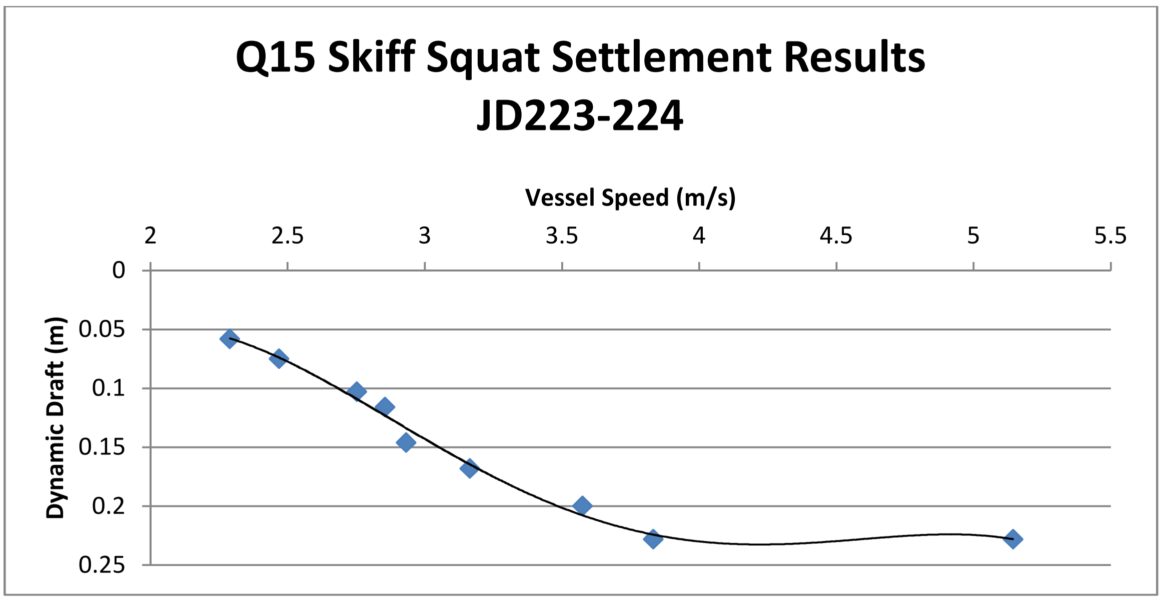


Figure 23 – Q15 Skiff settlement results. Vertical units are meters, positive down.

C.5. Tide Correctors and Project Wide Tide Correction Methodology

Traditional (discrete) tide zones were applied to the entire project to bring soundings to MLLW. The NWLON tide station at Red Dog Dock (949-1094) was used for tide corrections, with range and time correctors applied through a zone definition file (ZDF). Data from four BMPG submersible tide gauge deployments, which were located at the extreme ends of the survey area, was used in creation of the ZDF. Additional detail on tides and tide zoning is available in the project HVCR.

APPROVAL SHEET

For

H12520 through H12523

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the completion of this project were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate per the Statement of Work and Project Work Instructions. Other reports submitted with this survey include the Descriptive Report (one for each survey sheet) and the Horizontal and Vertical Control Report.

This survey is complete and adequate for its intended purpose.

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