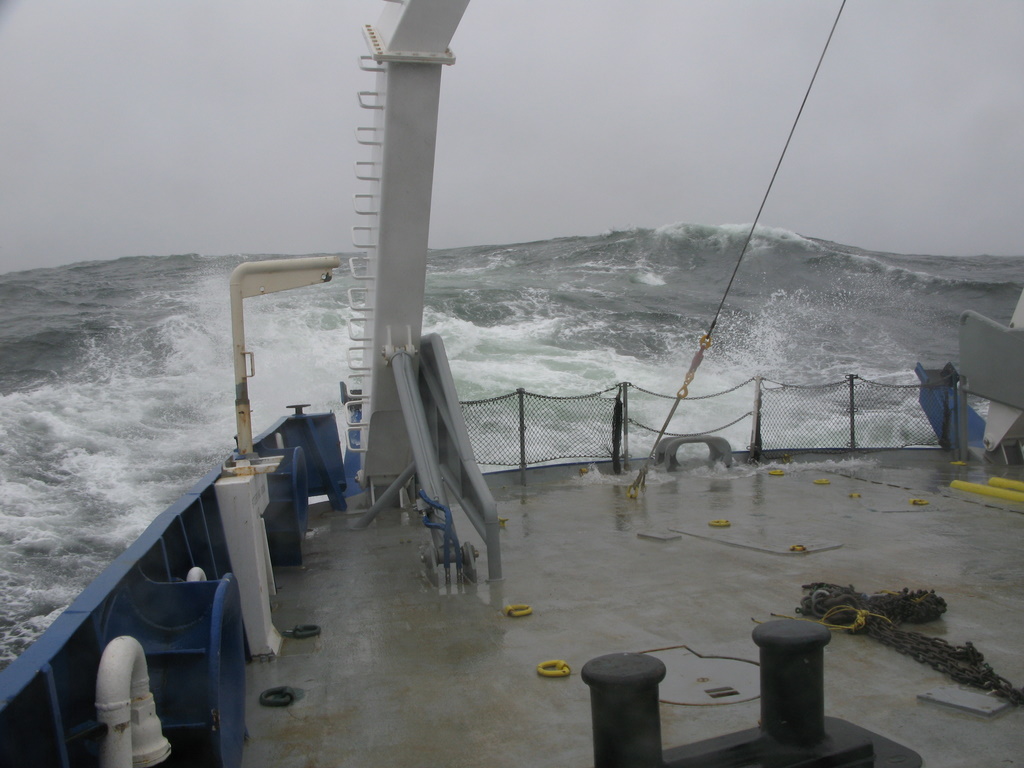
Data Acquisition and Processing Report

Pribilof Shell Hash Survey



Bering Sea wavescape from the back deck of the Mt. Mitchell

Contract Number: **DG133-C08-CQ-0005**

Vessels: R/V Mt. Mitchell

Survey: **Pribilof Shell Hash Survey**

State: **Alaska**

General Locality: **Central Bering Sea**

Sublocality: **Pribilof Islands**

Survey Dates: **June 16, 2009 to June 17, 2009**

Lead Hydrographer: **Chris Popham**

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***Overview***

All work for the Pribilof Shell Hash Survey was completed to meet NOS Hydrographic Surveys Specifications and Deliverables for 2008.

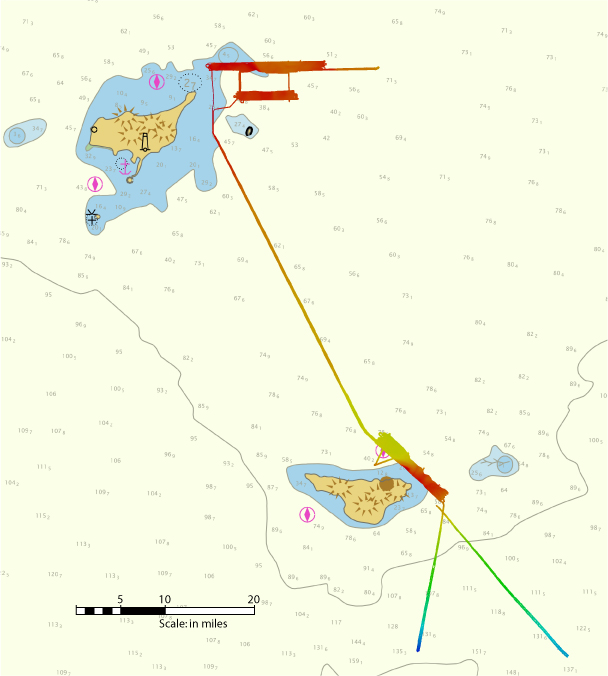


Figure 1 – Survey area for the Pribilof Shell Hash Survey. Background chart is NOAA ENC US3AK8CM 9th Edition.

1. Equipment
   1. Vessels

All data for this survey were acquired using the *Research Vessel Mt. Mitchell.*

* + 1. *R/V Mt. Mitchell*

Multibeam Bathymetric and Backscatter data for Pribilof Shell Hash Survey were acquired using the *R/V Mt. Mitchell.*

The *R/V Mt. Mitchell*, shown in , is a 70 meter steel hulled vessel with a 12.7 meter beam and a 3.9 meter draft. The ship was powered by two 1200 HP EMD/567C General Motors Diesel engines connected to Bird-Johnson controllable-pitch propellers operating between 10% and 80% pitch. Electrical power was provided by two Detroit Diesel 300 kW generating plants located in the engine room and one Detroit Diesel 75 kW auxiliary generator. The *R/V Mt. Mitchell* was outfitted with a hull-mounted Multibeam Echo Sounder System (MBES), Kongsberg Simrad EM 710RD. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.



Figure 2 – R/V Mt. Mitchell anchored in Seward, Alaska.

* + - 1. Equipment Overview

The equipment on board the *R/V Mt. Mitchell* performed within required specifications during the survey.

* + - 1. Major Operational Systems

*R/V Mt. Mitchell* Survey Equipment

Table – Table showing the major survey equipment used on board the R/V Mt. Mitchell.

|  |  |  |  |
| --- | --- | --- | --- |
| ***Description*** | Manufacturer | ***Model / Part*** | ***Serial Number*** |
| Multibeam Echosounder | Kongsberg Simrad | EM 710 RD | 201 |
| Sonar Acquisition | Primary: Simrad  Secondary: QPS | SIS 3.4.1  QINSY 8.0 | N/A |
| Positioning System | Applanix | POS M/V V4 | 3034 |
| Motion Sensor | Applanix | POS M/V - IMU 200 | 727-412110 |
| SV Probes | Lockheed Martin  Lockheed Martin  AML  AML | XCTD-2  XBT T-5  Smart SV & T  SV Plus V2 | 099922872-  0922883  342813 –  342836  005433  3317 |
| GPS corrector | Primary:  CNAV  Secondary:  Hemisphere GPS | 2050R NaviGator  MBX-3 | 601099  0171616000008 |

* + - 1. Sounding Equipment

A Kongsberg Simrad EM 710 RD multibeam echo sounder system was used aboard the *R/V Mt. Mitchell* during the Pribilof Shell Hash Survey

The EM 710 is a 200-beam Mill’s Cross system operating between 70 KHz and 100 KHz. The system features 2 degrees along-track, and a 2 degrees across-track beam angles. The EM 710 was set to high density equidistant mode to get 200 beams. To achieve these high density data, the sonar signal is sampled multiple times for each ping. Bathymetric datagrams were output from each echosounder via an Ethernet connection to the acquisition software. The system’s bottom tracking algorithm adjusts the gain, mode and range dependent parameters as required. The system uses a combination of phase and amplitude bottom detection to provide soundings with the best possible accuracy. The swath width and vessel speed were monitored and adjusted by the operator in order to meet NOS specifications.

* + - 1. Technical Specifications

Table 2 – Kongsberg EM 710 multibeam echosounder technical specifications.

|  |  |
| --- | --- |
| **Kongsberg EM 710** | |
| Sonar Operating Frequency | 70 kHz - 100 kHz |
| Beam Width, Across Track | 2.0° |
| Beam Width, Along Track | 2.0° |
| Number of Beams | 200 max |
| Max Swath Coverage | 140° |

* 1. Tide Gauge

The NOAA tide station at Village Cove, St. Paul Island, AK (946-4212) was used to provide verified tide data for the Pribilof Shell Hash Survey. The maximum tidal range for the survey was .8 meters (with an accuracy of +/-3mm). All data were downloaded from the NOAA Tides and Currents website at: http://tidesandcurrents.noaa.gov/.



Figure 3 - Location of tide station used in the Pribilof Shell Hash Survey.

* 1. Speed of Sound

Speed of Sound data were collected by vertical casts on the *R/V Mt. Mitchell* primarily using Lockheed Martin Sippican XBT T-5 and XCTD-2 expendable sound velocity profilers. An Applied Microsystems Smart SV&T was on board as well, and was used to verify the accuracy of the XBT and XCTDs.

Sound speed profiles were geographically distributed within the survey area and taken with a frequency limited by the number XBT and XCTD probes on hand. Sound speed profiles extended to 100% of the anticipated water depth. Sound velocity profiles were modified to repeat the final valid SV value at a user defined depth of 12,000m. This was necessary for SVP application in Kongsberg SIS acquisition software as SIS modifies its absorption coefficient algorithms based on a full ocean range of depths. No data quality issues related to speed of sound measurements were encountered during the survey, however in post processing a clear SV anomaly was encountered. This is fully discussed in the Data Acquisition and Processing Report (DAPR)

Refer to the Descriptive Report (DR), *Separate II: Sound Speed Data* for detailed information about specific cast dates and procedures used.

The following instruments were used to collect data for sound speed profiles on the *R/V Mt. Mitchell.*

R/V Mt. Mitchell

Table 3 – Table listing the sound speed measuring equipment used during the Pribilof Shell Hash Survey.

|  |  |
| --- | --- |
| Sound Velocity and Temp. Sensor | SV Plus V2 |
| Manufacturer | Applied Microsystems Ltd.  Sydney, British Columbia, Canada |
| Serial number | 3317 |
| Calibrated | 26/02/2009 |

|  |  |
| --- | --- |
| Sound Velocity and Temp. Sensor | Smart SV&T |
| Manufacturer | Applied Microsystems Ltd.  Sydney, British Columbia, Canada |
| Serial number | 5433 |
| Calibrated | 23/04/2009 |

|  |  |
| --- | --- |
| Expendable Temperature Profiler | XBT T-5 |
| Manufacturer | Lockheed Martin Sippican  Marion, Massachusetts, USA |
| Serial number | 342813 – 342836 |
| Calibrated | Prior to Shipment |

|  |  |
| --- | --- |
| Expendable Conductivity and Temp. Profiler | XCTD-2 |
| Manufacturer | Lockheed Martin Sippican  Marion, Massachusetts, USA |
| Serial number | 099922872 – 0922883 |
| Calibrated | Prior to Shipment |

* 1. Positioning Systems

Position control for the *R/V Mt. Mitchell* was provided by an Applanix Pos M/V v4 Positioning System. The primary source for navigation correctors was a C-NAV 2050R GcGPS (Globally corrected GPS). This system was selected because DGPS positioning was not available for this survey as the Pribilof Islands are located outside the range of Coast Guard Continually Operating Reference Stations (CORS). The CNAV uses a global network of positioning corrections broadcast by geostationary satellites eliminating the need for local reference stations. The CNAV system meets survey requirements with a claimed worldwide accuracy of 0.1 meters horizontally and 0.2 meters vertically. The vessel’s position was recorded using both Kongsberg SIS and QPS QINSy acquisition software at 1Hz intervals using National Marine Electronics Association (NMEA) message $GPGGA.

Two C-NAV system confidence checks were performed before and after the survey, within range of the U.S. Coast Guard Continually Operating Reference Station (CORS) located in Cold Bay, AK (Station ID 898). This station operates at a frequency of 289 kHz and was received by a CSI wireless MBX-3 Differential Beacon Receiver. The DGPS enabled POS M/V and the C-NAV positions were compared to a common node at regular intervals. The differences in the Northing and Easting values were calculated and graphed. The positions did not exceed 5 meters + 5 percent of the depth of the given line in section 3.1 of the Specifications and Deliverables April 2008. The DGPS confidence checks are provided in the DR, *Separates I: Acquisition and Processing Logs*.

Specific details addressing horizontal control activities associated with this project are discussed in the Vertical and Horizontal Control Report.

* 1. Attitude Sensors

An Applanix POS M/V Inertial Measurement Unit (IMU) 200 was used to measure heave, pitch and roll values to be used to correct for the motion in the sounding data from the *R/V Mt. Mitchell*. Detailed descriptions of all attitude corrections are provided in Section C: Corrections to Echo Soundings.

* 1. Data Collection
     1. Overview

The survey was conducted using Multibeam Bathymetry and Backscatter collection techniques with the *R/V Mt. Mitchell*. No single-beam or side-scan data were collected. On the *R/V Mt. Mitchell*, data were collected on a 24 hour basis using two crews with shift changes every 12 hours.

* + 1. Coverage

Within targeted survey blocks, lines were run to ensure a minimum of 100% multibeam coverage, as described by the requirements of the NOS Hydrographic Survey Specifications and deliverables, Section 5.1.1.

* + 1. Line Planning

Targeted survey areas were chosen en route to the Pribilofs. As targeted areas were chosen, planned lines were initially run to establish a baseline from which to expand. Beyond this however, the technique of “painting” was used for the majority of the survey.

* + 1. Ping Rates

The ping rate was determined by the SIS acquisition software and vessel speed was adjusted to meet NOS specifications. As a general rule, propeller pitch / vessel speed was held constant throughout a survey line, however with the varying depths near the Pribilofs, frequent changes in vessel speed were needed to maintain Ping Rates that met NOS specifications for sounding density. These changes in pitch and speed were documented in the daily acquisition logs. For the entirety of the Pribilof Shell Hash Survey, the ping rate met or exceeded the specifications set forth in NOS Hydrographic Survey Specifications and Deliverables, Section 5.1.1.

* 1. Software and Hardware Summary

Multibeam data were collected on an Intel Pentium IV PC using Kongsberg SIS data collection software (Bathymetric & Backscatter) operating in a Microsoft Windows XP environment. Additionally, data were input to QPS QINSy acquisition and navigation software and were used to generate a real-time digital terrain model (DTM) during each survey line. The DTM was used in the field to determine whether the survey line had been completed with adequate bottom coverage. The DTM was used as a field quality assurance tool and was not used during subsequent data processing. All raw bathymetric and backscatter data, as well as position and sensor data were recorded in the SIS native .all format and were processed using CARIS Hydrographic Information Processing System (HIPS). Final survey coverage determination was made following data processing with CARIS HIPS and SIPS.

CARIS HIPS hydrographic data processing software was used for multibeam quality assurance. Data post-processing procedures are described in detail in Section B. Quality Control.

Table 4 lists the software used on the *R/V Mt. Mitchell* during the survey and Table 5 lists the software used in the office during pre-survey planning and post-survey processing:

* + 1. Vessel Software

Table 4– Software used aboard the R/V Mt. Mitchell.

|  |  |  |  |
| --- | --- | --- | --- |
| Program Name | Version | Date | Primary Function |
| Kongsberg EM 710 |  |  | Sonar firmware |
| Kongsberg SIS | 3.4.1 |  | Kongsberg MB controller and collection software |
| QPS QINSy | 8.0 | 2008 | Multibeam data collection and navigation suite |
| POS MV V4 |  |  | Positioning |
| POS MV IMU – 200 |  |  | Attitude Sensor |
| Corpscon | 5.11 | 2001 | Coordinate conversion |
| Nautical Software Inc. Tides and Currents for Windows | 2.2 | 1996 | Predicted Tides |
| TerraSond Ltd. Simple SV Software | 1.0 | 2007 | Convert sound speed raw data to CARIS compatible format. |
| Posview | 3.4 | 2007 | Pos M/V setup and monitoring |
| Terramodel | 10.6 | 2009 | Line Planning |

* + 1. Office Software

Table 5 – Software used in the office during post processing.

|  |  |  |  |
| --- | --- | --- | --- |
| Program Name | Version | Date | Primary Function |
| CARIS HIPS & SIPS | 6.1 | 2006 | Multibeam data processing software |
| CARIS BASE Editor | 1.0 & 2.0 | 2006 | Bathymetry compilation and analysis software |
| CARIS GIS Professional | 4.4 | 2006 | Marine GIS information management software |
| Autodesk MAP 3D 2006 | 4.0 | 2006 | Drafting software |
| Blue Marble Geographics Geographic Transformer | 5.2 | 2006 | Image georeferencing and reprojection software |
| MapInfo Professional | 6.5 & 8.5 | 2001 & 2006 | Desktop mapping software |
| Corpscon | 5.11 | 2001 | Coordinate conversion software |
| Fledermaus / Geocoder | 7.0 | 2009 | Backscatter Processing |

1. Quality Control
   1. Overview

Every effort was made to ensure the integrity and traceability of multibeam bathymetry and backscatter, attitude, and navigational data as it was moved from the acquisition phase through processing. Consistency in file and object naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

CARIS HIPS 6.1 was used for the multibeam data processing tasks on this project. HIPS was designed to ensure that all edits and adjustments made to the raw data, and all computations performed with the data follow a specific order and are saved separately from the raw data to maintain the integrity of the original data.

* 1. Equipment Calibration

Each item of survey equipment was calibrated prior to the survey to assess the accuracy, precision, alignment, timing error, value uncertainty, and residual biases in roll, pitch, heading, and navigation. The EM 710 calibration was completed by conducting a patch test prior to transiting to the survey area. All sound velocity and water surface measurement instruments were factory calibrated within the 6 months before use as required in section 5.1.3.3 of the NOS Specification and Deliverables. Furthermore they were confidence checked during their use on the Pribilof Shell Hash Survey.

* 1. Survey System Confidence Checks

Secondary GPS data from a C-nav GPS receiver were collected concurrently with the position, attitude of the POS M/V. Both positioning systems were logged in QPS QINSy acquisition software. The C-Nav GPS data included position information, and C-Nav positional quality verification information. All data were time-referenced at 1-second intervals. These are not entirely independent positional measurements as the POS M/V was receiving positional correctors from the C-Nav. This was necessary as the survey area was outside the range of Coast guard DGPS stations.

Independent positional confidence checks were performed however before and after the survey with in range of the coast guard DGPS beacon in Cold Bay, AK. Details of this check are addressed in section A.1.4 of this report.

Cross lines were run as a confidence check for the multibeam sonar. The total linear nautical miles of crosslines exceeded five percent of the linear nautical miles of main scheme lines. Initial data processing was performed on board the acquisition vessel upon the completion of each survey line. Adjustments were then made to equipment settings based on preliminary processing and, if necessary, survey lines were rerun.

A nadir beam confidence check was performed on the MBES prior to survey. The confidence check consisted of comparing lead line depths with depths logged by the MBES nadir beam. The calibration check was performed by measuring the depth under the ship with a calibrated sounding lead line and comparing the value with the nadir-beam depth recorded by the MBES. All measurements were corrected to vessel central reference point (CRP). The lead line used for the calibration checks was constructed from a metric steel-reinforced fiberglass survey tape with a steel weight attached to the end in such a way that the bottom of the weight was 0.0 m. The lead line was checked prior to the survey for accurate length. Lead line measurements were taken from punch marks established during the vessel survey. The starboard and port measurements were averaged and the value was reduced to the CRP. This value was compared to the nadir depth reduced to the CRP. The differences between measured and observed values were within sounding error limits specified for this survey.

The DR, *Separate I: Acquisition and processing logs* contains a summary of the calibration checks performed for each survey.

* 1. Data Collection

Multibeam bathymetry and backscatter data collection was performed using Kongsberg SIS data acquisition software. The file naming convention was inherent to SIS and ensured that individual survey lines had unique names based on time of collection. SIS software generated “.all” files which in addition to bathymetry and backscatter, contained positional and attitude information, both surface and full profile sound velocity, and vessel offset and alignment calibration values. All raw data files were stored on the acquisition computer’s hard drive for the duration of the survey.

Multibeam bathymetry data were also logged by QPS QINSy acquisition software for the EM 710. These files included navigation, attitude and heading data from the Pos MV as well as the secondary positioning data from the CNAV

The POS M/V was set up to log Pos Pac data for both PPK and true heave to use in post processing if deemed necessary.

SVP data were acquired with Sippican WinMark 21Sound velocity profiler software as binary .rdf files and exported in ascii .edf file format. The raw files from XCTD probes were further edited into a format compatible with TerraSond Ltd. Simple SVP conversion software. Sound velocity files were then converted to CARIS format with Simple SVP formatting software. CARIS .svp files were stored in the SVP folder in the CARIS folder structure. Sound velocity profiles were further converted into .asvp format for real-time use in Kongsberg SIS acquisition software.

Chronological logs containing information specific to each line were maintained as an independent reference to aid in data integration and error tracking. Acquisition logs included the line name, start and end times, ping rate, range and power settings for each sonar in each acquisition software. Acquisition logs included any additional comments deemed significant by the operator.

* 1. Initial File Handling

Shipboard data handling proceeded as follows: As multibeam data collection was conducted, Kongsberg SIS Acquisition software split the raw .all files into thirty minute (30 min) segments. Each segment was then organized by Julian day, and placed onto the network data storage device. The .all files are then converted into CARIS HIPS multibeam data processing format and then saved into the CARIS directory. Ultimately the project data reside on a networked attached storage (NAS) device in a directory identifying the project name, vessel name, and Julian date.

All acquisition data (both raw and processed) resided on a NAS unit with a redundancy level of RAID 5. The NAS unit itself was independently backed-up twice daily onto an independent mirrored storage device. The 2 tiered levels of back-ups insured data security and the ability of the system to resist catastrophic equipment failure.

* 1. Field Data Processing

Preliminary multibeam data processing was completed aboard the survey vessel. Following the initial file conversion and backup, predicted tide data were loaded and each line was merged with the sounding data in CARIS HIPS. Navigation, Heave, Pitch, and Roll were already applied and accounted for by the Simrad beam steering algorithms, but were examined for errors in CARIS HIPS. The data were then cleaned using CARIS HIPS and SIPS subset editor and a multi-resolution BASE Surface was created to verify coverage and provide quality control feedback to the survey crew.



Figure 4 illustrates the major steps in the data acquisition and reduction process. The text following the diagram provides a detailed explanation of each step.

* 1. Office Data Processing
     1. Initial Processing: Import, QC, and Predicted Tide Application

TerraSond, Ltd. incorporates a systematic, rigorous approach to the editing and development of survey data received from the field. This ensures the maintenance of data integrity throughout the editing process.

CARIS HIPS software was used to create a folder structure organized by project, vessel, and Julian day to store data. Multibeam raw data were imported into CARIS HIPS using the CARIS conversion wizard module. The wizard was used to create a directory for each line and separate the “.all” files into sub-files which contained individual sensor information. All data entries were time-referenced using the time associated with the “.all” file to relate the navigation, azimuth, heave, pitch, roll and slant range depths sensor files.

CARIS HIPS was used for the majority of the processing and adjustments made during sounding reduction. CARIS HIPS does not allow raw data manipulation during processing. All raw data is maintained in the original, unmodified, format to ensure data integrity. TerraSond, Ltd. uses well defined procedures during the sounding reduction process and all actions are tracked to ensure that no steps are omitted or performed out of sequence.

Survey lines were initially opened in the HIPS line editor mode by selecting the project, vessel, day and desired line.

Preliminary soundings were tide adjusted using predicted tide data from the National Water Level Observation Network (NWLON) station at Village Cove, St. Paul, AK (946-4212) through June 25th, 2009. No range, amplitude, or zoning schemes were applied. Refer to Section C. Corrections to Echo Soundings, of this report, for detailed information concerning final sounding reduction.

Attitude data were viewed in the CARIS Attitude Editor which displayed simultaneous graphical representation of all attitude data using a common x-axis scaled by time. The Attitude Editor, like the Navigation Editor, was used to query the data and reject erroneous values.

Navigation data were reviewed using the CARIS Navigation Editor. The review consisted of a visual inspection of plotted fixes noting any gaps in the data or unusual jumps in vessel position. Discrepancies were rare and were handled on a case-by-case basis. Unusable data were rejected with interpolation using a loose Bezier curve. Data were queried for time, position, delta time, speed, and status and, if necessary, the status of the data was changed from accepted to rejected.

* + 1. Initial Merging

After inspecting the navigation and attitude data, the tide corrected data were merged with the navigation and attitude data. This initial merging step was conducted with an incomplete vessel configuration file featuring preliminary patch calibration, and sensor offset values. The merging process converted time-domain data into spatial-domain, geographically referenced soundings, and enabled the area based data editing process.

* + 1. Area Editing

Following the merging process, area-based editing processes in CARIS HIPS Subset Editor was performed during the office review of survey soundings. During subset editing, the operator was presented with two and three-dimensional views of the soundings and a moveable bounding box to restrict the number of soundings being reviewed. Soundings were viewed from the south (looking north), from the west (looking east) and in plan view (looking down). These perspectives, as well as controlling the size and position of the bounding box, allowed the operator to compare lines, view features from different angles, measure features, query soundings and change sounding status flags. Soundings were also examined in the three-dimensional window as points, wire frame or a surface which could be rotated on any plane. Vertical exaggeration was increased as required to amplify trends or features. Soundings were flagged as accepted, rejected, designated, outstanding or examined.

In the first phase of area editing, processors examined the entire survey area in CARIS HIPS Subset Editor and rejected outlying soundings unsupported by data from adjacent survey lines. Simultaneously, the data were scrutinized for any potential tide and sound velocity issues that would require further investigation.

* + 1. Anomalous SV Profiles

Sound Velocity (SV) application in CARIS HIPS 6.1 revealed a sound velocity anomaly that became apparent upon inspection of soundings in subset editing.

The SV anomaly took the form of a consistent frown throughout the dataset.

SV casts were applied by the CARIS HIPS “Nearest-in-Distance” function. The “Nearest in Distance” was the preferred method of SV application as the survey was conducted through several distinct water bodies (assumed from real time surface SV values) and other methods of SV application proved less consistent.

Troubleshooting efforts turned to the SV application and beam tracing algorithms in CARIS. CARIS’s Simrad SV application strips the beam corrections applied by the Simrad system in real time, and re-applies them in processing. Terrasond was concerned that CARIS was not performing this correctly and/or doubly correcting the beam trajectories. Communications with CARIS representatives confirmed that Terrasond was using the most recent software versions and that SV corrections were indeed being applied correctly.

Further investigation of the HIPS Vessel configuration with CARIS representatives assured us that our vessel setup was correct.

Focus turned to the SV casts themselves. Sound velocity casts were taken with Lockheed Martin Expendable Bathymetric Thermographs (XBT’s) and expendable conductivity/temperature/depth sensors (XCTD’s). The XBT’s measure water temperature and apply a user-defined salinity (from XCTD) to derive sound velocity.

In communications with Lockheed Martin, XBT’s are least reliable in bodies of water featuring large changes in salinity, as a single salinity value is used to calculate the sound velocity for the entire water column. The Bering Sea features a well documented cold-water body at depth possessing different salinity characteristics that could contribute to this SV anomaly. However on inspection of the XCTD data for both St. George and St. Paul, no sizeable conductivity/salinity changes are apparent.

Additionally, the accuracy of the XBT-derived sound velocities was checked at the end of the survey with a traditional AML Smart Probe and was well with in the NOS specified tolerances.

Terrasond could not find a solution to this sound velocity anomaly. In light of the consistent nature of the frown throughout the survey, approval was sought from NOAA to use a single SV profile from St. George to apply to St. George Data, and an averaged SV profile for the entire Pribilof region to apply to St. Paul data. This procedure nearly eliminates the SV anomaly in the data set, and brings the survey to a level of internal consistency such that all crosslines pass NOS spec crossline criteria for an IHO order 1 survey.

The DR, *Appendix V: Supplemental Survey Records & Correspondence* contains the entirety of this communication with NOAA.

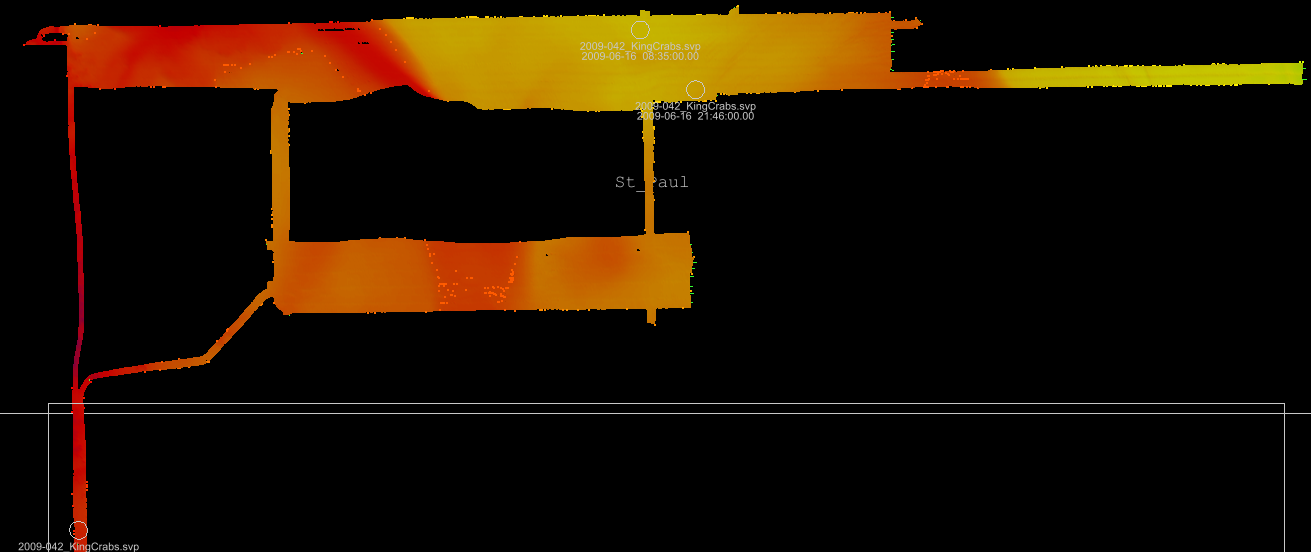


Figure 5: St Paul survey area featuring SV Cast locations

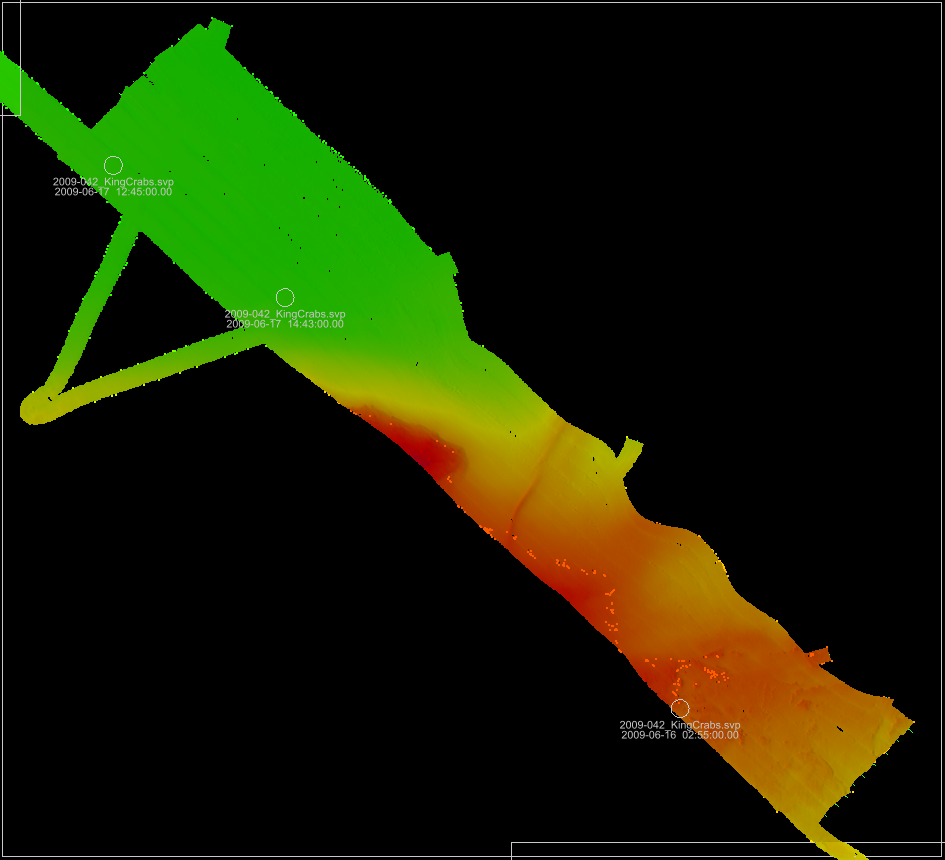


Figure 6: St. George survey area featuring SV cast locations

Figure 7: Graph of SV profiles. Two high velocity outliers were discarded as they created “smiles”. The Southern St. George profile was used for St. George data. The Averaged velocity was used for St. Paul data and Northern Transit lines.

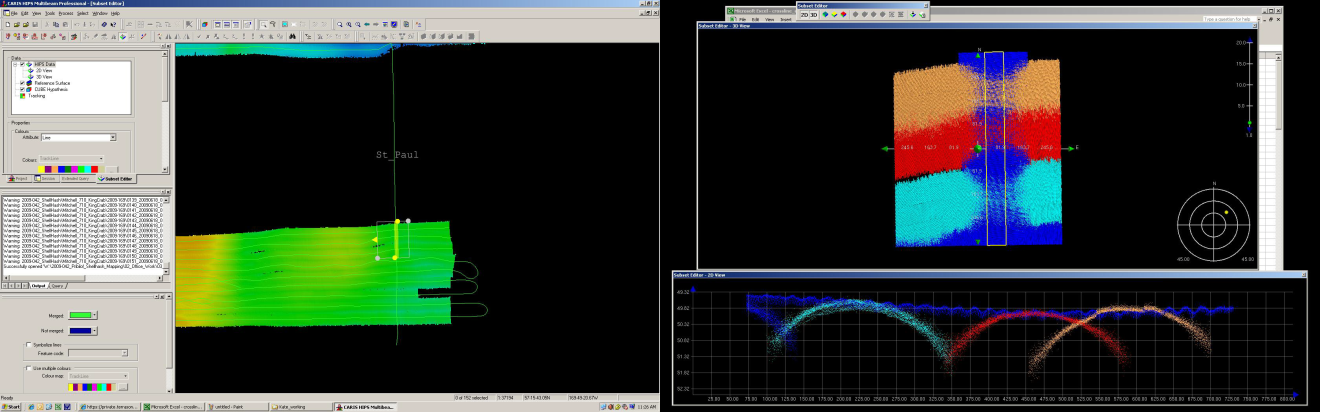


Figure 8: CARIS HIPS Subset editor snapshot of 2d and 3d views showing pre-refraction-corrected data and the SV anomaly

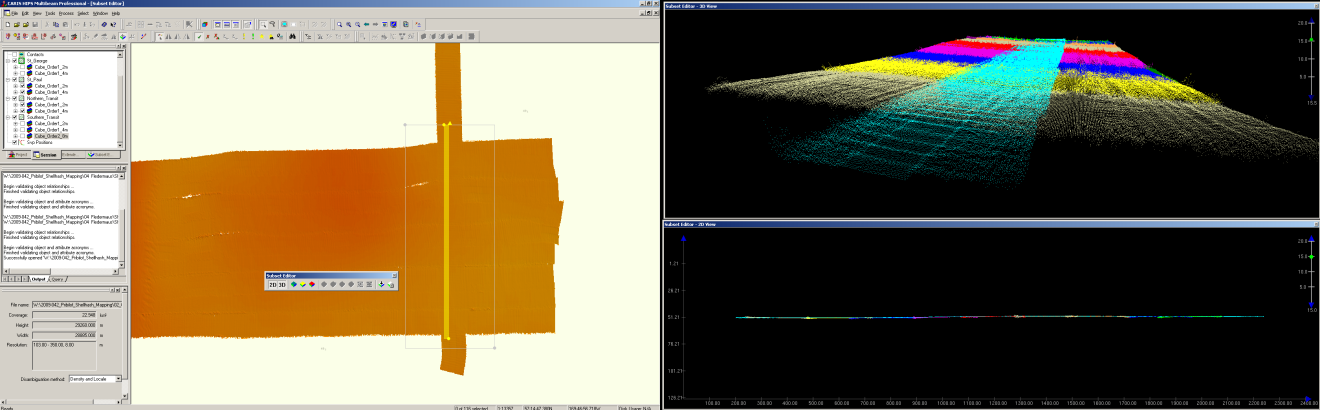


Figure 9: CARIS HIPS Subset editor snapshot of 2d and 3d views showing post-corrected data

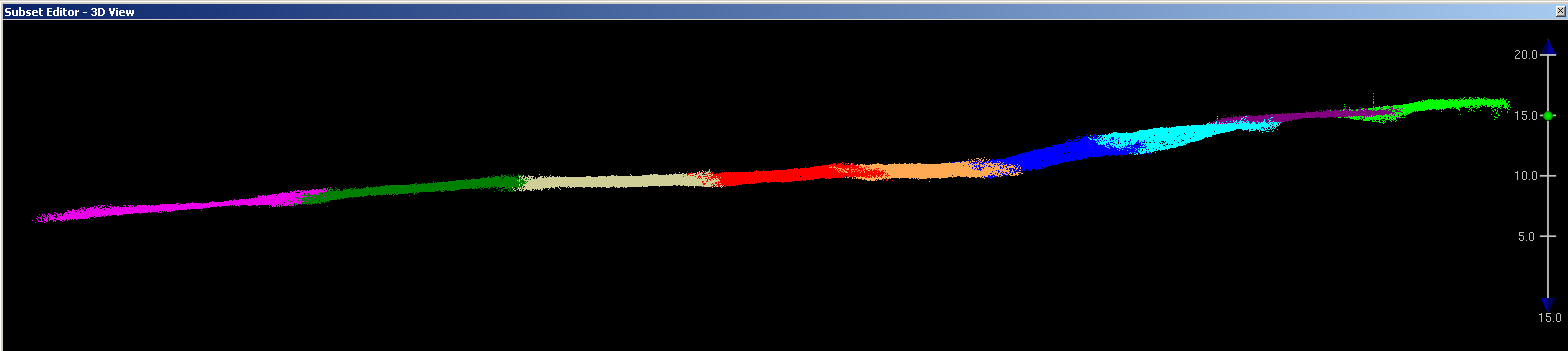


Figure 10: CARIS HIPS 2d snapshot showing a cross section of the data vertically exaggerated to 15x, notice the internal agreement of data post correction.

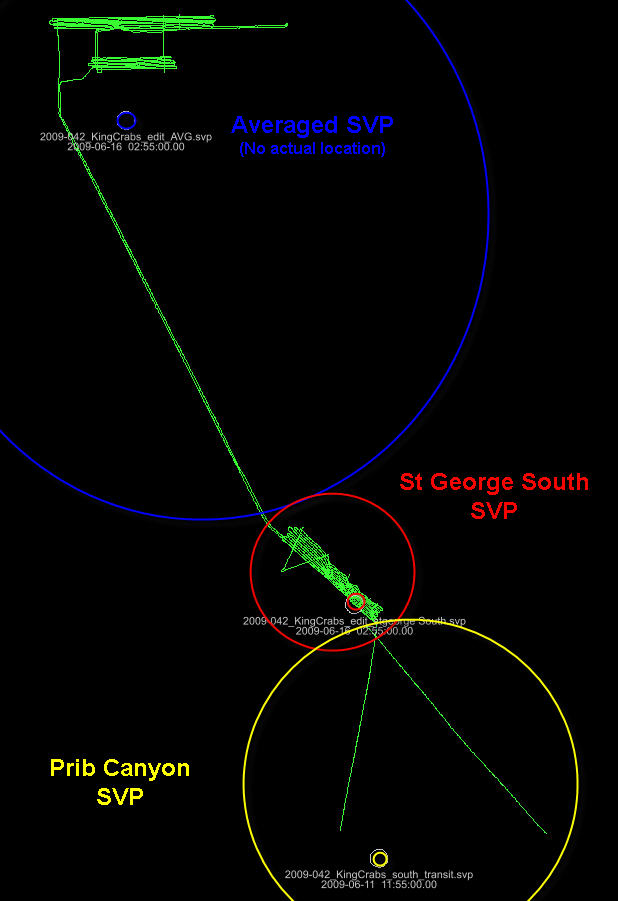


Figure 11: CARIS HIPS screen grab diagramming the final SV application solution for the Pribilof Shell Hash Survey.

* + 1. HIPS Final Processing

Several finalized values were applied to the data in the final processing steps in CARIS HIPS. A verified tide file was downloaded and applied to the survey area prior to the final merge. Sound Velocity casts were applied based on the methods described above in section *C.7.4.*

Static draft observations were entered in the vessel configuration file. The measure down value used to calculate this value varied 3cm between the beginning and the end of the survey therefore for simplicity; a single value was used for static draft based on the initial measure down value. The 3cm maximum potential error accrued from the application of a single static draft value is well within the error budget of this survey.

Dynamic draft values were calculated and entered in the HIPS vessel configuration file. CARIS HIPS uses dynamic draft tables based on vessel speed and not propeller pitch as was the controlled variable on-board the *R/V Mitchell*. Average vessel speed was computed for the range of propeller pitches.

The final processing step before TPE calculation and data export was a final merging of all data. This merge resulted in the final geographical positions of each sounding relative (horizontally) to the NAD83 ellipsoid, projected in UTM Zone 2N (m) and vertically to the Mean Lower Low Water level datum established for Village Cove, St. Paul, AK.

* + 1. TPE

The finalized BASE surfaces in CARIS incorporate uncertainty values derived from Total Propagated Error (TPE). CARIS HIPS TPE calculation assigned a horizontal and depth error estimate to each sounding. TPE values represent, at a 95% confidence level, the difference between computed horizontal and vertical sounding positions and their true position values. CARIS HIPS computed TPE error values by aggregating individual error sources such as navigation, gyro (heading), heave, pitch, roll, tide, latency, sensor offsets and individual sonar model characteristics. Stored in the HIPS Vessel File, these error sources were obtained from manufacturers during the instrument calibration process, determined during the vessel survey (sensor offsets) or while running operational tests (patch test, settlement and squat). The error budgets for the *R/V Mt. Mitchell* are found in Table 7 on the following page.

Table 6– R/V Mt. Mitchell error values used in computing Total Propagated Error (TPE).

| **Error Source** | **Method** | **Error Value** |
| --- | --- | --- |
| Motion Gyro | Published by Manufacturer | 0.050 (deg) |
| Heave | Published by Manufacturer | 5% amp |
| Roll | Published by Manufacturer | 0.050 (deg) |
| Pitch | Published by Manufacturer | 0.050 (deg) |
| Position Navigation | Published by Manufacturer | 1.000 (m) |
| Transducer Timing | Estimated | 0.001 (sec) |
| Navigation Timing | Estimated | 0.001 (sec) |
| Gyro Timing | Estimated | 0.001 (sec) |
| Heave Timing | Estimated | 0.001 (sec) |
| Pitch Timing | Estimated | 0.001 (sec) |
| Roll Timing | Estimated | 0.001 (sec) |
| Offset X | Direct Measurement | 0.002 (m) |
| Offset Y | Direct Measurement | 0.002 (m) |
| Offset Z | Direct Measurement | 0.002 (m) |
| Vessel Speed | Published by Manufacturer | 1.00 (m/s) |
| Loading | Published by Manufacturer | 0.070 (m) |
| Draft | Published by Manufacturer | 0.070 (m) |
| Delta Draft | Direct Measurement | 0.005 (m) |
| MRU Alignment Gyro | Direct Measurement | 0.21 (deg) (EM710) |
| 0.969 (deg) (EM120 |
| MRU Alignment Roll/Pitch | Direct Measurement | 0.080 (deg) (EM710) |
| 0.892 (deg) (EM120) |
| Sound Velocity | Published by Manufacturer | 0.05 (m/sec) |
| Tide Gauge | Published by Manufacturer | 0.014 (m) |

Uncertainty values derived from CARIS HIPS TPE computation were used to create International Hydrographic Organization (IHO) S-44 compliant datasets as well as calculate depth surfaces weighted by uncertainty. Soundings were generally shoaler than 100m and were filtered to reject soundings with uncertainty values that did not meet IHO Order 1 standards. Two transit lines run to the south of St. George featured depths greater than 100m but were still held to IHO order 1 scrutiny. IHO uncertainty thresholds were determined using the following equation:

**\_\_\_\_\_\_\_\_\_\_\_**

**±√ [a2+ (b\*d)2] where: for d < 100 meters**

**a=0.5 m**

**b=0.013 m**

**d=depth (m)**

* + 1. Gridded Base Surfaces

The final depth information for the Pribilof Shell Hash Survey is submitted as multi-resolution CARIS BASE Uncertainty surfaces which represent the seafloor at the time of survey. All steps have been taken to ensure the data have been correctly processed and appropriate designated soundings, representing the least depth of significant contacts, have been selected and retained in the finalized surface.

The submittal of a grid of varying resolution was necessary due to the wide depth range of the survey, which spanned multiple NOS specified depth resolution ranges.

2009 survey depths were submitted as CARIS BASE surfaces which were as weighted by the greater of either the standard deviation of sounding values, or *a priori* uncertainty values derived from HIPS TPE calculation. Additionally, one sun-illuminated, geographically referenced Digital Terrain Model image depicting the coverage of the survey area was submitted. All grids are projected to UTM Zone 2 North, NAD 1983. Naming conventions for each base surface are as follows:

Table 7– R/V Mt. Mitchell error values used in computing Total Propagated Error (TPE).

|  |  |  |
| --- | --- | --- |
| **Depth Range (m)** | **BASE Surface Resolution** | **Surface Name** |
| 27-52 | 2m | St\_Paul\_2m\_CUBE\_Order1 |
| 46-115 | 4m | St\_Paul\_4m\_CUBE\_Order1 |
| 27-52 | 2m | St\_George\_2m\_CUBE\_Order1 |
| 46-115 | 4m | St\_George\_4m\_CUBE\_Order1 |
| 27-52 | 2m | North\_Transit\_2m\_CUBE\_Order1 |
| 46-115 | 4m | North\_Transit\_4m\_CUBE\_Order1 |
| 27-52 | 2m | Southern\_Transit\_2m\_CUBE\_Order1 |
| 46-115 | 4m | Southern\_Transit\_2m\_CUBE\_Order1 |
| 103-350 | 8m | Southern Transit\_8m\_CUBE\_Order1 |

* + 1. Chart Compare

Since final, processed multibeam depths are no longer delivered as a fixed-scale smooth sheet of selected, shoal-biased soundings, it was not necessary to decimate multibeam data to this extent. However, a sounding selection process was performed as a final quality control check and to provide a means of effectively comparing processed survey depths to those appearing on the current editions of the Electronic Navigation Charts (ENC) of the area. CARIS Field Sheet Editor was used to bin survey data at project depth resolution, from this grid, shoal-biased soundings were extracted. An inspection of the survey data was then made by investigating areas where soundings and/or bins disagreed with published values. Areas involving a charting recommendation, such as the addition of a new feature or shoaling area were thoroughly examined. Although depth contouring, a component of the fixed-scale smooth sheet, is no longer required, ENC contours were compared with contours generated from the CUBE surfaces. This comparison was used for evaluating the adequacy of the ENC and for making future charting recommendations that are included in each DR *Section D.2: Additional Results.*

* + 1. Crossline Analysis

The crossline analysis was conducted using CARIS HIPS QC Report routine. In this beam by beam depth analysis, the crossline is compared to the finalized base surface. The differences in depth were grouped by beam number, and statistics were computed for the percentage of soundings whose depth differences fall within IHO survey Order 1.

A summary of the results for the survey is in the DR. The QC Reports are included in the *Separate IV: Checkpoint Summary & Crossline Reports*.

* + 1. Shoreline Verification

There was no shoreline verification assigned for the Pribilof Shell Hash Survey

1. Corrections to Echo Soundings

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

* 1. Vessel Offsets

Sensor locations were established by a precise survey of the vessel using a combination of conventional survey instruments. All sensors were referenced to previously established control points onboard the *R/V Mt. Mitchell.* Separation distances between the two POS M/V GPS antennas were measured directly with a survey tape and then verified during the Applanix POS M/V internal calibration. Sensor positional and angular offsets were determined prior to survey, and applied during collection in Kongsberg SIS acquisition software. These initial offset values were then replaced during post-processing in CARIS HIPS with finalized values. Detailed vessel drawings and offset descriptions are provided at the end of this section and represent the final offsets used by CARIS HIPS.

* + 1. Vessel Survey

R/V Mt. Mitchell

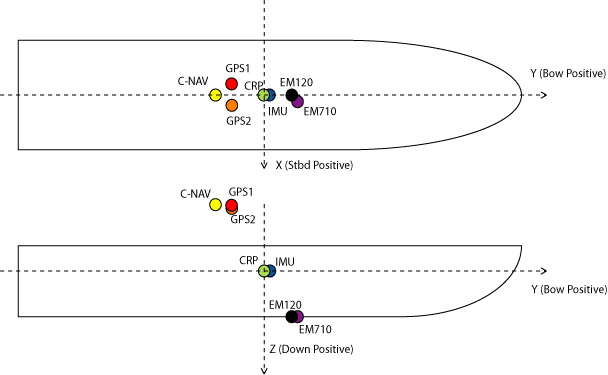


Figure 12 - R/V Mt. Mitchell vessel survey showing the relative positions of the installed survey equipment.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Offset from CRP (m) based on CARIS Convention** | | | | |
| Equipment | Manufacturer / Model | X | Y | Z |
| IMU | Applanix POS M/V | 0.072 | 0.261 | -0.168 |
| MB Transducer | Kongsberg EM 710 | 1 | 3.685 | 2.553 |
| GPS1 (Primary Ant.) | Applanix POS M/V | -1.085 | -4.791 | 14.499 |
| GPS2 (Secondary Ant.) | Applanix POS M/V | 0.913 | -4.789 | 14.497 |
| C-NAV (Antennae) | C-NAV | -0.09 | -5.506 | 14.2 |

Table 8 – R/V Mt. Mitchell offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

* + 1. Heave, Pitch and Roll

Heave, pitch, and roll (HPR) data for the *R/V Mt. Mitchell* were measured using an Applanix POS M/V Attitude and Positioning System. The POS M/V output HPR values for the *R/V Mt. Mitchell* CRP. The system provided output as a binary data string via RS-232 serial cable to the SIS and QINSy acquisition software at 25Hz. Heave, roll and pitch corrections were applied during acquisition in SIS, where the SIMRAD systems used attitude values to steer both incoming and outgoing beams.

* + 1. Patch Test Data

Patch tests were performed on *R/V Mt. Mitchell* to determine system latency, and composite offset angles (roll, pitch and azimuth) for the transducer and motion sensor.

Patch tests were conducted prior to the beginning of the 2009 survey. A listing of the patch tests performed for the 2009 survey is provided in Table 14. The EM 710 patch was run multiple times and the second EM 710 patch became the official patch used in the survey.

Table 9 – Patch tests performed for instrument calibration during the Pribilof Shell Hash Survey.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Vessel** | **Julian Date** | **Longitude (DMS)** | **Latitude (DMS)** | **Reason** |
| *R/V Mt. Mitchell* | 2009-154 | 166° 34’ 30” | 53° 53’ 30” | EM710 Initial calibration |
| *R/V Mt. Mitchell* | 2009-163 | 169° 20’ 00” | 56° 07’ 00” | EM710 Official Calibration |

Patch test lines were run as described below to determine the following offsets:

* + 1. Navigation Latency

A single survey line was run twice, in the same direction, at different speeds over a distinct slope.

* + 1. Pitch

Pitch offset was determined by running three pairs of reciprocal lines at the same speed, perpendicular to a slope.

* + 1. Azimuth

Azimuth (yaw) offset was calculated by running three adjacent pairs of reciprocal lines at the same speed perpendicular to a slope.

* + 1. Roll

The roll was calculated and compensated for by running pairs of reciprocal survey lines at the same speed over a regular and flat sea floor.

The offset values for pitch, azimuth, roll and navigation latency from the positioning system were resolved using the calibration editor in CARIS Subset Editor. The time-referenced values were then stored in the appropriate HVF file. Offset and latency corrections were applied to the raw sounding data during the merge process in CARIS.

* 1. Speed of Sound through Water

Sound Velocity profiles were primarily collected using Lockheed Martin Sippican XBT T-5 and XCTD-2 expendable bathymetric thermographs. Additionally an AML Smart probe was used to verify the accuracy of the XBT and XCTDs. Six sound velocity profiles were taken over the course of two days, three in each area. Sound velocity casts were additionally spaced geographically to represent the spatial distribution of data.

Sound speed corrections were loaded into the Kongsberg SIS acquisition software and applied in real-time to the raw sounding data. Ultimately these sound speed corrections were removed from the raw data and applied in a more systematic method in CARIS HIPS.

The DR, *Separate II: Sound Speed Data* contains a detailed listing of the sound speed profiles and applicable cast dates used during the 2009 survey.

* 1. Static Draft

Static draft was determined by measuring down from a survey punch on the port and starboard side of the survey vessel to the waterline, then averaging the two measurements. Measure-downs were conducted in calm waters prior to commencing survey, and after completion as Sea state precluded accurate measurement while at sea. It was the intention to calculate a linear trend between initial and final measurements to calculate each day’s draft; however with a difference of only 5cm between pre- and post- survey values, the initial measure-down was used for the entire survey. The static draft measurement was entered in the CARIS HIPS Vessel File (HVF) and applied to sounding data during final processing.

* 1. Settlement and Squat

R/V Mt. Mitchell

Settlement and squat measurements for *R/V Mt. Mitchell* were conducted using Post Processing Kinematic (PPK) GPS Survey Techniques in Akun Bay near Unimak Pass, Alaska on June 21, 2009. Measurements were made using a POS M/V attitude and positioning sensor, and settlement values were recorded during vessel propeller pitches ranging from 10–80 percent. These pitches were selected to represent the practical operational limits of propeller pitches during the survey.



Figure 13 - R/V Mt. Mitchell Settlement & Squat Measurements.

Figure 14- R/V Mt. Mitchell graph of Propeller Pitch vs. Speed. This links the Terrasond squat test with Caris HIPS need for speed.

Figure 15 - R/V Mt. Mitchell Speed vs. Settlement 8used in CARIS HIPS.

Table 10 – R/V Mt. Mitchell speed vs. settlement graph

|  |  |
| --- | --- |
| **Speed (m/s)** | **Settlement (m)** |
| 1.59 | -0.001 |
| 2.57 | 0.02 |
| 3.47 | 0.05 |
| 4.49 | 0.06 |
| 5.18 | 0.12 |
| 5.80 | 0.17 |

A kinematic base station (Trimble 5700 w Zephyr L1/L2), was set up on shore within ~5 kilometers of the survey vessel. The base station logged Carrier Phase corrections internally as did the *R/V Mt. Mitchell’s*  POS M/V. Using these logged data, the position of the *R/V Mt. Mitchell* was post-processed to a vertical accuracy under 2 cm.

The Squat Settlement was recorded as follows: A static session was logged for three minutes with no way on; the engine RPM / propeller pitch was then increased to achieve the desired vessel pitch. Once the vessel was at the desired pitch, and at constant speed, measurements were logged for three more minutes. Power was then removed and the vessel was brought to a drift. Three more minutes of static data was then logged. This procedure was repeated throughout the RPM / propeller pitch range used when surveying.

Settlement was calculated by averaging the static measurements at the beginning and end of lines and comparing this average with the average measurements while the vessel was under way throughout the pitch range. A graph was then constructed to illustrate settlement changes as a function of vessels pitch. Draft modifications in the CARIS HIPS Vessel Configuration file take into consideration speed instead of vessel pitch, however. To bridge this gap, propeller pitch was graphed versus average vessel speed (sampled in two directions), and then speed was graphed versus settlement, and the table was assembled

* 1. Tide Correctors

The tidal datum for the survey was Chart Datum, Mean Lower Low Water (MLLW) for the National Water Level Observation Network (NWLON) station at Village Cove, St. Paul Island, AK (946-4212). Predicted tide data used during the data acquisition portion of the survey were downloaded from the NOAA Tides and Currents Predicted Tides website in ASCII format and applied to the raw data in CARIS HIPS and SIPS during the merge step of initial data processing. Verified tide data were ultimately downloaded and applied in final processing in office.

* 1. Project Wide Tide Correction Methodology

A single tidal gauge solution was used for the entirety of the survey area per the SOW.

LETTER OF APPROVAL

REGISTRY Numbers: N/a (Survey Name: Pribilof Shell Hash Survey)

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of the Pribilof Shell Hash Survey 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 as per the Statement of Work. Other reports submitted with the Pribilof Shell Hash Survey include the Descriptive Reports and the Horizontal and Vertical Control Report.

I believe this survey is complete and adequate for its intended purpose.



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Chris Popham, Lead Hydrographer

TerraSond Ltd.

Date\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_