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

Data Acquisition and Processing Report

Type of Survey Hydrographic Survey

Field No. H12115

Registry No. OPR-R144-KR-09

LOCALITY

State Alaska

General Locality Central Bering Sea

2009

CHIEF OF PARTY

Brian Busey

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DATE November 2010

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NOAA FORM 77-28 (11-72)

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

REGISTRY No

HYDROGRAPHIC TITLE SHEET

Data Acquisition and Processing Report
OPR-R144-KR-09

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. **H12115**

State Alaska

General Locality Central Bering Sea

Sub-Locality Pribilof_Canyon

Scale N/A **Date of Survey** June4th-June18th,2009

Instructions dated N/A **Project No.** OPR-R144-KR-09

Vessel *R/V Mt. Mitchell*

Chief of party Brian_Busey

Surveyed by TerraSond Ltd.

Soundings by echo sounder, lead line, pole Multibeam Echosounder

Graphic record scaled by N/A

Graphic record checked by N/A **Automated Plot** N/A

Verification by N/A

Soundings in fathoms feet at MLW MLLW Meters at MLLW

REMARKS:

Contractor: TerraSond Ltd. All times recorded in UTC

1617 South Industrial Way, Suite 3

Palmer, AK 99645

Data Acquisition and Processing Report
OPR-R144-KR-09

Bering Sea sunrise from the Mt. Mitchell

Registry Number: **H12115**

Vessels*:* ***R/V Mt. Mitchell***

Survey: **A**

State: **Alaska**

General Locality: **Central Bering Sea**

Sublocality: **Pribilof Canyon**

Survey Dates: **June 4, 2009 to June 18, 2009**

Lead Hydrographer: **Brian Busey**

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A. Overview

All work performed for this survey was completed, as specified in the Professional Services Contract from the Marine Conservation Alliance Foundation, to meet NOS Hydrographic Surveys Specifications and Deliverables for 2009.

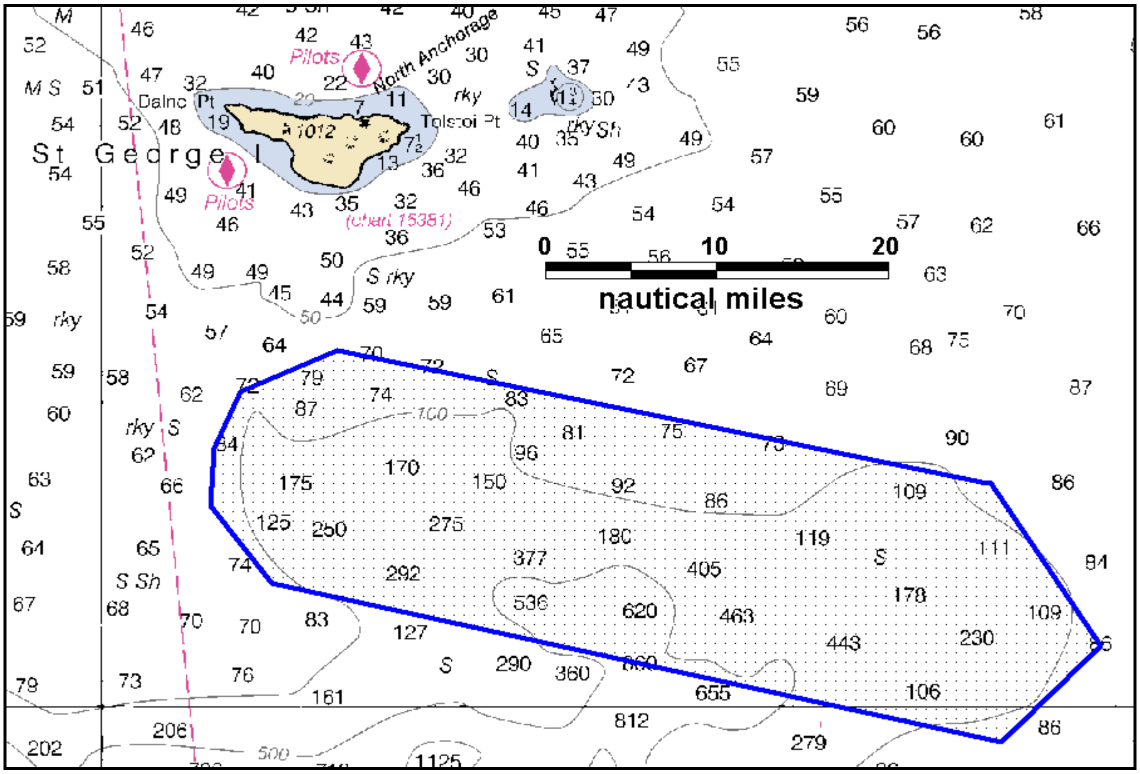

Figure 1 – Survey area for OPR-R144-KR-09. Chart16011 3rd Edition, July 2009 Soundings in Fathoms

B. Equipment

B.1. Vessels

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

B.1.1. R/V Mt. Mitchell

Multibeam Bathymetric and Backscatter data for survey H12115 were acquired using the *R/V Mt. Mitchell.*

The *R/V Mt. Mitchell*, shown in Figure 2, is a 70 meter steel-hulled vessel with a 12.7 meter beam and a 3.9 meter draft. The ship is powered by two 1200 HP EMD/567C General Motors Diesel engines connected to two Bird-Johnson controllable-pitch propellers operating between 10% and 80% pitch. Electrical power is 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* is outfitted with 2 hull-mounted Multibeam Echo Sounder Systems (MBES), a Kongsberg Simrad EM 710RD and a

Kongsberg Simrad EM 120. 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.

B.1.1.1. Equipment Overview

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

B.1.1.2. Major Operational Systems

R/V Mt. Mitchell **Survey Equipment**

Table 1 – Table showing the major survey equipment used on board the R/V Mt. Mitchell.

Description	***Manufacturer***	***Model / Part***	***Serial Number***
Multibeam Echosounder	Kongsberg Simrad Kongsberg Simrad	EM 710 RD EM 120	201 119
Sonar Acquisition	Primary: Simrad Secondary: QPS	SIS 3.4.1 QINSY 8.0	N/A
Positioning System	C-NAV	CNAV 2050R	N/A
Motion Sensor	Applanix	POS M/V 320 V4	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

B.1.1.3. Sounding Equipment

Kongsberg Simrad EM 120, and EM 710 RD multibeam echo sounder systems were used aboard the *R/V Mt. Mitchell* during OPR-R144-KR-09.

The EM 120 is a 191-beam Mill's cross system operating at 12 KHz, and the EM 710 is a 200-beam Mill's Cross system operating between 70 KHz and 100 KHz. Both systems employ a 2 degree along-track beam angle and a 2 degree across-track beam angle. The EM 710 was set to high density equidistant mode to get 200 beams and the EM 120 was set to high density mode to get 190 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.

B.1.1.4. Technical Specifications

Table 2 – Kongsberg EM 120 multibeam echosounder technical specifications.

Kongsberg EM 120	
Sonar Operating Frequency	12 kHz
Beam Width, Across Track	2.0°
Beam Width, Along Track	2.0°
Number of Beams	191 max
Max Swath Coverage	150°

Table 3 – 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°

B.1.2. 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 Canyon Survey. The maximum range for the period during the survey was 1.58 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 946-4212 tide station used in OPR-R144-KR-09.

B.1.3. Speed of Sound

Speed of Sound data was 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 to meet the criteria specified in NOS Hydrographic Surveys Specifications and Deliverables. Sound speed profiles extended to >85% of the anticipated water depth to a maximum depth of ~1200m. This was the functional depth limit of the Sippican XBT and XCTD probes. Sound velocity profiles were assumed to change minimally below this depth and 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.

Refer to the Descriptive Report, *Separate II: Sound Speed Data* for detailed information about specific cast dates and sound speed comparisons. Also, *Section B.2.1: Multibeam Bathymetry* of the Descriptive report for discussion on sound speed application and issues.

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

R/V Mt. Mitchell

Table 4 – Table listing the sound speed measuring equipment used during OPR-R144-KR-09.

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

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

B.1.4. Positioning Systems

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 Pribilof Canyon is 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 manufacturer's specified worldwide accuracy of 0.1 m horizontally and 0.2 m vertically exceeds survey requirements. The vessel's position was recorded using both Kongsberg SIS and QPS QINSy acquisition softwares at 1Hz intervals using National Marine Electronics Association (NMEA) message $GPGGA.

A C-NAV system confidence check was performed before 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: Horizontal Position Accuracy* of NOS Hydrographic Specifications and Deliverables April 2009. The horizontal position confidence check is provided in *Separates I: Acquisition Logs & Confidence Checks* of the Descriptive Report.

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

B.1.5. Attitude Sensors

An Applanix POS M/V Inertial Measurement Unit (IMU) model 200 (a component of the POSMV 320 V4 system) was used to measure heave, pitch and roll values 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 D: Corrections to Echo Soundings* of this report.

B.2. Data Collection

B.2.1. 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 was collected on a 24 hour basis using two crews with shift changes every 12 hours.

B.2.2. Coverage

Survey 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 5.1.2: Coverage.*

B.2.3. Line Planning

Since swath width was dependent on factors including depth and slope of the terrain the preplanning of survey lines was considered to be prohibitively complex. Planned lines were initially run to establish the location of the canyon; however the technique of "painting", whereby the vessel surveyed by following the edge of the coverage, was used for the majority of the survey.

B.2.4. 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 widely varying depths of the Pribilof Canyon, 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 survey H12115, the ping rate met or exceeded the specifications set forth in NOS Hydrographic Survey Specifications and Deliverables 2009, *Section 5.1.1: Accuracy and Resolution Standards*.

B.2.5. Software and Hardware Summary

Multibeam data was collected on an Intel Pentium IV PC using Kongsberg SIS data collection software (Bathymetric & Backscatter) operating in a Microsoft Windows XP environment. Additionally, data was inputted into QPS QINSy acquisition and navigation software and 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 was 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 C: Quality Control* of this report.

Table 5 lists the software used on the *R/V Mt. Mitchell* during the survey and *Table 6* lists the software used in the office during pre-survey planning and post-survey processing:

B.2.5.1. Vessel Software

Table 5 – Software used aboard the R/V Mt. Mitchell

Program Name	Version	Date	Primary Function
Kongsberg EM 710 / 120			Sonar firmware
Kongsberg SIS	3.4.1		Kongsberg MB controller and collection software
QPS QINSy	8.0	2008	Multibeam data collection and navigation suite
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

B.2.5.2. Office Software

Table 6 – 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 Notebook	3.1	2009	S-57 Compilation
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

C. Quality Control

C.1. Overview

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.

C.2. Equipment Calibration

The primary 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, and the EM 120 was patched during the survey, after it was determined that the EM120 would be used to augment the EM710 data. The patch values and detailed description of procedures can be found in *Section D.1.3: Patch Test Data* of this report.

The sound speed probe SV plus V2 was factory calibrated within the 6 months before use as required in *Section 5.1.3.3: Speed of Sound Corrections* of the NOS Specification and Deliverables. A comparison check between a XBT and the SV plus V2 was conducted prior to survey to verify accuracies. Both the calibration report and sound speed comparison can be found in *Seperates II: Sound Speed Data.*

C.3. Survey System Confidence Checks

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 was time-referenced at 1-second intervals.

An independent positional confidence check was performed before the survey within range of the coast guard DGPS beacon in Cold Bay, AK. Details of this check are addressed in *Section B.1.4: Positioning Systems* of this report.

Comparison lines were collected on 2009-173 in Akun Bay, AK between the *R/V Mt. Mitchell*, *R/V Mt. Augustine*, and *M/V Bluefin* as a multibeam sonar confidence check. The altitude data for the *R/V Mt. Augustine* and *M/V Bluefin* was corrected using PPK and the Mt. Mitchell with DGPS. There was good agreement between the *R/V Mt. Mitchell* and the other vessels with 0.30m and 0.13m vertical difference from the *M/V Bluefin* and *R/V Mt. Augustine* respectively. The multibeam sonar confidence check can be found in *Separate I: Acquisition Logs and Confidence Checks* of the Descriptive Report.

In addition, cross lines were run as a confidence check for the multibeam sonars. The total linear nautical miles of crosslines exceeded five percent of the linear nautical miles of main scheme lines. Details on crossline analysis can be found in *Section C.7.8: Crossline Analysis* of this report and *Section B.2.2: Crosslines* of the Descriptive report.

C.4. 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 attitude data from the POS MV as well as the positioning data from the CNAV.

SVP data was acquired with Sippican WinMark 21 Sound 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, mode and frequency settings for each sonar. Acquisition logs included any additional comments deemed significant by the operator.

C.5. 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 resided 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 equipment failure.

C.6. 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 was then cleaned using CARIS HIPS and SIPS subset editor and a BASE Surface was created to verify coverage and provide quality control feedback to the survey crew.

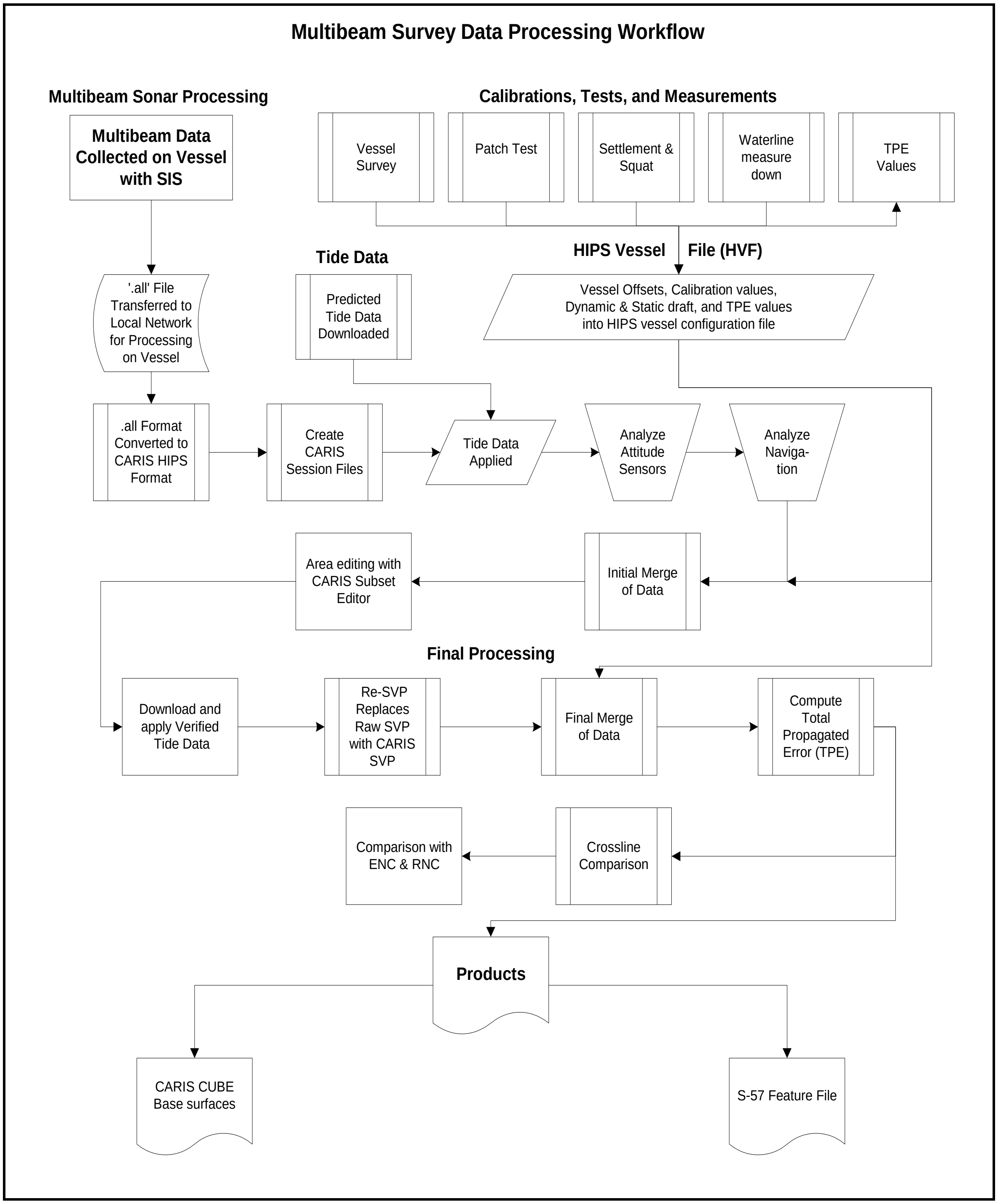

Figure 4- The major steps in data acquisition and processing.

C.7. Office Data Processing

C.7.1. Initial Processing: Import, QC, and Predicted Tide Application

CARIS HIPS software was used to create a folder structure organized by project, vessel, and Julian day to store data. Multibeam raw data was 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. 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) until verified data was available. No range, amplitude, or zoning schemes were applied. Refer to *Section D: Corrections to Echo Soundings*, of this report, for detailed information concerning final sounding reduction.

Attitude data was 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 was 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 was rejected with interpolation using a loose Bezier curve. Data was queried for time, position, delta time, speed, and status and, if necessary, the status of the data was changed from accepted to rejected.

C.7.2. Initial Merging

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

C.7.3. Area Editing

Following the merge 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 or rejected.

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 was scrutinized for any potential tide and sound velocity issues that would require further investigation.

C.7.4. HIPS Final Processing

Several finalized values were applied to the data in the final processing steps in CARIS HIPS. A verified tide file named "VillageCove_GMT_M_June_VerfdTides.tid" was downloaded and applied to the survey data prior to the final merge. Additionally, the locations and times of sound speed profiles were displayed graphically to ensure that time-appropriate profiles were applied to the entire survey. Moreover, each sound speed cast was inspected for data quality. The soundings were sound speed corrected a final time using the CARIS HIPS file named "2009-031_Pribelof_Canyon_SVP.svp" based on two methods "Previous in Time" and "Nearest in Distance within time, 12 hours" on an individual survey line basis. For a more detailed account on sound speed application, issues, and a list of lines applied with "Previous in Time" see *Section B.2.1: Multibeam Bathymetry* of the Descriptive Report.

Dynamic draft table 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 Mitchell. Average vessel speed was computed for the range of propeller pitches.

The final processing step before TPE calculation and data export was the 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.

C.7.5. TPE

The finalized BASE surface exported in CARIS incorporated 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.

Table 7 – 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, 0.050 (m)
Roll	Published by Manufacturer	0.050 (deg)
Pitch	Published by Manufacturer	0.050 (deg)
Position Navigation	Published by Manufacturer	1.000 (m)
Transducer Timing	Recommended value according to NOAA HTD document for using serial cables for connection.	0.010 (sec)
Navigation Timing	Recommended value according to NOAA HTD document for using serial cables for connection.	0.010 (sec)
Gyro Timing	Recommended value according to NOAA HTD document for using serial cables for connection.	0.010 (sec)
Heave Timing	Recommended value according to NOAA HTD document for using serial cables for connection.	0.010 (sec)
Pitch Timing	Recommended value according to NOAA HTD document for using serial cables for connection.	0.010 (sec)
Roll Timing	Recommended value according to NOAA HTD document for using serial cables for connection.	0.010 (sec)
Offset X	Direct Measurement	0.002 (m)
Offset Y	Direct Measurement	0.002 (m)
Offset Z	Direct Measurement	0.002 (m)
Vessel Speed	Estimated value based on variability.	1.00 (m/s)
Loading	Direct Measurement	0.070 (m)

Draft	Direct Measurement	0.070 (m)
Delta Draft	Direct Measurement	0.005 (m)
MRU Alignment Gyro	St. Deviation from iterations of patch test data processed in CARIS HIPS	0.21 (deg) (EM710) 0.969 (deg) (EM120)
MRU Alignment Roll/Pitch	St. Deviation from iterations of patch test data processed in CARIS HIPS	0.080 (deg) (EM710) 0.892 (deg) (EM120)
Sound Speed	The temporal/spatial variability of SVP collected in survey area.	3.0 (m/sec) (Measured) 1.0 (m/sec) (Surface)
Tide	Published by data source (No zoning was used for this survey)	0.01 (m) (Measured) 0.00 (m) (Zoning)

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. All soundings were deeper than 100 m and so must meet IHO Order 2 standards. IHO uncertainty thresholds were determined using the following equation:

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

where: **<u>for d > 100 meters</u>**

a=1.0 m
b=0.023 m
d=depth (m)

C.7.6. Gridded Surfaces

The final depth information for OPR-R144-KR-09 is submitted as a CARIS cube base surface which represents the seafloor at the time of survey. All steps have been taken to ensure the data have been correctly processed.

The submittal of grids of varying resolutions 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 two CARIS cube base surfaces which were weighted by the greater of either the standard deviation of sounding values, or *a priori* uncertainty values derived from HIPS TPE calculation. All grids are projected to UTM Zone 2 North, NAD 1983. Naming conventions and details for each grid are as follows:

Table 8 – Submitted CARIS cube base surfaces

	Fieldsheet	Base surface	Depth Range(m)	Resolution (m)
1	H12115_8m	103to350m_Final_0.hns	103-350	8

2	H12115_16m	326to2500m_Final_0.hns	326-2500	16

C.7.7. 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 in a 300 meter radius. 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. ENC contours were compared with contours generated from the variable resolution cube base surface. This comparison was used for evaluating the adequacy of the ENC and for making future charting recommendations that are included in each Descriptive Report *Section D.1: Chart Comparison.*

C.7.8 Crossline Analysis

Crossline comparisons were completed using a sounding to surface method through CARIS HIPS QC report utility.

Each crossline was selected and run through the process, which calculated the difference between each accepted crossline sounding and a BASE surface created from the mainscheme data. Due to the large depth range in H12115, two surfaces with different resolutions and depth ranges were used for the comparison. An 8m resolution surface with depth range of 103 to 350m and a 16 m resolution surface with depth range of 326 to 2500m resolution. Cross lines from both the EM120 and EM710 were compared to each surface where intersection occurred.

The differences in depth were grouped by beam number and statistics computed which included the percentage of soundings compared whose differences from the BASE surface fall within IHO S-44 Order 2.

All of the beams meet IHO S-44 Order 2 specifications at the 95 % confidence level or better. Refer to *Separate IV: Crossline_Comparisons* for the QC Reports.

C.7.9 Shoreline Verification

There was no shoreline verification assigned for OPR-R144-KR-09.

D. Corrections to Echo Soundings

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

D.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 *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. Detailed vessel drawings and offset descriptions are provided at the end of this section.

D.1.1. Vessel Survey

R/V Mt. Mitchell

Figure 5 - R/V Mt. Mitchell vessel survey showing the relative positions of the installed survey equipment.

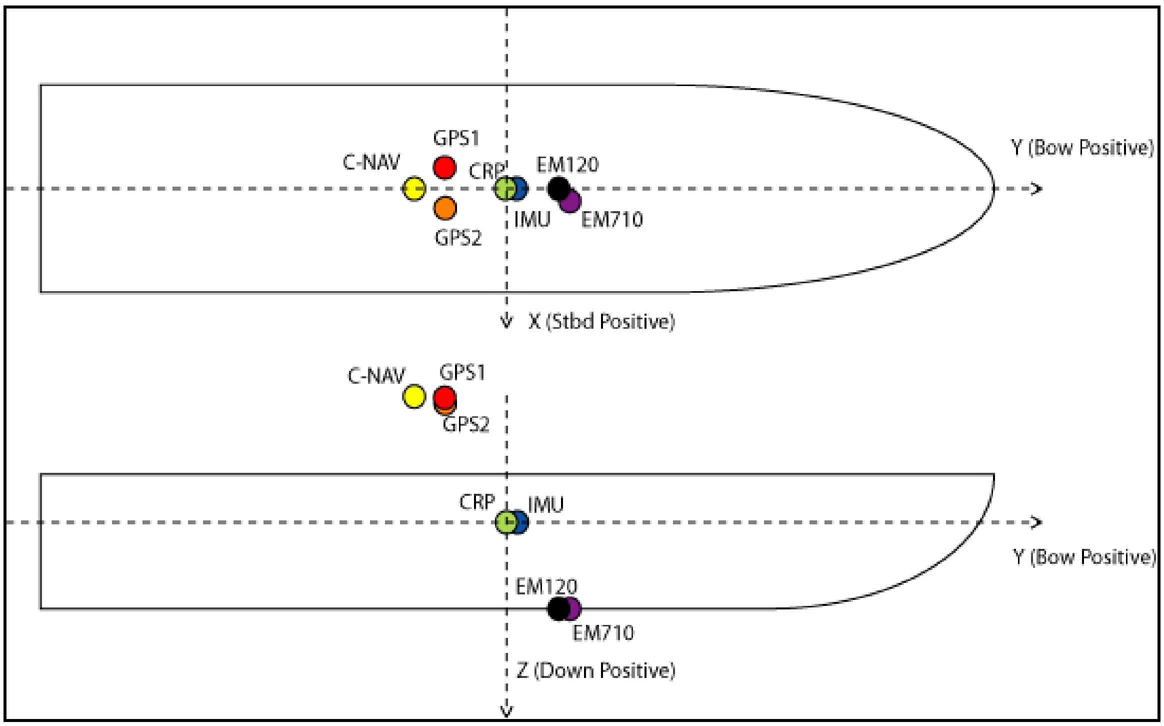

Table 9 – R/V Mt. Mitchell offset measurements determined during the initial vessel survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.

Equipment	Manufacturer / Model	Offset from CRP (m) based on CARIS Convention		
		X	Y	Z
IMU	Applanix POS M/V	+0.072	+0.261	-0.168
MB Receiver	Kongsberg EM 710	+1.00	+3.685	+2.553
MB Transducer	Kongsberg EM710	+0.893	+4.319	+2.526
MB Receiver	Kongsberg EM 120	-0.024	+2.764	+2.593
MB Transducer	Kongsberg EM 120	-0.020	+5.375	+2.500
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 (Antenna)	C-NAV	-0.090	-5.506	+14.200

D.1.2. 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 from the Mt. Mitchell CRP. The system provided output as a binary data string via RS-232 serial cable to SIS and QINSy acquisition softwares 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.

D.1.3. 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 10*.

Table 10 – Patch tests performed for instrument calibration during OPR-R144-KR-09.

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”	EM710/120 Official Calibration

The first patch test was performed on 2009-154, involving the EM710 only, where preliminary patch values for pitch, azimuth, and roll were resolved using the program SeaCal. SeaCal a program in SIS acquisition software, uses least squares adjustment to calculate patch values from lines acquired as described in the below sections. These values were entered into SIS and applied in real time to the data. A second patch test was performed on 2009-163 involving both the EM710 and EM120. For the EM710 system the second patch test was processed in CARIS HIPS using the calibration tool and was later applied in the vessel configuration file in processing. The CARIS HIPS produced patch values were applied in addition to the preliminary values applied to the data in SIS in real time. The same process was done for the EM120 however values produced in both SeaCal and CARIS HIPS involved the second patch test data only. The patch values applied to the data can be viewed in *Table 11*.

A detailed description of CARIS vessel configuration file can be found in *Section D.5: CARIS HIPS Vessel Configuration File* of this report.

Table 11- Patch values for the survey OPR-R144-KR-09

Multibeam System	Processing software used	Date Patch data was acquired	Pitch (deg)		Roll (deg)		Azimuth (deg)	
			Transducer	Receiver	Transducer	Receiver	Transducer	Receiver
EM710	SeaCal	2009-154	-0.390	0.090	1.770	0.830	0.000	0.000
EM710	CARIS*	2009-163	2.120		-0.670		0.800	
EM120	SeaCal	2009-163	1.840	1.560	-0.310	-0.290	0.000	0.000
EM120	CARIS*	2009-163	-0.090		0.000		0.140	

* The patch values processed in CARIS are a refinement to the SIS values applied to the raw data.

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

D.1.3.1 Navigation Latency

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

D.1.3.2 Pitch

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

D.1.3.3 Azimuth

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

D.1.3.4 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.

D.2. Speed of Sound through Water

Sound speed data for OPR-R144-KR-09 was collected to meet the sounding accuracy standards addressed in *Section 5.1.1* of the NOS Hydrographic Surveyors Specifications and Deliverables Manual for 2009. 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. Sound velocity profiles were taken up to twice a day (with the exception of June 18 2009 where, due to resources available no profile was taken), in depths representative of the day's survey area. Sound velocity casts were additionally spaced geographically to represent the spatial distribution of data. In areas deeper than the capacity of the Sippican probes, the deepest SV reading collected was used for all data below max probe depth. This only occurred in depths greater than ~1200m, well below the thermocline, where sound velocity is believed to be relatively constant.

Sound speed corrections were loaded into the Kongsberg SIS acquisition software and applied in real-time to the raw sounding data. When the data is converted into CARIS HIPS and SIPS, these sound speed corrections are carried over into the CARIS line directory. Final processing of the sounding data involves the original sound speed corrections to be overwritten by the file "2009-031_Pribelof_Canyon_SVP.svp" which applies the sound speed according to "Nearest in Distance with in Time, 12 hours" and in some cases "Previous in Time". For a more information on sound speed such as methods of application, issues, and a list of lines processed with "Previous in Time" view *Section B.2.1: Multibeam Bathymetry* in the Descriptive Report.

For a detailed listing of the sound speed profiles and applicable cast dates used during the 2009 survey view *Separate II: Sound Speed Data* of the Descriptive Report.

D.3. Static Draft

Static draft was determined by measuring down from a survey punch mark 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 as sea state precluded accurate measurement while at sea. The value -2.33 m was entered into SIS and applied in real-time to all the survey data except for the lines listed in *Table 12* with the incorrect waterline entered. An incorrect value of -2.56 m was entered in the first three lines collected with the EM120. Since the difference between the two values is 0.23m, which at the depths of this survey is well within the allowable vertical accuracy according to *Section 5.1.1: Accuracy and Resolution Standards* of the

NOS Hydrographic Surveys Specifications and Deliverables, 2009 and therefore was not corrected in processing.

Table 12- List of EM120 lines with the incorrect waterline entered.

Multibeam System	Date	Line Name
EM120	2009-156	0000_20090605_034314_UNITY_Mt_Mitchell_EM120
EM120	2009-156	0001_20090605_041314_UNITY_Mt_Mitchell_EM120
EM120	2009-156	0000_20090605_044314_UNITY_Mt_Mitchell_EM120

D.4. 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 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.

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.

The POS file was processed in POSPac MMS 5.1 with data from the Akun Bay base station to produce an SBET file that was used to apply horizontal and vertical GPS position to the line files in CARIS. CARIS was then used to compute GPS tide, which accounts for vessel offset as well as heave. After the navigation data was loaded in CARIS, the GPS tide was computed and extracted for the final settlement computation. For comparison, GPS heights were also exported straight from POSPac and used to run a comparison settlement computation.

The final settlement computations were calculated using an excel spreadsheet. Settlement was determined by calculating the change in tide from the static drift before each run to the static drift immediately following that run. This was used to determine the tide height at each run, which was subtracted from the dynamic value to give the settlement value. 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.

***R/V Mt. Mitchell* Settlement Results**

Table 13 – R/V Mt. Mitchell average pitch vs .speed and settlement measurements

Pitch	Speed (kts)	Speed (m/s)	Settlement (m)
25	3.099	1.590	-0.010
35	4.997	2.570	0.020
45	6.750	3.470	0.050
55	8.724	4.490	0.060
65	10.078	5.180	0.120
75	11.273	5.800	0.170

Figure 6 – R/V Mt. Mitchell Settlement Results and CARIS Draft Table values.

D.5. CARIS HIPS Vessel Configuration File

The CARIS HIPS and SIPS vessel configuration file ".hvf" is used to apply sensor offsets, calibration, and error values to the soundings through various processes. For OPR-R144-KR-09 data was collected as ".all" files in SIS acquisition software from two multibeam systems, the Simrad EM710 and EM120. As a result special consideration needs to be taken when compiling the ".hvf" files for each system. The vessel configuration file for this survey was created based on the document CARIS Technical Note- Sound Velocity Corrections for Simrad EM Data and can be found in *Appendix I: Supplemental Processing Notes* of this report.

D.5.1 Swath 1 and Swath 2

Both the Simrad EM710 and EM120 are large multibeam systems that involve separate mounting of the transducer and receiver components. For this reason how the transducer and receiver get sound speed corrected needs to be dealt with separately. In order to achieve this application a Swath 2 section needs to be added to permit a second SVP section to be added in the ".hvf" file. Adding a second SVP section is the only purpose for Swath 2, therefore a "Start beam number" of 201 was entered in Swath 2 disregarded this section during the 'merge' process in CARIS HIPS and SIPS.

The ".all" file contains all offsets and preliminary patch values that were determined pre-survey and applied to the data in real-time. These values are carried through during conversion into CARIS HIPS and SIPS and do not need to be entered into Swath 1. As discussed in *Section D.1.3: Patch Test Data* of this report, preliminary patch values were established first in SeaCal and applied to the data in real time through SIS. The values entered in Swath 1 under Pitch, Roll, and Yaw are minor adjustments to the data in addition to the preliminary patch values which will be applied during the 'merge' process in CARIS HIPS and SIPS.

Also, in Swath 1 it is necessary to choose the correct model for proper Total Propagated Error application. In order to choose the Simrad EM120 model an updated Devicemodel.xml file was provided from CARIS. This file was placed on the processing computer under the CARIS directory in order to create the Mitchell_120.hvf file with the correct model. This file along with the CARIS help desk can be found in *Appendix I: Supplemental Processing Notes* of this report.

D.5.2 Navigation, Gyro, Heave, Pitch, and Roll

The ".all" files also contain the offsets and attitude data pertaining to Navigation, Heave, Pitch, and Roll. This information is applied in real-time to the data and carried through upon conversion into CARIS HIPS and SIPS. Hence no offsets are entered and no attitude data is applied in these sections of the ".hvf" file.

D.5.3 Draft

The dynamic draft values are not contained in the ".all" files. A draft table of settlement verses vessel speed is applied in the ".hvf". For the table of these values and an explanation of how they were determined go to *Section D.4: Settlement and Squat* of this report.

D.5.4 TPE values

The offsets entered under TPE are the average of the transducer and receiver from the MRU and Navigation. Information on the values entered in for Standard Deviation can be found in *Section C.7.5- TPE* of this report.

D.5.5 SVP 1 and SVP 2

As discussed in Section D.5.1- Swath 1 and Swath 2, the transducer and receiver for the Simrad EM710 and EM120 must be sound speed corrected uniquely due to separate mounting. This insures the proper application of sound speed in the water column to the data according to where the two components of the multibeam systems are located. SVP 1 contains the offsets and preliminary patch values applied to the data in real-time according to the transducer and SVP 2 the receiver.

D.5.6 Waterline Height

The ".all" files contain the waterline height which was determined pre-survey. The waterline height is entered in the ".hvf" for sound speed correction purposes and not applied to the data in the 'merge' process. For an explanation of how this value was determined view *Section D.3: Static Draft* in this report.

D.6. Tide Correctors

The tidal datum for the survey was Chart Datum, Mean Lower Low Water (MLLW) from 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 was 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 initial data processing. The predicted tide file named VillageCove _GMT_M_June_PredTides.tid was not submitted with this survey since it is a preliminary file which was overwritten in final processing by VillageCove_GMT_M_June_VerfdTides.tid, verified tide data downloaded from NOAA Tides and Currents.

D.7. Project Wide Tide Correction Methodology

A single tidal gauge solution (Village Cove, St. Paul Island, AK (946-4212)) was used for the entirety of the survey area per the SOW.

LETTER OF APPROVAL

REGISTRY Numbers: H12115

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of surveys H12115 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 OPR-R144-KR-09 include the Descriptive Reports and the Horizontal and Vertical Control Report.

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

Brian Busey

Digitally signed by Brian Busey
DN: CN = Brian Busey, C = US, O = TerraSond
Date: 2010.11.08 15:08:56 -09'00'

Brian Busey, Vice President of Operations
TerraSond Ltd.

Date__Nov.08/2010______________