DATA ACQUISITION AND PROCESSING REPORT

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Applicable Surveys

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UNITED STATES NAVY BASE

APRA HARBOR, GUAM

A. EQUIPMENT

All survey data acquired by United States Navy (USN) Fleet Survey Team (FST) were acquired with Survey Vessel Swamp Fox. Vessel Swamp Fox has one sonar mounting arm on the port side of the vessel from which the Reson 8125 multibeam echosounder (MBES) is mounted. The Klein 3000 Side Scan Sonar is operated in the stern-towed configuration. Although not used for this survey, SWAMPFOX is equipped with the Odom CV vertical beam echosounder (VBES), which is mounted in a transducer void, centerline aft.

The methods and systems described in this report are used to meet complete coverage and object detection coverage requirements and are in accordance with the *OCS Hydrographic Surveys Specifications and Deliverables Manual* (3/2007), Hydrographic Survey Directives, and the OCS *Field Procedures Manual for Hydrographic Surveying* (3/2007, v 2.1).

A.1. ECHOSOUNDING EQUIPMENT

The Odom Echotrac CV2 VBES is used as a single-frequency digital recording echosounder system with a digital recorder. The frequency settings range from 100 kHz to 1 MHz, though the normal operating frequency is 200 kHz. The manufacturer specifications of this sonar are included in Appendix I of this report.

The data is digitally recorded in meters as .bin files and Hypack files. The .bin files replace paper-trace records and can be viewed in Pydro Post Acquisition Tools. The Hypack files are converted to Caris HDCS data for processing. The Odom CV is primarily used simultaneously with the Klein 3000 SSS.

The ODOM Echotrac CV2 is inappropriate for sole use in situations requiring complete coverage or object detection coverage. However, combined with SSS data, the ODOM Echotrac CV can be used to meet NOAA specifications for complete and object detection coverage.

RESON SEABAT 8125 MULTIBEAM ECHOSOUNDER

The Reson SeaBat 8125 MBES is a single-frequency, digital-recording MBES with an operating frequency of 455 kHz. The RESON 8125 transducer consists of a flat transmitter array and solid cylindrical receiver array installed on a manually deployable arm off the port side of vessel Swamp Fox.

The Reson 8125 forms 240 beams each of which has a 0.5° across-track beam footprint for a maximum total swath width of 120°. Each beam has an along-track resolution of 1°. The ping rate is nominally 20-40 Hz, but may vary according to operating conditions. The Reson 8125 sonar is capable of bottom detection in depths from 3-120m. Specifications for this sonar are included in Appendix I of this report.

The Reson 8125 performs active beam steering to correct for sound speed at the transducer head using a surface sound speed sensor. This sensor is discussed in the Sound Speed Equipment section of this report[1]. Real-time attitude data from the vessel's Applanix POS-MV attitude sensor is also input to the Reson 8125 to aid beam steering, though attitude correction is performed post-acquisition in Caris HIPS. The Applanix POS-MV attitude sensor is discussed in the Positioning and Orientation Equipment section of this report.

Reson 8125 data are acquired in meters using Hysweep .RAW and HSX format. In addition to bathymetry, Reson "Snippets" and side scan data are also recorded in the HSX file. Reson "Snippets" and side scan data are not routinely used to generate charting products and are archived for second party scientific purposes such as sea bottom characterization, fish habit studies, or geological studies. Reson 8125 user parameters and surface sound speed are also recorded within the HSX file.

[1] An Odom Digibar is used aboard vessel Swamp Fox for this purpose.

A.2. Acoustic Imaging Equipment

KLEIN 3000 High-speed Side Scan Sonar

The Klein 3000 high-resolution side-scan sonar system is a digital-recording, beam-forming acoustic imagery device with a dual operating frequency of 100 and 500 kHz and vertical beam angle of 40°. The Klein 3000 system consists of a Klein towfish, a Transceiver/Processing Unit (TPU), and a computer for user interface.

The along-track resolution is approximately 30cm at the 100m range scale, even when acquiring data at speeds up to 10 knots. Across-track resolution is typically 7.5cm at the 100m range scale. The achievable 0.3m resolution meets the *OCS Hydrographic Surveys Specifications and Deliverables Manual* for object detection. ISIS Sonar Pro is used to acquire data with the Klein 3000 SSS.

A.3. Manual Sounding Equipment

Vessel Swamp Fox is equipped with one lead line, which is comprised of survey grade measuring tape with a dive weigh attached.

A.4. Positioning and Orientation Equipment

Vessel Swamp Fox is equipped with a NAVCOM SF2050M Realtime DGPS receiver. The NAVCOM includes a GPS receiver capable of receiving external WADGPS and kinematic correctors from satellites. The system outputs position information once per second. Best expected position accuracy with the NAVCOM system is less than one meter with 5 or more space vehicle vectors in the solution.

Vessel Swamp Fox uses an Applanix POS-MV 320 Version 3 inertial positioning and orientation system along with the NAVCOM (DGPS) for a highly accurate blended position and orientation solution.

The POS/MV 320 includes dual GPS antennas, an inertial measurement unit (IMU), and data processor (PCS). The IMU measures linear and angular accelerations corresponding

to the major motions of the vessel (heave, pitch, roll) and inputs this data to the PCS, where it is combined with a GPS position determined by carrier-phase differential measurements to give the final position solution. Heading is calculated using a GPS-azimuthal measurement system (GAMS); two offset GPS receivers mounted on the cabin of the vessel input to the PCS.

The blended DGPS and inertial position/orientation solution has typical values of 0.02° true roll and pitch accuracy, 0.02° heading accuracy, 2m position accuracy, and 0.03 ms^{-1} speed accuracy. These parameters are monitored in real time during acquisition using the POS/MV controller software. These values meet the position accuracy standard for an IHO Order 1 survey.

Vessel Swamp Fox is set up according to the "Precise Timing" method, a sonar acquisition configuration which applies a time stamp at the point of acquisition to all incoming sonar, attitude, and positioning data[2]. The timing message is generated by the POS/MV and synchronizes the sonar system time with the POS/MV UTC time.

Although "Precise Timing" reduces the effect of time latency on MBES data, corrections for residual time latency biases must still be made via a patch test.

POS-MV True Heave files (.000) are also recorded during bathymetric data acquisition and applied in Caris HIPS/SIPS during post processing.

A.5. Sound Speed Profilers

Sea-Bird SBE19 CTD Profiler with Optics

Vessel Swamp Fox acquires water column sound speed data using a Sea-Bird Electronics SeaCat SBE19 Conductivity-Temperature-Depth (CTD) profiler. Temperature is measured directly. Salinity is calculated from measured electrical conductivity. Depth is calculated from strain gauge pressure. The SBE19 is capable of CTD profiling at depths from 0-350m. The SBE19 is deployed by an electric winch over the port side of vessel Swamp Fox.

The CTD was returned to the manufacturer for calibration August 2007. Calibration documents are contained in Appendix IV of this report.

Sea Surface Sound Velocimeters

[2] Further documentation on Precise Timing may be found in Appendix III of the 2007 Field Procedures Manual.

Vessel Swamp Fox uses an Odom Digibar Pro for surface sound speed input to the Reson 8125. Unlike the CTD profiler, sea surface sound speed is calculated using two-way travel time. A pulse of known frequency is emitted and reflected off a surface. The two-way travel time is measured over the known distance between the transmitter and reflective surface, from which the sound speed is then calculated.

ODOM HYDROGRAPHIC SYSTEMS DIGIBAR PRO

The Digibar Pro is a real-time time-of-flight sea surface sound velocimeter. The manufacturer specified sound speed accuracy is 0.3 ms^{-1}. Aboard vessel Swamp Fox the Digibar probe is mounted to top of the deployable sonar arm plate, below which the Reson 8125 is mounted. Data are sent in real time to the Reson 8P.

The Digibar Pro has not been calibrated since it was purchased in 2005.

B. SOFTWARE SYSTEMS

B.1 ACQUISITION SOFTWARE

HYPACK MAX

Hypack Max is a multi-function marine survey software package. Hypack Max is used for line planning, vessel navigation and for acquisition of VBES, MBES data and detached positions. Survey lines, vessel position with respect to lines, and various navigation parameters are displayed for the helmsman. Hypack also controls Hysweep data logging on the acquisition computer, allowing RAW and HSX files to be named by their Hypack line file name and time of acquisition.

The primary adjustable user settings during MBES operations are transmit power, range, gain, pulse length, pulse rate, spreading and absorption. Typically power, range and gain are the only settings that are adjusted during the logging of a line. The pulse length, spreading and absorption are set for the survey depth area and are rarely adjusted. The ping rate is set to its maximum because the Reson 8125 will only use the highest possible ping rate for the vessel speed and depth at any given time.

SONAR PRO V 9.5

Sonar Pro is a Windows-based acquisition software package that provides real-time data display and sonar control. Sonar Pro is used to acquire Klein 3000 data in XTF format. Data acquisition is monitored real time by a qualified sonar operator.

The primary user settings that are adjustable during SSS acquisition are the range scale and the resolution. Typically, the range scale and resolution are set prior to logging data and not changed again until the surveyed depth area changes.

B.2. PROCESSING SOFTWARE

CARIS HIPS/SIPS V 6.1

Caris HIPS/SIPS (Hydrographic Information Processing System/ Side-scan Information Processing System) is used for processing, correcting, and analyzing all bathymetric, side scan, and phase-differencing bathymetric sonar data.

Caris HIPS is used for converting, correcting, cleaning, and analyzing gridded bathymetric data. Caris SIPS is used for converting and correcting side-scan sonar imagery and for contact selection and mosaic generation. Phase-differencing bathymetric sonar XTF files are processed in Caris as both bathymetric and side scan data files.

HSTP PYDRO

Pydro is a proprietary program developed and maintained by NOAA's Hydrographic Systems and Technology Program (HSTP), and is used primarily for feature management. Multibeam contacts (designated soundings), SSS contacts, and detached position are analyzed, grouped, and assigned S-57 classifications. Weighted grids (Caris surfaces) are imported into Pydro and excessed at survey scale for chart comparison. The Pydro Preliminary Smooth Sheet file (.pss) is delivered to the Atlantic Hydrographic Branch as part of the final submission package.

With the newest release of Pydro (v.7.x) the ability to process Tidal Constituents and Residual Interpolator (TCARI) tides has been implemented. If provided in the project instructions, the TCARI file for the area is loaded into Pydro along with the predicted, observed, or verified tide files for the corresponding stations. With this implementation, tides are no longer processed within Caris HIPS. Further discussion of TCARI is found in the Water Level Corrections section of this report.

SEA-BIRD CTD PROCESSING SOFTWARE

The Sea-Bird CTD processing suite consists of the programs SEATERM, SBEDataProcessing-Win32 and SeaSave-Win32. SEATERM is used to connect the CTD and download the binary cast data. Once the cast is uploaded to the processing computer, it is processed with the post-processing modules in SEASOFT-Win32. SBE Data Processing©, a Windows 2000/XP program, is part of the SEASOFT-Win32 software suite. SBE Data Processing consists of modular, menu-driven routines to convert, edit, process, and plot oceanographic data acquired with Sea-Bird instruments

(CTD data as well as auxiliary sensor data). For further details about the Sea-Bird SEASOFT© Software, refer to the Sea-bird electronics .pdf in Appendix II of this report.

MAPINFO PROFESSIONAL 8.5

MapInfo Professional is the Geographic Information System (GIS) software package used by SWAMP FOX. MapInfo is used for sheet management, final data analysis and creating end-user products such as chartlets and survey plots.

C. ACQUISITION METHODS

The project instructions assigned to SWAMP FOX call for Complete or Object Detection Coverage as defined in the FPM.

Where 200% SSS with VBES is used to comply with object detection requirements, two SSS line plans (100% coverage and 200% coverage) are created using the range scales appropriate for the survey area. Line spacing for the first 100% coverage is 120m at the 75 meter range scale and 160m at the 100 meter range scale. The line spacing for the second 100% coverage line plan is identical to the spacing for the first 100%, and the first line of the second 100% coverage is offset by half the line spacing. Vertical beam echo sounder data is acquired simultaneously with SSS data acquisition and used as the sole source of bathymetric data for charting purposes.

When the project instructions require complete coverage, MBES lines are planned at a spacing of two to three times the water depth and acquired at a speed of three to four knots. The design of the sonar pole mount is the speed limiting factor for all other modes of acquisition. The maximum survey speed is around eight knots; otherwise water wake from the pole is forced over the gunwale of the vessel. All lines are run parallel to each other except cross lines.

CROSS LINES

Cross lines are acquired in accordance with the *OCS Field Procedures Manual* as a confidence check of the survey data. Survey lines are planned such that ten percent of the total linear nautical miles are cross lines. Cross lines are planned perpendicular to main scheme lines when survey area allows. Cross lines are compared to the product navigation surface in Caris HIPS 6.1. The results of the Cross line QC test are submitted in Separate V of the Descriptive Report of each project.

D. CORRECTIONS TO ECHO SOUNDING AND QUALITY CONTROL

D.1. SOUND SPEED

SBE19 CONDUCTIVITY, TEMPERATURE AND DEPTH (CTD) PROFILER

Sound speed profiles acquired with the Sea-Bird Electronics SeaCat SBE19 CTD profiler are processed using the Sea Bird programs SBEDataProcessing-Win32 and SeaSave-Win32, which generates sound speed profile (SVP) files that are used to correct bathymetric HDCS data in Caris HIPS. Sound speed correctors are applied to MBES and VBES soundings during post processing.

The interval at which CTD casts are conducted depends on the data acquisition type, survey area and prevailing conditions. At a minimum, one CTD cast per week for VBES sound speed correction and one CTD cast every three to four hours for MBES acquisition is conducted. Casts are conducted more frequently when changing survey areas, or when survey conditions such as weather, tide, or current change sufficiently.

D.2. WATER LEVEL CORRECTORS

Soundings are initially reduced to Mean Lower-Low Water (MLLW) using predicted tides or preliminary (observed) zoned water level data. Data are obtained from the local, primary tide gauges through the Center for Operational Oceanographic Products and Services (CO-OPS) website (http://tidesandcurrents.noaa.gov/olddata). Predicted or observed water level files are converted to Caris tide files (.tid) and applied to all sounding data using either discrete tide zoning in Caris HIPS (.zdf files) or the TCARI module in Pydro if provided by CO-OPS.

After data acquisition is complete, a request for final, approved water levels is submitted to CO-OPS. Once final approved water levels are received, sounding data are re-corrected to MLLW using either the verified zones or the verified TCARI files.

D.3. HEAVE, PITCH, ROLL AND HEADING, INCLUDING BIASES AND NAVIGATION TIMING ERRORS

Heave, pitch, roll, and timing bias values for vessel Swamp Fox are determined during a patch test after a system is newly mounted on the sonar arm. Vessel offsets, dynamic draft correctors, and system bias values are entered in the sonar's Caris Hydrographic Vessel Files (.hvf) and applied during Caris' merge process.

D.4. VESSEL OFFSETS AND DYNAMIC DRAFT CORRECTORS

The vessel offsets were measured with a total station survey by the Navy Fleet Survey Team using traditional methods in accordance with NOAA Field Procedures Manual and Spec's and Deliverables at Stennis Space Center, MS on 03 March 2008 The offsets are found in Appendix III of this report, and are also entered in the HVFs submitted with each survey. The dynamic draft values used for SWAMPFOX are those measured prior to patch testing at Apra Harbor, Guam. The dynamic draft values are entered in the HVFs submitted with each survey.

E. Data Processing and Quality Control

E.1. Bathymetry

Raw bathymetry data (HSX and Hypack) are converted into Caris HDCS data format upon completion of daily acquisition. Conversion parameters vary for each data format, and are stored in the LogFile of each HDCS processed line folder. After conversion, data are corrected with true heave, tides, and sound speed and then merged. Following merge, Total Propagated Error (TPE) is calculated.

For further explanation of TPE calculations refer to Section 4.2.1.1 of the 2007 *OCS Field Procedures Manual* (v. 2.2, March 2007).

Vertical Beam Bathymetry

When VBES is the sole source of bathymetry (e.g. 200% SSS + VBES survey), VBES is converted to Caris HDCS and processed as described in the previous paragraph. The data is then examined and cleaned in Caris Singlebeam Editor. Digital records (.bin files) are used to provide extra information during data cleaning. The .bin files are viewed in Pydro Post Acquisition Tools. After the data has been processed and cleaned, an uncertainty-weighted BASE Surface is computed (usually at a resolution of five meters).

Multibeam Bathymetry

Depending on acquisition type, MBES bathymetry is analyzed using Caris BASE surface layers. Caris BASE surfaces are described in detail in the 2007 *OCS Field Procedures Manual* and the *Caris HIPS/SIPS 6.1 Users Manual*.

When the primary source of bathymetry for a survey area is a combination of VBES and MBES, a collection of finalized CUBE surfaces is generated as the depth product of the survey. The data is examined and cleaned as necessary to reject gross fliers and to identify systematic data errors. Systematic errors are corrected or removed from the project, documentation of which is found in the survey processing notes or descriptive report. The surface names contain the resolution at which they were created, which is based on depth and data density.

When Complete or Object Detection MBES is the primary source of bathymetry, data are processed using CUBE. After computation of TPE, MBES lines are either used to create a new surface or are added to an existing surface. The resulting layers are analyzed by the data processor to identify fliers and/or systematic errors, and to identify significant bottom features. Fliers are rejected by the data processor in Caris Subset Editor (multi-line spatial view) or Caris Swath Editor (single-line time-series view). Systematic errors are identified and documented by the data processor. Least depths of navigationally significant features are flagged as "designated soundings," which both identifies the object as a navigationally significant object for import into Pydro and forces the depth of the grid to match the least depth of the feature.

After data editing is complete, grids are finalized and combined for delivery to the Atlantic Hydrographic Branch. Surface resolution depends on depth and survey type (see *OCS Hydrographic Specifications and Deliverables Manual* for further information), and is specified in the name of the surface.

E.2. IMAGERY

After acquisition, SSS data are converted from XTF format to Caris HDCS format. Fish height, vessel heading (gyro), and vessel navigation records are then reviewed and corrected and recalculated. Data are then slant-range corrected to 0.1m with beam pattern correction. The slant-range corrected SSS imagery data are closely examined for contacts. Imaged objects are evaluated for significance based upon apparent shadow length and appearance. Contacts are selected[3] and saved to a contact file within the respective Caris HDCS line file and inserted into Pydro for feature management.

Two mosaics are created after SSS data have been processed; one of the first 100% of coverage and one of the second 100% of coverage (200%). If any deficiencies in the SSS coverage are found, a holiday line file is created from the mosaics, and additional lines of SSS are acquired.

E.3. BATHYMETRY ANALYSIS AND FEATURE CLASSIFICATION

Following data cleaning in Caris HIPS and SIPS, the following items are inserted into Pydro and saved in a Preliminary Smooth Sheet (PSS) file: finalized weighted bathymetry grids, SSS contacts, MBES designated soundings, detached positions (DPs), Geographic Positions (GP), bottom samples (Hypack DPs), and AWOIS items. The Pydro .pss is used for survey analysis and feature management.

Images of contacts exported from Caris are displayed in the Image Notebook Editor in Pydro. Contacts are arranged by day and line and can be selected in the data "Tree" window. Information concerning a specific contact is reviewed in the Editor Notebook

[3] Contact selection includes measuring apparent height, selecting contact position, and creating a contact snapshot (*.tif) image.

Window in Pydro. This information includes position, surrounding depths, contact cross references, and charting recommendations.

Each contact is reviewed, and information flags are set accordingly as described in the Pydro Data Flagging Decision Tree (Figure 4-22 in the *OCS Field Procedures Manual*). Contacts appearing significant[4] are further investigated with MBES or VBES.

Multiple representations of one distinct feature (e.g. contacts from two or more SSS lines on a wreck) may be correlated together. For a group of correlated features, one representation is selected as the primary contact, and all others are selected as secondary contacts with respect to the primary contact.

After a feature is fully classified, primary features are flagged as "Resolved." If a primary feature is flagged "Resolved," then the secondary features correlated to that primary feature are automatically flagged "Resolved" and are given the same full classification as the primary feature.

After all items within the PSS have been resolved, three reports are generated for submission to the Atlantic Hydrographic Branch: Feature Report, AWOIS Report, and DTON report[5].

E.4. Survey Deliverables and Ancillary Product Generation

All data are submitted digitally in close-keeping with section 5.1.2.2 the *OCS Hydrographic Field Procedures Manuel*; including raw and processed sonar data, ancillary correction data (tides, sound speed, true heave, hydrographic vessel files, etc), supporting products (Pydro PSS files, Caris sessions and field sheets); and all supporting reports and documentation.

The final bathymetric deliverable is a collection of gridded surfaces. Side scan sonar mosaics are also submitted as evidence of appropriate imagery coverage. These mosaics are also used to identify contacts, as well as general bottom type. Bathymetric surfaces and SSS mosaics are submitted in their respective Caris field sheets. In addition, the Pydro Preliminary Smooth Sheet (PSS) file is submitted as the record of survey feature management.

E. Approval

[4] Significant features are defined by the Hydrographic Survey Specifications and Deliverables as an object rising more than one meter above the seafloor in water depths of 0-20 meters, and an object rising 10% of depth above the seafloor in water depths greater than 20 meters.

[5] Danger to Navigation (DTON) reports are generated immediately after discovery and are so submitted to the Marine Chart Division of the NOAA Office of Coast Survey. Multiple DTON reports during the course of a survey are possible. If no dangers are found during the course of a survey, no report is generated.

As Team Leader, I have ensured that standard field surveying and processing procedures were utilized in accordance with the *NOS Hydrographic Manual, Fourth Edition*; *Field Procedures Manual,* and the *NOS Hydrographic Surveys Specifications and Deliverables*.

I acknowledge that all of the information contained in this report is complete and accurate to the best of my knowledge.

LT(jg) Stephen C Kuzirian, NOAA
Team Leader, SWAMP FOX

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As Team Leader, I have ensured that standard field surveying and processing procedures were utilized in accordance with the *NOS Hydrographic Manual, Fourth Edition; Field Procedures Manual*, and the *NOS Hydrographic Surveys Specifications and Deliverables*.

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