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

# Data Acquisition & Processing Report

*Type of Survey* *Multibeam and Side Scan Sonar*

*Project No.* *OPR-L430-NRT6-13, S-L922-NRT6-13, S-L919-NRT6-13*

*Time Frame:* *2013 Field Season*

LOCALITY

*State:*
*California*

*General Locality:*
*San Francisco Bay and Vicinity*

**2013**

**CHIEF OF PARTY**

*Laura Pagano*

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**DATE**______________________________________________

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# Data Acquisition and Processing Report

**NOAA S3003**

**NRT6-13**

## Introduction

NOAA Navigation Response Team 6 (NRT6) is a mobile hydrographic survey team that operates in the southwestern region of the United States. The primary survey platform for NRT 6 is NOAA launch S3003, a 27-ft vessel built by SeaArk of Monticello, Arkansas, and delivered to NOAA in 2004. NRT 6 is staffed by three physical scientist technicians.

NRT 6's primary mission includes acquiring hydrographic survey data used to update NOS nautical charts. The team is also equipped to rapidly respond to navigationally significant events such as natural disasters, vessel groundings, and other incidents. NRT 6 responds to survey requests in the state of California and other geographic areas as necessary, made by harbormasters, pilots, and other stakeholders. Hydrographic surveys are performed using multibeam, side scan, and single beam sonars. Land-based surveying of shoreline features is performed using a Trimble GeoXH handheld GPS unit. A 32-ft trailer serves as a mobile field office, and is equipped with several data processing workstations.

This Data Acquisition and Processing Report (DAPR) details all Navigation Response Team 6 (NRT6) survey equipment and methods used to acquire and process survey data. Systems were selected for use during this project based on instructions from the Field Procedures Manual, Project Instructions, and Hydrographic Survey Specifications and Deliverables. Survey systems and methods used during this project were also chosen based on the water depth, sea and weather conditions, and the ability of the vessel to safely navigate the area.

# A. Equipment

## A.1 Survey Launch S3003

Survey Lunch S3003 is a 27-ft SeaArk Commander, and is used to acquire side scan sonar data, multibeam echosounder data, singlebeam echosounder data, and sound velocity profiles. The 4.5 ton launch is 8 feet wide, has a static draft of 0.5 meters, and is powered by twin 150hp Honda outboards.

**S3003 Vessel Information**

| | |
|---|---|
| **Hull Number:** | **S3003** |
| **Builder:** | **SeaArk** |
| **Built:** | **2003** |
| **Length Overall:** | **33 ft.** |
| **Beam:** | **8 ft.** |
| **Draft:** | **1.6 ft.** |
| **Cruising Speed** | **28kts** |
| **Min/Max Survey Speed:** | **4-8kts.** |
| **Primary Echosounder:** | **Hull-mounted Simrad EM3002 MBES** |
| **Secondary Echosounder:** | **Hull-mounted ODOM Echotrac CV VBES** |
| **Imagery System** | **Towed Klein 3000 Side Scan Sonar system** |
| **Sound Velocity Profiler:** | **Sea-Bird SeaCat SBE 19+ CTD Profiler** |
| **Surface Sound Velocity Probe:** | **ODOM Digibar Pro** |

## A.2 Sounding Equipment

### A.2.1 Shallow Water Multibeam Sonar

S3003 is equipped with a Kongsberg Simrad EM 3002 shallow water multibeam echosounder. The EM 3002 collects sounding and backscatter data at 300 kHz with 254 receive beams, which provide an optimal swath of 130°. The system is relatively “hands-off”, with range scale, power, gain, and other parameters automatically controlled by the sonar system. Please see Appendices 3 and 4 for further information on the Simrad EM3002 setup.

The sonar head contains a flat-face transducer (Mills Cross configuration) and all transmitter and receiver elements encased in an acoustically transparent medium. The transmit beam is steerable to compensate for mounting angle and vessel pitch.


*Figure 1: Hull-mounted Simrad EM 3002 transducer.*

The processing unit performs the beam-forming, bottom detection, and controls the sonar head with respect to gain, ping rate, and transmit angle. It also contains the interfaces for all time-critical external sensors such as attitude data, position, and the 1 PPS (pulse per second) signal.

EM3002 SIS (Seafloor Information System) software operates on the Hypack computer and communicates via Ethernet connection, and is used to control adjustable parameters. The controller software also transmits real time sound velocity measurements (from a Digibar Pro velocimeter mounted near the sonar head) to the processing unit for initial beamforming and steering.

The sonar head is hull mounted aft of the vessel cabin, centered on the keel line. The POS/MV IMU is centered above the sonar head. Please see the CARIS HVF for offset values.

The sound velocity probe is mounted on the transom, between the outboard engines. The probe is housed in a PVC tube, which is then inserted into two brackets attached to the transom. This removable configuration allows for higher transit speeds between survey areas, while keeping the probe protected.

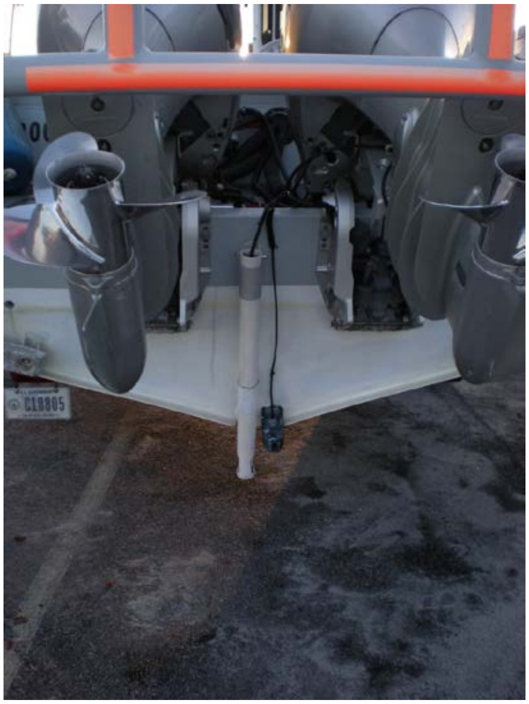
*Figure 2: S3003 Digibar mount and protective PVC sheath.*

A problem with this configuration is the tendency for air bubbles (turbulence) and debris, mostly floating eel grass, to become trapped in the PVC tube, leading to large errors in the sound velocity. This in turn causes the multibeam to incorrectly steer the incoming pings, seen as large “frowns” in the bathymetry. Data exhibiting this problem are noted, and data are re-acquired over the problem areas.

The problem of turbulence and eel grass has subsequently been mitigated for the most part by installing a 6 inch longer PVC tube so as to extend the velocity probe deeper below the water surface. Since this installation, we have seen fewer beam steering sound velocity errors. However, during times of calmer seas and/or cleaner water, free of floating eel grass we still prefer to use the shallower PVC tube as it is less likely to suffer debris damage and interference from the engines in the “up” position during transit between survey areas.

### A.2.2 Side Scan Sonar

NRT 6 operates a Klein 3000 side scan sonar system, used for the detection of submerged wrecks and obstructions. The system operates at 500 kHz and 100 kHz, and is able to provide side scan data from ranges between 25 and 500 meters; typical surveys see the SSS used in high frequency mode, with range scales between 50 and 100 meters, as specified in the HSSD section 6.2.4. The system consists of a towfish, deployed from a rotating boom on the aft deck (see figure 3). The towfish is connected to a slip ring attached to an electric winch, which is connected to the Transceiver and Processing Unit (TPU). The TPU is networked to a workstation that allows the user to control various parameters, view SSS imagery and record sonar files. Measurements to the towpoint can be found in the survey offset report, Appendix 1, and a calibration report for the system is found in Appendix 9.

*Figure 3: Klein 3000 SSS Towfish.*

The Klein Systems 3000 sonar system includes:

• Dual frequency (100 kHz, 500 kHz) towfish with 300 PSI pressure sensor
• Transceiver Processing Unit (TPU)
• Acquisition Workstation
• Thirty-three meter Kevlar reinforced tow cable
• SonarPro software and VX Works TPU operating system

The horizontal beam widths for the low and high frequencies are 1° and 2° respectively. The vertical beam width is 40°. Maximum range scale is 150 meters at the high frequency, and 500 meters using the low frequency.

All SSS data collection is controlled using the SonarPro software operating in a Microsoft Windows XP environment on the Acquisition Workstation. Control signals are sent to the towfish and data is received from the towfish via the TPU. Data is recorded digitally and stored on the Acquisition Workstation in Klein SDF format.

Side scan sonar lines are spaced according to the range scale appropriate for the water depth. Lines are planned with a minimum of 25 meters of overlap with adjacent swaths. Vessel speed is adjusted to ensure that an object one meter square in size would be detected and clearly imaged across the sonar swath. Typical SSS collection speed is five knots. Confidence checks are performed by observing operation of the SSS along pier faces, buoy blocks, and in areas with known targets.

High frequency of 500 KHz is utilized as the primary frequency for data collection, with low frequency observed, but not logged. The maximum range scale used is 100 meters, with operation on the 50 to 75 meter range scales more typical. Fish height is kept at eight to twenty percent of the range scale, except in very shallow areas (< 6 meters).

S3003 is equipped with a Dynapar cable counter used to measures the length of towfish cable deployed by counting revolutions of the towing block on the J-frame. The length of cable deployed is computed automatically and output directly to the Acquisition Workstation where it is used by the SonarPro software and logged in the SDF data format.

### A.2.3 Vertical Beam Echosounder

S3003 is equipped with an Odom Echotrac CV Vertical Beam Echosounder (VBES). The Odom CV is a single-beam echo sounder, operating at 208 kHz with an 8° beam. Unlike previous Odom Echotrac models, the CV has no display or paper record on the actual processor; rather, sounding data is displayed in Hypack. VBES data are collected infrequently, as both multibeam and side scan sonar may be operated simultaneously. This system is used infrequently, as most projects now require the collection of SWMB data.

### A.2.4 Lead line

NRT6 uses a lead line for echosounder calibration tests. It is a non-stretching synthetic line, marked every half-meter, with a lead weight attached at the bottom. See Appendix 7, the Sounding System Comparison, for details.

## A.3 Positioning Equipment

### A.3.1 POS MV Positioning and Orientation System

S3003 is equipped with an Applanix Model 320 Version 4 POS/MV, interfaced with controller software installed on the Hypack computer. A Trimble DSM 132 provides differential correctors to the POS/MV, and is also interfaced on the Hypack computer via Trimble TSIP talker software. The Inertial Measurement Unit (IMU) is located in a hatch aft of the cabin, directly over the multibeam transducer. The antennae are located on the top of the cabin, on mounts that raise them off of the deck. The antenna for the Trimble receiver is located on the top of the mast.


*Figure 4: IMU mounted in hatch directly above the multibeam transducer.*

### A.3.2 Trimble DSM212

Survey launch S3003 is equipped with a Trimble DSM212L integrated 12-channel GPS receiver and dual-channel DGPS beacon receiver. The beacon receiver can simultaneously monitor two independent U.S. Coast Guard (USCG) DGPS beacons.

There are three modes: Auto-Range, which locks onto the beacon nearest the vessel, Auto-Power, which locks onto the beacon with the greatest signal strength, and Manual, which allows the user to select the desired beacon. Additionally, the DSM212L can accept differential correctors (RTCM messages) from an external source such as a user established DGPS reference station.

The following parameters can be monitored in real-time through Trimble's TSIP Talker software to ensure position data quality: number of satellites used in the solution, horizontal dilution of precision (HDOP), latency of correctors and beacon signal strength. The DSM212L is configured in the auto-range mode to only use correctors from the nearest USCG beacon, to go off-line if the age of DGPS correctors exceeded 20 seconds, and to exclude satellites with an altitude below 8°. The DSM212L is used to supply differential correctors (RTCM) to the POS MV primary GPS receiver through the DIFF port on the POS MV PCS.

*Figure 5: View of top of house on Launch S3003. Center GPS antenna is used by Trimble DSM 132 receiver, and two lower antennae are used by the POS/MV.*

### A.3.3 Trimble GeoXH Handheld GPS

The GeoXH is used to position AtoNs and assist with shoreline. Fixed Aids to Navigation (AtoNs) are occupied for a minute or longer, which allows for a horizontal precision of 0.1 meter or less after post-processing.

NRT6 processes rover data collected on the GeoXH using Pathfinder software. Data are post-processed using local CORS stations. Typical processing uses multiple CORS sites, as there are numerous sites in NRT6's operating area.

For AtoNs, the processed file is then exported as a SHP file, and formatted for submission to MCD, as outlined in Appendix 5 of the Field Procedures Manual.

## A.4 Software

Basic descriptions of the various software used for acquisition, processing, and other tasks are listed below. For further information, including details about software versions and other information, please see the Appendix 5, Hydrographic Systems Inventory.

### A.4.1 Acquisition Software

A.4.1.1 Hypack

Coastal Oceanographic's Hypack Max is used for vessel navigation and line tracking during data acquisition.  NRT6 used HYPACK 2013 for this survey.

Hypack Max's Survey program is used to log SBES data and is used in conjunction with Hypack Max's Hysweep Survey program to log MBES data. SBES and MBES data are logged in the Hypack "raw" format, with SBES data using the day number as an extension and MBES data using the .hsx extension. Both are ASCII text files.

A.4.1.2 SonarPro

Klein SonarPro version 11.6 is used to monitor and log all side scan sonar data from the Klein 3000 sonar. Data is recorded in the Klein SDF format.

A.4.1.3 Seafloor Information System (SIS)

This sonar is interfaced with the acquisition PC using the Simrad EM3002 SIS (Seafloor Information System) software application.  SIS is used to acquire data from the EM3002 by creating .ALL files.  Hypack Hysweep is still used to acquire .HSX files but these files are only being used for the purpose of real time matrix display.

### A.4.2 Processing Software

A.4.2.1 CARIS HIPS/SIPS

NRT6 uses CARIS HIPS/SIPS 7.1, updated with the most current hotfixes, to process all sonar data.  See Appendixes 10 and 11 of the HSRR for a detailed discussion of the current CARIS HVF file.

A.4.2.2 MapInfo

Mapinfo 10.5 is used on all processing computers for project planning, and creating survey products.  HydroMI, a NOAA in-house software application, is used with MapInfo to convert planned lines for use with Hypack, create chartlets, and perform a number of other survey-related tasks.

A.4.2.3 Pydro

The latest version of Pydro is installed on the three main processing workstations.  Pydro is used to organize survey feature data and bathymetry, to generate reports, and for a number of other survey-related tasks.

A.4.2.4 CARIS Bathy DataBASE

The latest version of CARIS Bathy DataBASE 4.0 is installed on the three main processing workstations. CARIS Bathy DataBASE is used to organize survey feature data, bathymetry, and for a number of other survey-related tasks.

### A.4.3 Other Software

Velocipy is used to process CTD casts into CARIS .SVP files, used to correct the sound velocity profile in CARIS.

# B. Data Processing and Quality Control

## B.1 Shallow-Water Multibeam Data

Shallow-water multibeam (SWMB) data were monitored in real-time using the 2-D and 3-D data display windows in Hypack Hysweep, and the Simrad controller window. As the Simrad EM3002 is a relatively “hands-off” system, few parameters are adjustable by the sonar operator. Ping rate, range scale, power, and gain are all automatically adjusted by the Simrad system. In the Runtime Parameters menu, under Sounder Main, the user is able to set a maximum ping rate, and a minimum and maximum depth.

Simrad SIS .ALL files were converted to CARIS HDCS files following acquisition. Tide, sound velocity (SVP), vessel offset, dynamic draft, and True Heave correctors were then applied and merged with depth, position and attitude data to compute the corrected depth and position of each sounding. The Total Propagated Uncertainty (TPU) was then computed for each sounding, using the error values included in the CARIS HIPS Vessel File (HVF). TPU values are used to create a Bathymetry Associated with Statistical Error (BASE) surface, a grid comprised of nodes that contain bathymetric and uncertainty information. NRT6 uses the Combined Uncertainty and Bathymetric Estimator (CUBE) algorithm to create BASE surfaces from SWMB data. The CUBE algorithm creates a BASE surface grid by first creating depth hypotheses at each grid node, and then using density, locale, or a combination of the two to choose the best hypothesis. NRT6 used the parameters (and the associated XML file) outlined in Hydrographic Technical Directive 2009-2 for the surfaces generated in this survey. Specifically, NRT6 used the NOAA_1m and NOAA_0.5m CUBE parameters. Please see the HVF Review, located in the HSRR, for updated information on the TPU values used in during this project.

The BASE surface is then used to conduct area-based editing in CARIS subset mode, which allows the processor to focus on specific areas with higher uncertainty values and also a high number of CUBE hypotheses. In addition to area-based editing, subset tiles were also used to systematically review the entire project area in subset mode. Both of these review methods include removing fliers and or noise in the water column, as well as picking the least depth on significant contacts. Filtering was also used to assist in cleaning noise and fliers. NRT6 used the IHO Order 1 filter in CARIS for this project.

### B.2 Side Scan Sonar Data

Side Scan Sonar (SSS) data were collected and monitored with Klein Sonar Pro Version 11.6. Files were saved in .SDF format. Range scale, gain, and towfish height were all adjusted to ensure the collection of quality data, and that the imagery and towfish height met the requirements of the HSSD. Sonar imagery quality checks were performed on objects located within the survey area.

.SDF are converted to CARIS SIPS files, and reviewed for significant contacts using the Side Scan Editor. Contacts are then exported into Pydro, where they are then examined and categorized based on significance. Significant contacts are noted, and are later developed using SWMB. Mosaics of the data are created to ensure complete coverage of the survey area.

All SSS data were examined and re-acquired if motion artifacts, boat wakes, or refraction prevented the identification of targets while examining side scan data.

### B.3 Composite Source File

A composite source file (CSF) was included with this project. The CSF items are imported into Caris Bathy DataBASE and filtered down to assigned items. Boat sheets with images of the CSF items located on the chart are created, and used for notes on the items while surveying.

After surveying is complete, all mandatory fields in Caris Bathy DataBASE are populated for each CSF item. If the item was not found or investigated, the S-57 information from the original CSF is retained.

## C. Corrections to Echo Soundings

### C.1 Sound Velocity

NRT 6 collects conductivity, temperature, and density (CTD) data using an SBE 19+ to determine sound speed profiles, which are used to correct multibeam sonar data. The SBE19 generates a raw hexadecimal file (*.hex), which is used by Velocipy, a NOAA in-house program that coverts .hex files to files used to correct multibeam data. Please see Appendices 5 and 6 for serial numbers and the latest calibration reports.

An Odom Digibar Pro is used for continuous sound velocity measurements at the face of the multibeam transducer to correct for the geometry of a flat transducer array. The

Odom Digibar Pro is mounted on the transom, housed inside a PVC tube that allows a free flow of water over the sensor. Sound speed data is sent from the Odom Controller to the Hypack acquisition PC via a serial cable. Please see Appendices 5 and 6 for serial numbers and the latest calibration reports.

## C.2 Vessel Offsets and Dynamic Draft Corrections

Measurements to verify the vessel offsets currently used by NRT6 were taken by a survey team from the National Geodetic Survey in 2009. New offset measurements from the reference point to the multibeam transducer and IMU were taken following the retrofitting of the multibeam transducer. Both were relocated to points aft of the cabin. Please see Appendix 1 for the NGS Offset Measurement Report.

Static and dynamic offsets, unless otherwise noted, are entered into CARIS HIPS Vessel Files (HVF). A separate HVF is used for the multibeam and singlebeam echosounders, and for 100% and 200% sidescan. Uncertainty values for all offset measurements are also recorded in the HVF, in the Total Propagated Uncertainty section.

Angular offsets and navigation timing errors of the multibeam system were determined using a patch test. A series of calibration lines are run and processed using the CARIS Calibration mode. The patch test was acquired on March 27$^{th}$, 2013 and can be found in Appendix 8 of this report.

Static and dynamic offsets (settlement and squat values), angular offsets, and navigation timing errors are entered into the CARIS HIPS Vessel File (HVF), which is used to correct CARIS HDCS data.

### C.2.1 Vessel Static Offsets

In March 2009, personnel from the National Geodetic Survey measured the offsets of all sensors aboard launch S3003, following the re-installation of the multibeam transducer to a hull-mounted configuration. NGS values for the multibeam transducer and IMU agreed with the initial post-installation measurements (measured by NRT6 personnel) to within a centimeter in all dimensions. Please see Appendix 1 for the NGS Offset Measurement Report.

NRT6 uses a reference point that is located near the vessel center of motion, from which all offsets are measured. The POS controller sets the center of Navigation and Attitude at the reference point on the IMU. Sensor offsets from the reference point are then entered into the CARIS HVF. Please see Appendix 11 for the HVF Report.

### C.2.2 POS MV Phase Center Offset Adjustment

The phase center for the POS MV was determined to be 1 cm below the top of the antenna. The antenna was measure from its base to the top, and a value of 4.6 cm (see the engineering drawing below, Figure 1) was subtracted from the total measured value to obtain the offset from the top of the antenna to the phase center. The measured vertical offset value from the NGS survey, from the IMU to the port GPS antenna is -2.587 (in POS coordinate system with Z-axis positive downward). Corrected for the phase center, this value is now -2.577. This correction only affects the offset from the Primary GPS antenna to the IMU, which is entered in the POS Controller software. See Appendix 4 for a screen grab of the updated offset values in the POS MV Lever Arms & Mounting Angles window.

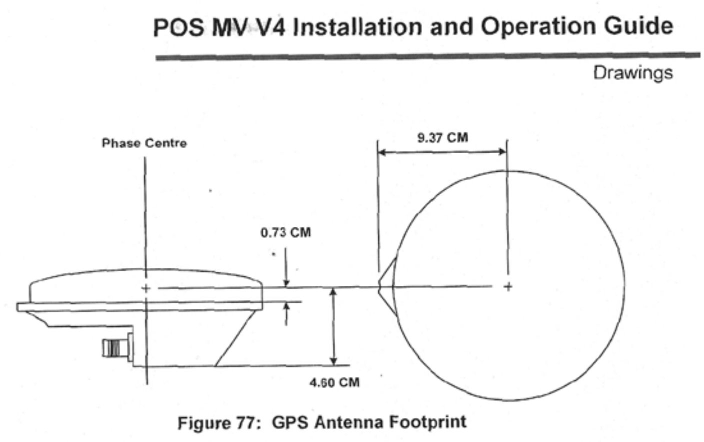


*Figure 6: Engineering drawing from POS MV manual, Appendix E.*

### C.2.3 Vessel Dynamic Offsets

C.2.3.1 Static Draft

The static draft of the vessel was measured on March 30th, 2009. This measurement was made separately from the NGS survey, as the waterline was not clearly marked at the time of that survey. The vessel was again leveled, using the IMU plane of reference, and levels and t-squares were used for measurements. The resulting waterline value is -.024 m from the reference point, and has changed .026 m. The waterline was chosen to be the line of marine growth on the vessel hull. The main source of uncertainty in this measurement was choosing the waterline. The thickness of the marine growth line was approximately 2 cm, which is larger than the assumed uncertainty for the actual measurement, and thereby used as the Draft TPU value in the HVF.

C.2.3.2 Dynamic Draft

A dynamic draft test was conducted in March 2013. This test was performed using the Ellipsoid Referenced Dynamic Draft Method (ERDDM) or PPK method outlined in section 1.4.2.1.2.1 of the Field Procedures Manual. The results were satisfactory, and were entered into the Draft section of the CARIS HVF. Please see Appendix 2 for a report detailing the process of calculating the dynamic draft values.

## C.3 Heave, Pitch, Roll, Heading, and Timing

The POS/MV 320 provided attitude data to SIS, which stored the data in the ALL multibeam file. Attitude data quality is monitored while surveying by monitoring the POS Controller window, which is installed on the Hypack workstation. Alarms are triggered when accuracy values fall below user-determined values.

As discussed in the previous section, navigation timing error is determined using the patch test, and applied to data using the CARIS HVF.

## C.4 Water Level Correctors

Soundings were reduced to Mean Lower-Low Water (MLLW) using preliminary tides, taken from stations 9414750 – Alameda, 9414290 – San Francisco, 9414863 – Richmond, 9415144 – Port Chicago, and 9414523 – Redwood City. The Zone Definition File for this project was L430NRT62013CORP.zdf. The .zdf file breaks the survey area into polygons that take into account the magnitude and time differences from a primary tide gauge. Once available, the verified tide data is applied before submitting hydrographic survey data.

# D. Approval

As Chief of Party, I have ensured that standard field surveying and processing procedures were used during this project in accordance with the Field Procedures Manual, and the NOS Hydrographic Surveys Specifications and Deliverables Manual, as updated for 2013.

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

Approved and Forwarded: PAGANO.LAURA.A.1365885520 Digitally signed by PAGANO.LAURA.A.1365885520 DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=OTHER, cn=PAGANO.LAURA.A.1365885520 Date: 2013.08.26 14:50:07 -07'00'

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