W00099

NOAA FORM 76-35A

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

DESCRIPTIVE REPORT

Type of Survey HYDROGRAPHIC

Field No.

Registry No. W00099

LOCALITY

State Micronesia, Northern Marianas Islands

General Locality Phillipine Sea

Sublocality Farallon de Medinilla Island and Vicinity

2001

CHIEF OF PARTY
Maxim F. Van Norden

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DATE

NOAA FORM 77-28
(11-72)

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

REGISTER NO.

HYDROGRAPHIC TITLE SHEET

W00099

ISTRUCTIONS 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.

State **Micronesia, Northern Marianas Islands**

General Locali **Phillipine Sea**

Sublocality **Farallon de Medinilla Island and Vicinity**

Scale **1:25,000** Date of Survey **January 8 - March 20, 2001**

Instructions Dated Project No.

Vessel **LIDAR(SHOALS), USNS SUMNER**

Chief of Party **Maxim F. Van Norden**

Surveyed by **U.S. Naval Hydrographic Office**

Soundings taken by echo sounder, hand lead, pole **Lidar, Simrad Em 121 and 1002 multibeam**

Graphic record scaled by **Fleet Survey Team**

Graphic record checked by **Fleet Survey Team**

Evaluation by **David Sinson** Automated plo **HP Designjet1050c**

Verification by **Physical Scientist: David Sinson, Cartographer: Russ Davies**

Soundings in **meters** at **MLLW**

REMARKS: **Revisions and annotations appearing as endnotes were generated by the cartographer during office processing.**

All depths listed in this report are referenced to mean lower low water unless otherwise noted.

UTM Zone 55

Outside Source Data Evaluation
Survey W00099

Farallon de Medinilla, Commonwealth of the Northern Marianna Islands
January 8 – March 20, 2001

Data Acquired by:
Naval Oceanographic Office
Stennis Space Center, Mississippi

A. GENERAL INFORMATION

A.1 Background

This survey includes reconnaissance multibeam echosounder and LIght Detecting And Ranging (LIDAR) bathymetry data in the vicinity of the island of Farallon de Medinilla. The survey was conducted by U.S. Naval Oceanographic Office (NAVO) personnel aboard the USNS SUMNER, a 329-ft Pathfinder Class Hydrographic Survey Ship, and the Scanning Hydrographic Operational Airborne LIDAR Survey (SHOALS) operated on a DHC6/300 Twin Otter aircraft.

A.2 Area Surveyed

The area surveyed surrounds the island of Farallon de Medinilla (FdM) which lies approx. 50 miles north of Saipan Island within the Commonwealth of Northern Marianna Islands (CNMI). LIDAR data were collected in near-shore waters and multibeam data were collected in waters 40 meters and deeper. There is a coverage gap surrounding FDM in an area too deep for LIDAR and too hazardous for ship operations.

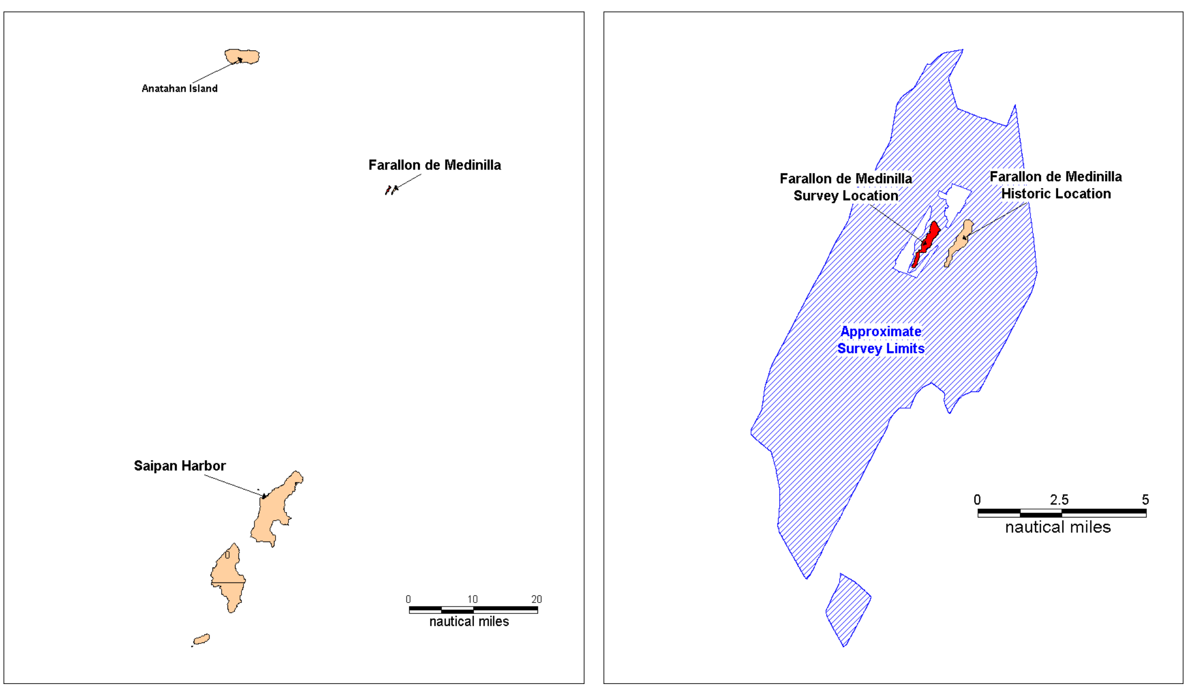

Figure 1: Location and approximate survey limits for W00099

A.3 Survey Scope

Of the objectives listed in the NAVO Report of Survey, Section 1.1.6, this survey was reviewed for the following applications:

- Confirm charted position of FDM.
- Updating of NOAA chart 81068.[1]

A.4 Data and Reports

The following data and documentation were received from NAVO:[2]

- Fdm_updated Caris format smooth sheet
- Fdm_updated120203.pdf Adobe format smooth sheet
- Fdm_101503 reduced-density sounding data in .CRS and ASCII XYZ text format
- WESTPAC LIDAR Report of Survey:
  APNDX A SURV AREAS.doc
  APNDX B TIDE ZONES.doc
  APNDX C TIDE STATIONS.doc
  APNDX D WP COVERAGE.doc
  APNDX E NAVAIDS.doc
  APNDX F SUMNER ERRORS.doc
  APNDX G LIDAR ACCURACY.doc

Additional data submitted in support of this survey and source:[3]

- NAVO memo "Cruise Report, SURVEYOPS 6103-01, USNS SUMNER (T-AGS 61)", dated 25 January 2001
- Lessons Learned in Multi-Platform Hydrographic Surveys, 2002: van Norden, M.F, Ebrite, S., Cronin, D.J., Ventura, Don. IEEE
- Tide zoning correctors – NOAA CO-OPS
- Verified tide correctors from temporary NOAA gauge – NOAA CO-OPS 1633227 TANAPAG HARBOR, SAIPAN, N MARIANAS IS

B. DATA ACQUISTION AND PROCESSING

A complete description of data acquisition and processing systems, quality control procedures and data processing methods can be found in the *WESTPAC LIDAR ROS* [4]and *Cruise Report, SURVEYOPS 6103-01* for LIDAR and USNS SUMNER [5] multibeam operations respectively. The Evaluator's summary and discussions of methods follows.

B.1 Data Acquisition

USNS SUMNER Multibeam:
The USNS SUMNER collected approximately 95% of the data around Farallon de Medinilla in waters generally deeper than 40 meters. The USNS SUMNER is a 329-foot T-AGS 60 class vessel equipped with the Science Applications International Corporation (SAIC) Integrated Survey System (ISS-60) for data collection. The motion sensor was a POS/MV. The vessel was also equipped with a SIMRAD EM 121 and a 1002 multibeam sonar system for survey operations. NAVO reported that one hundred percent shallow-water multibeam (SWMB) coverage was obtained in the survey area in waters 40 meters and

deeper or where the ship's safety would permit. Positioning was obtained using Fugro/Chance Omnistar Wide Area DGPS service. A CTD, XBT and SST/SV were used to sample for sound velocity.

Although the NAVO Report of Survey states that no report was written specifically discussing the USNS SUMNER operations, a memo titled "Cruise Report, SURVEYOPS 6103-01, USNS SUMNER (T-AGS 61)" and dated 25 January 2001 was provided by NAVO and reviewed for information about survey operations. Additional survey information was included in an IEEE paper titles "Lessons Learned in Multi-Platform Hydrographic Surveys".

LIDAR:
The LIDAR portion of the survey was conducted using the SHOALS 400 Airborne system mounted on a DeHaviland Twin Otter aircraft. The LIDAR system was calibrated prior to survey operations and whenever major system components effecting data accuracy were changed or adjusted.

Positioning was provided by Ashtech Z-12 GPS receivers. Based on E-mail communications [6] with Scott Ebrite of NAVO all LIDAR positions were obtained using stand-alone GPS mode due to insufficient DGPS beacon coverage in the survey area. No calibrations of this receiver were conducted during the survey, but HDOP, PDOP, and SNR were monitored for data quality purposes. PDOP's of greater than four, GPS outages of longer than ten seconds, and positions solutions using less than four space vehicles resulted in rejection of the data, and reacquisition.

B.2 Corrections to Soundings

USNS SUMNER Multibeam:

Draft Correction:
Static draft correctors were applied during data acquisition in the Simrad multibeam software. Changes to the static draft were not monitored during the survey. NAVO personnel assess the error to be 0.1 meters at the beginning of the survey, and increased to 0.8 meters for FdM over the course of the survey due to fuel burn off.

Sound Velocity Correction:
Sound velocity casts were conducted at least on a daily basis; typically casts were taken early each morning and late each evening. All casts were visually displayed and overlaid for comparison purposes. In addition XBT's were performed on a 6 hour interval. Surface sound velocity was monitored in real time, and additional SVP casts were taken as local conditions warranted. Sound velocity correctors were applied during data acquisition in the Simrad software. NAVO personnel assessed the error associated with the sound speed sensor error as being within 0.5 meters per second, and the surface sound speed sensor error being within 0.05 meters per second. No sound velocity data were provided for this survey. The Evaluator was unable to independently confirm the number or location of sound velocity casts conducted during this portion of the survey. The Evaluator was also unable to review the soundings in CARIS subset mode, since neither raw nor processed data were provided to NOAA. The sound velocity sampling regime did not follow the NOAA standard practice of sampling sound velocity a minimum of every four hours. No sound velocity confidence checks were documented for the survey. The NOS Hydrographic Survey Specifications and Deliverables Manual section 5.4.5 states that the maximum allowable error for sound velocity is 0.30 meters plus 0.5% of the depth. Without additional information or data, the Evaluator believes that errors associated with sound velocity could exceed NOS Hydrographic Survey Specifications.

Heave, Roll, and Pitch Corrections:
A POS/MV provided motion correctors including attitude, heading, and heave to the Simrad EM 1002. NAVO personnel assessed the error of the various sensors as follows: heave 0.05 meters, roll 0.1 meter, pitch 0.1 meters, and heading 0.2 degrees. In addition the Integrated Survey System (ISS-60) was configured to have the POS/MV apply the motion sensor offsets. According to the paper *Lessons Learned in Multi-Platform Hydrographic Surveys*, and Appendix F of the *WEST PAC LIDAR ROS* this lead to motion sensor offsets being applied twice, once in the POS/MV and again in the Simrad software, and also created a motion-induced heave error which resulted in double-application of heave. See appendix F of the *WESTPAC LIDAR ROS* for additional information. Scott Ebrite estimated the error as varying from between ±0.2 to 0.3 meters. The NOS Hydrographic Survey Specifications and Deliverables section 5.4.5 states that the maximum allowable error for Heave error is 0.20 meters. The Evaluator reviewed the PFM file, of the full density data in Fledermaus and did not observe any heave artifacts or other indications of a systematic error. However the NAVO analysis shows that the data fails to meet HSSDM requirements.

Tide corrections:
Tides were obtained from NOAA tide gauge, 1633227 (Tanapag Harbor, Saipan). Verified tides from the NOAA CO-OPS website were applied to all data. E-mail communication with Scott Ebrite of NAVO stated that all data was zone-corrected. The NOAA CO-OPS zoning was modified by NAVO personnel. See section **C.2** of this report for more specifics concerning the modification of tide zones. NAVO personnel assessed the error associated with tidal measurements to be 0.025, and the error for co-tidal corrections to be 0.35 meters. The NOS Hydrographic Survey Specifications and Deliverables section 5.4.5 states that the maximum allowable error for Tide/water level error to be 0.45 meters. The Evaluator agrees with the NAVO assessment, and believes that the tidal data and zoning meet these requirements.

Offsets:
E-mail conversations with Scott Ebrite of NAVO stated that vessel offsets were applied to the SWMB data. Appendix F of the *WESTPAC LIDAR ROS* provided estimates of the errors associated with the vessel offsets.

LIDAR:

Heave Corrections:
The aircraft platform motion was compensated for by an aircraft-mounted inertial navigation system. This resolved undulations in the flight path. Aircraft movement outside of normal parameters resulted in "jerk" flags and rejected data. The NOS Hydrographic Survey Specifications and Deliverables Manual (HSSDM) section 5.4.5 states that the maximum allowable error for heave error is 0.20 meters. The Evaluator concludes the errors associated with heave are minimal with LIDAR, and meet the requirements of the NOS Hydrographic Surveys Specifications and Deliverables Manual.

Tide corrections:
Tides were obtained from NOAA tide gauge, 1633227 (Tanapag Harbor, Saipan). Verified tides from the NOAA CO-OPS website were applied to all survey data. E-mail communication with Scott Ebrite of NAVO stated that all data were corrected for tidal zoning. The NOAA CO-OPS provided zoning was modified by NAVO personnel.[7] See section **C.2** of this report for more specifics concerning the modification of tide zones. NAVO personnel assessed the error associated with tidal measurements to be 0.025, and the error for co-tidal corrections to be 0.35 meters. The NOS Hydrographic Survey Specifications and Deliverables Manual section 5.4.5 states that the maximum allowable error for Tide/water level error to be 0.45 meters. The Evaluator agrees with the NAVO assessment and the tidal data and zoning meet these requirements.

<u>Offsets:</u>
The LIDAR ROS stated that no offsets were apparently applied to the LIDAR data. It also states that in-flight calibration was conducted prior to the start of survey operations; this should be considered roughly analogous to patch testing a multibeam platform. The offsets were then applied to the remainder of the data in the form of a "STATIC" file.

B3. Data Processing and Quality Control

Hydrographer:

<u>SWMB:</u>
Limited documentation on SWMB processing was provided by NAVO. Processing flow diagrams were provided as part of an updated *WESTPAC LIDAR ROS*. These indicated that all relevant correctors and processes had been applied to the data. E-mail conversations with Scott Ebrite of NAVO stated that the data was edited and cleaned using in-house data processors including the NAVO Bathy-Hydro Post-Processing suite (BHPP). Data processing was conducted using BHPP, and included the use of Area-Based Editor (ABE). The statistical surface of the data set was reviewed by NAVO personnel to identify areas needing additional review.

<u>LIDAR:</u>
The SHOALS proprietary data processing suite was used for processing LIDAR data. SHOALS personnel field-processed, verified, and validated the data concurrent with data acquisition. Verification included comparison of collected data to existing charted and data and prior soundings. Data was initially processed using automated processing software. Data were then manually reviewed, including review of individual waveforms as needed and edited for obvious anomalies. Final cleaned data were binned at 4x4 meters, and output as an XYZ file. See section 3.2-3.5.5 of the *WESTPAC LIDAR ROS* for additional information on data processing and quality control procedures. Time-tagged position and depth and laser waveform files were then transferred to the NAVO system Bathy-Hydro Post-Processing suite (BHPP). Data quality control and validation was carried out using the NAVO Area Based Editor (ABE).

Evaluator:

Full-density sounding data were imported from .CVS files into IVS Fledermaus for quality analysis. Generally, multibeam data were collected in depths greater than 40 meters and LIDAR acquisition was performed in proximity to the island and over the northern shoal areas. Data were distinguished by acquisition platform in the data through sounding density and depth. Figure 2 illustrates multibeam and LIDAR coverage densities: multibeam soundings are at the top; 200% LIDAR coverage is shown in the lower left; 100% 4-meter spot spacing LIDAR is shown in the mid-right section.

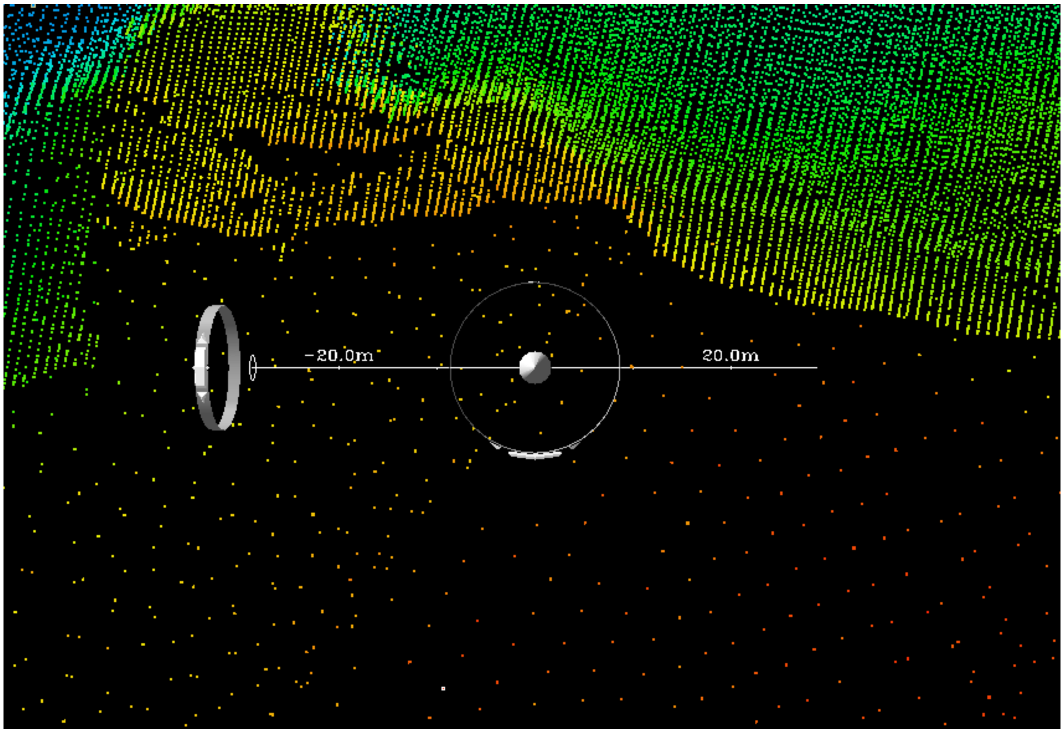

Figure 2: LIDAR and multibeam sounding densities

Coverage:

100% multibeam coverage was acquired in water depths greater than approximately 40 meters. Sounding spacing in 60 meters was approximately 1-2 meters as illustrated in Figure 4.

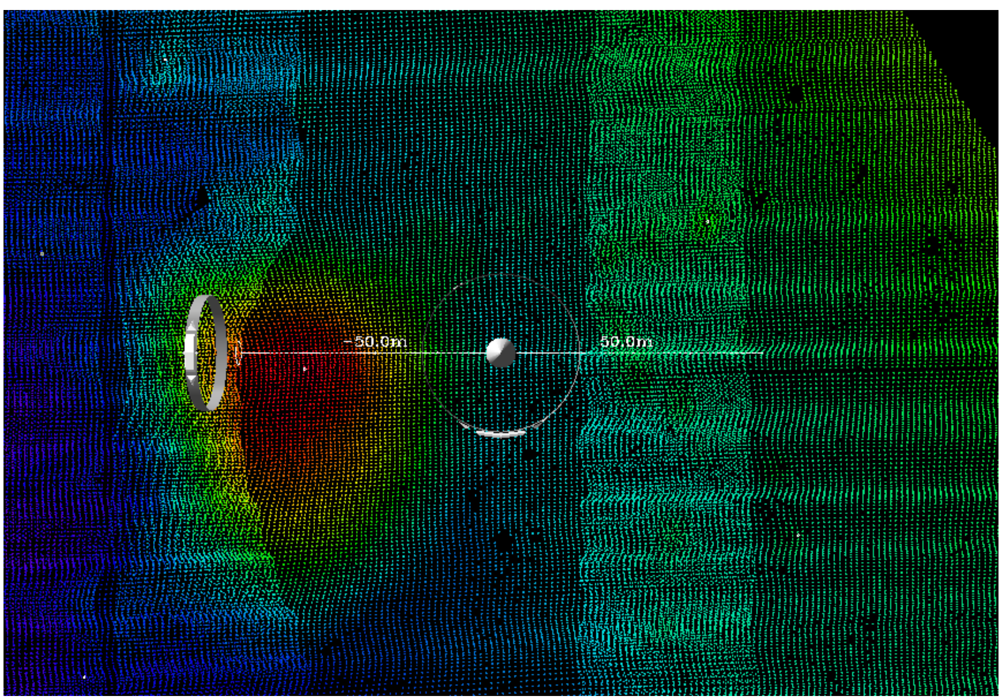

Figure 3: Multibeam sounding coverage

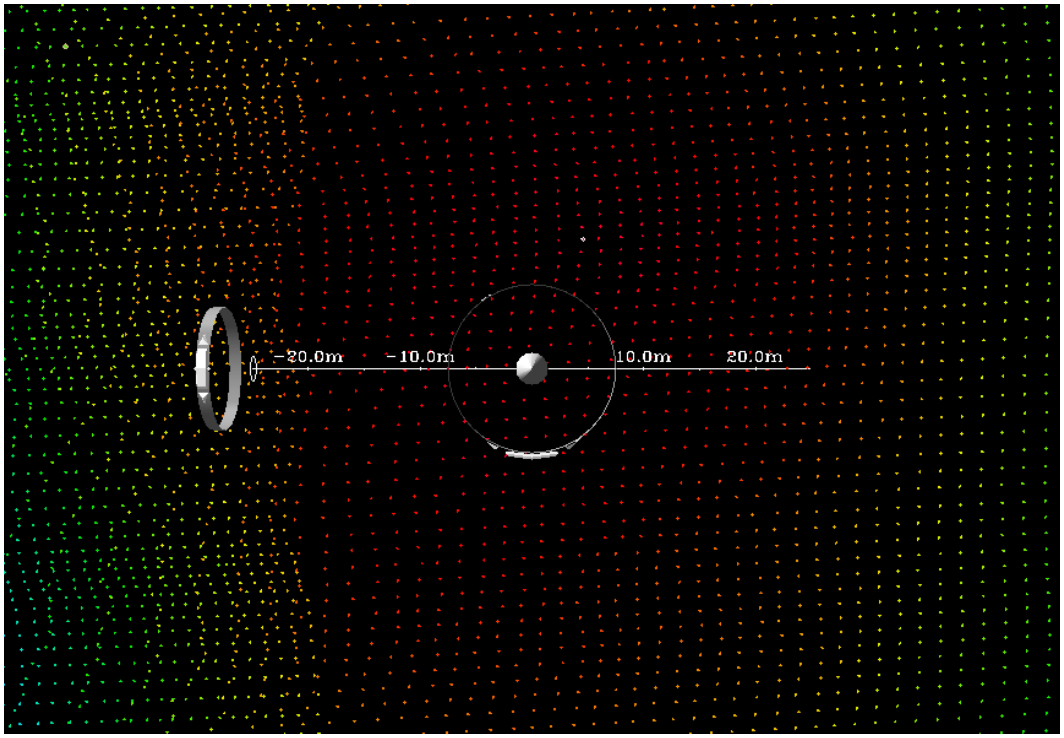

Figure 4: Multibeam sounding density

<u>LIDAR Bathymetry:</u>
LIDAR bathymetry was acquired in waters adjacent to the island and over shoal areas in less than approximately 40-meter water depths. The Evaluator reviewed the Pure File Magic (PFM) file of the full-density LIDAR sounding data in Fledermaus.

<u>LIDAR Coverage:</u>
In general, 100% 4-meter spot spacing coverage was obtained with overlap between lines; however there were holidays, most notably in the northern portion of the survey in shoal areas and surf. Typical LIDAR coverage is illustrated in figure 5.

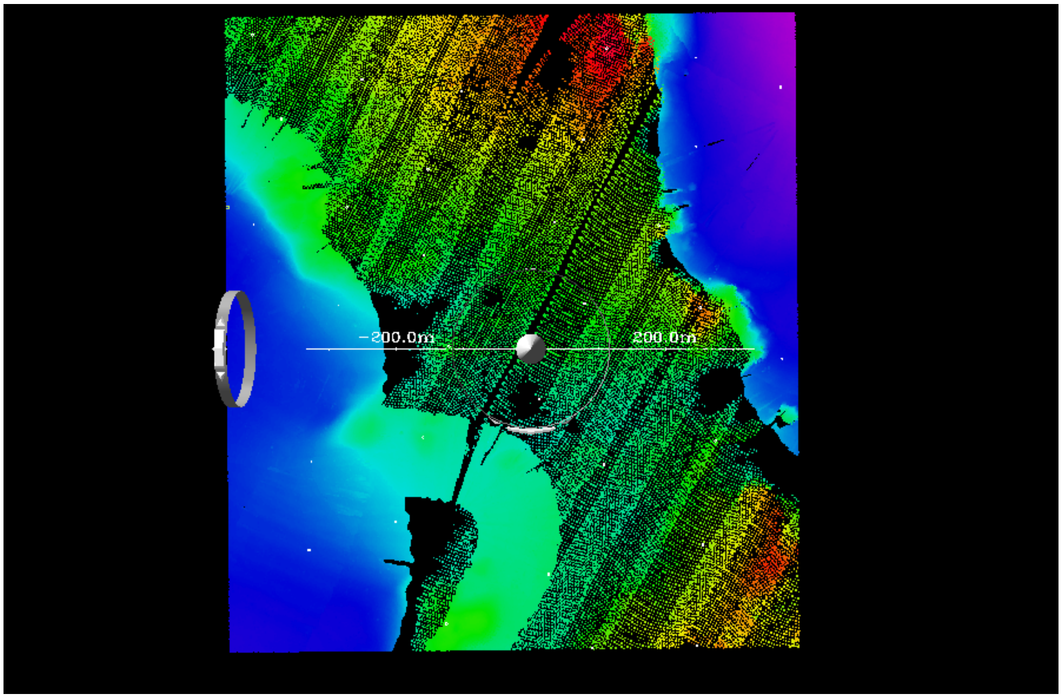

Figure 5: LIDAR sounding coverage

Internal Data Consistency

Cross lines:
Cross line data were not acquired or evaluated for this survey.

LIDAR to Multibeam Comparison:
General agreement was observed between LIDAR and multibeam soundings at overlap and junctions as illustrated in Figures 6 for depths and features. The difference between multibeam and LIDAR soundings, based on 100 samples observed by NAVO, averaged 0.72 meters, with differences as large as 1.22 meters and as small as 0.22 meters. In general LIDAR and Multibeam compare within IHO Order 2 limits. Conversations with Scott Ebrite of NAVO attributed the variability between systems, to differences between the static draft corrector value and the actual draft during the survey. In addition the previously mentioned motioned induced heave error for the SWMB data was thought to contribute to this difference.

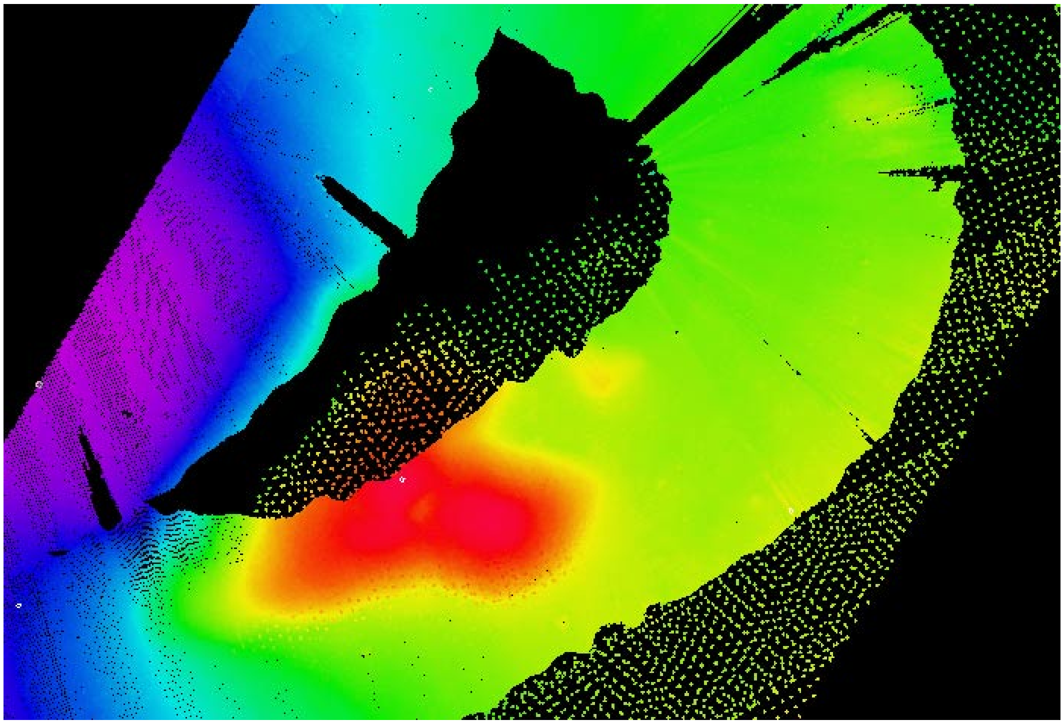

Figure 6: Multibeam-LIDAR junction and overlap

Data Quality Factors

Sea State:
The survey of FDM was conducted in moderate sea states.

Sound Velocity:
Convex or concave line profiles (gross indication of sound velocity errors) were not observed in multibeam data during review in Fledermaus. NAVO personnel observed that the outer beams of the EM1002 data were being refracted upward, resulting in the depths from the outer beams being more shoal than the inner beams. It was determined that the outer beams were statistically different from the inner beams as well as different from the LIDAR data. In order to eliminate this error NAVO rejected data beyond a 120^{o} swath width.

Motion, Attitude, Draft, Heave:
Motion, attitude and tide/heave artifacts were observed in the multibeam data but were typically on the order of less than 2 meters. This is consistent with errors noted with double application of attitude correctors, the motion-induced heave error, and draft errors up to 0.8 meters due to fuel loading. Figure 7 illustrates general agreement of depths along contours, at line overlaps and across seafloor features.

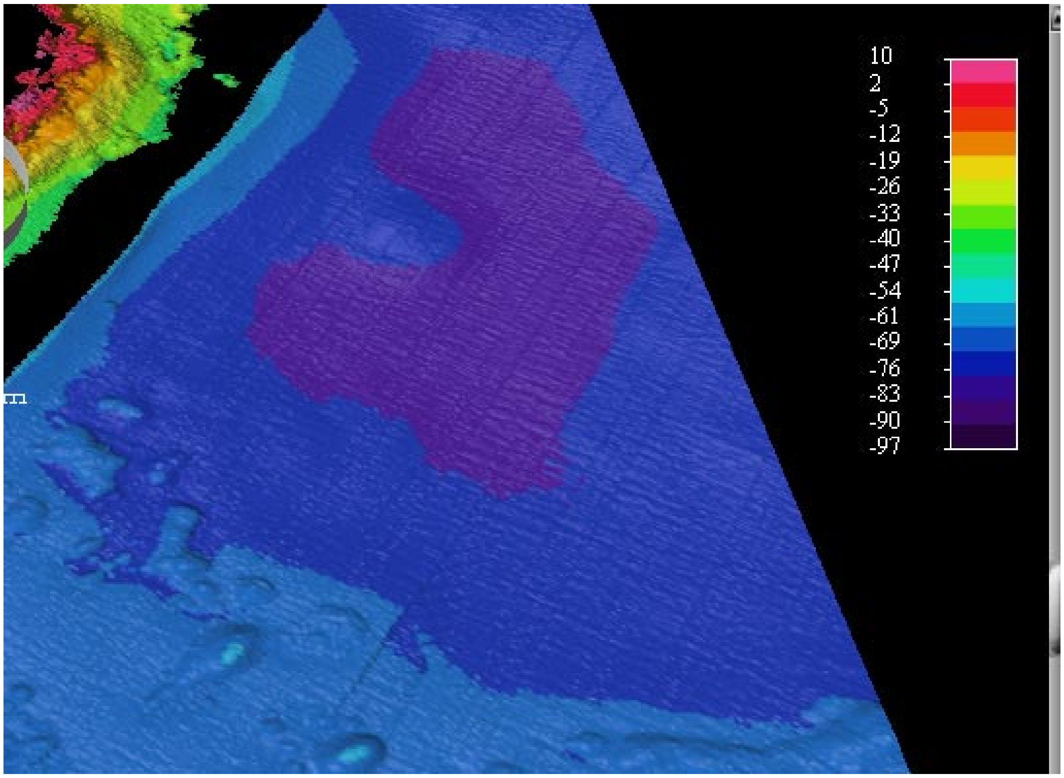

Figure 7: Multibeam motion, attitude and tide/heave artifacts

LIDAR Bias Error:
It should be noted that testing of the SHOALS 1000 LIDAR system at the Navy's South Florida Test Facility in 2003 confirmed a suspected deep bias error which would have also been present in the SHOALS 400 LIDAR system used during this survey. Section 4.4 of the *WESTPAC LIDAR ROS* discusses a deep bias error as ***"****An offset was discovered in the LIDAR data… This offset ranges from 8 cm deeper* at 10m depth to 82 cm deeper at 40 meters depth.**"** See section 4.4 of the *WESTPAC LIDAR* ROS for additional discussion of this error. All of the SHOALS data in this survey has been corrected for the depth bias that was discovered and resubmitted to NOAA.

B4. Data Decimation

Sounding Selection: According to the *WESTPAC LIDAR ROS* section 7.4.9 data were decimated using a NAVO area-based shoal biased sounding selection algorithm. No additional information was provided as to the specifics of this algorithm.

The Naval Oceanographic Office provided PHB with a decimated, shoal-biased dataset and a full-density dataset. The sounding density of the final decimated data set was 1.5 meters at the scale of survey, where supported by acquired sounding coverage. Visual examination of the complete sounding data set at the Pacific Hydrographic Branch did not reveal any least depths more shoal than the excessed data set. PHB did not further decimate or otherwise excess the data.

C. VERTICAL AND HORIZONTAL CONTROL

C.1 Horizontal Control

The horizontal datum for survey W00099 was World Geodetic System 1984 (WGS 84). Data were provided in Universal Transverse Mercator, zone 55, based on the WGS 1984 spheroid.

LIDAR positions were obtained from an Ashtech Z-12 GPS receiver onboard the survey aircraft. All LIDAR positions for FdM were obtained using stand-alone GPS mode due to insufficient DGPS beacon coverage in the survey area. No calibrations of this receiver were conducted during the survey, but HDOP, PDOP, and SNR were monitored for data quality purposes. Stand alone GPS provides a global average accuracy of 13 meters (95% confidence level) horizontally and 22 meters (95% confidence level) vertically, according to the Federal Radio Navigation Plan. This meets the IHO Order 2 requirement of 20 m + 5% of depth but does not meet the positioning accuracy requirements of the NOS Hydrographic Surveys Specifications and Deliverables Manual.

USNS SUMNER utilized the Fugro/Chance Wide Area DGPS system known as Omnistar. Accuracy analysis for the area, conducted by Fugro/Chance, indicated positioning errors of 2.0 to 2.5 meters with spurious spikes of 5.0 to 8.0 meters. This is within horizontal positioning requirements of the NOS Hydrographic Surveys and Specifications Deliverables Manual.

C.2 Vertical Control

The vertical datum for surveys W00099 was Mean Lower-Low Water (MLLW). [8] Tides were obtained from NOAA tide gauge, 1633227 (Tanapag Harbor, Saipan). The applied tide file was verified tides from the CO-OPS website. See section 6.7 of the *WESTPAC LIDAR ROS* for additional information on application of tide correctors to the data. All data were zone corrected. NAVO personnel determined that zoning based on the Saipan gauge was more appropriate for the survey than zoning based on the gauge at Apra Harbor. Because the Tanapag Harbor gauge was located in one of the tide zones, NAVO personnel were able to "reverse" the zones as follows:

NAVO			NOAA		
MAR300	0 min	1.0	MAR300	0 min	0.98
MAR301	6 min	1.0	MAR301	0 min	1.0
MAR302	6 min	1.0	MAR302	0 min	0.98
MAR303	0 min	0.97	MAR303	-6 min	0.93

NOAA-provided tide zones MAR300 and MAR301 were split from Ushi Pt., Tinian to 15º 10' 00" N by 145º 30' 00" E. All correctors are in reference to the tide gauge in Saipan (163-3227). While some differences were noted between NOAA and NAVO derived zoning, CO-OPS stated the NAVO modification to the tidal zoning would not significantly impact the vertical accuracy. No tidal data was provided to the Evaluator for this survey. The Evaluator concludes that the tidal data and zoning meet NOS Hydrographic Surveys Specifications and Deliverables.

D. ANALYSIS AND RECOMMENDATIONS

D.1 Error Analysis

Please see the *WESTPAC LIDAR ROS* for NAVO's analysis of depth errors. The Evaluator generally agrees with the methodology used by NAVO in this assessment, and that the data likely meet specifications as noted in the NAVO reports for depth accuracy. Specific discussions of data accuracy and error issues are discussed below in section **D.2**.

D.2 Discussion of Data Quality and Suitability for Charting

LIDAR:
As discussed in the *WESTPAC LIDAR ROS* the instrumental accuracy error was assessed as being minimal (0.1 meters). Positional accuracy was stated as meeting IHO Order 2 specifications, due to the lack of DGPS positioning. The *WESTPAC LIDAR ROS* states: "*Theoretically, all navy areas meet IHO Order 1 target/object detection requirements for depths from 7m to 20m with single flight coverage. While at depths deeper than 20m signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects.*" In addition subsequent testing of the CHARTS system which utilizes the same operating principles and algorithms detected 2 meter and larger targets 100% of the time in depths from 5 to 30 meters. While it was noted that multiple flights would improve the confidence in the data, due to NOAA's limited experience with LIDAR and lack of standard specifications and procedures and empirical test results for utilizing LIDAR for item investigations, the Evaluator cannot confidently say that object detection standards were met in areas with merely 200% LIDAR.

To sum up the evaluation of LIDAR data acquired on survey W00099: [9]

- The LIDAR do not meet NOS positioning accuracy requirements due to the use of stand-alone GPS; positioning should be considered to meet IHO Order 2 requirements;
- The LIDAR data do meet NOS requirements for depth accuracy;
- The LIDAR data cannot be considered to meet NOS requirements for object detection and full bottom search.

Based on this evaluation, and a review of the vintage of charted data for Tinian, LIDAR data on survey W00099 should be considered adequate for:

- Drawing depth curves on charts
- Charting soundings to delineate the general bathymetry of the seafloor and new shoals detected during the survey

LIDAR data should not be considered adequate to:

- Disprove charted wrecks, rocks, obstructions, or shoals;
- Acquire definitive least depths on wrecks, rocks, obstructions, or shoals;

SWMB:
No *Report of Survey* describing data acquisition, processing, and quality control procedures for the SUMNER multibeam data was provided. The paper *Lessons Learned in Multi-Platform Hydrographic Surveys* provided some general details. According to this paper, the motion sensor offsets were applied twice, creating a motion-induced heave error, and no corrective action was possible. NAVO personnel assessed this error to be between ±0.2 and 0.3 meters.

To sum up the evaluation of multibeam data acquired on survey W00099: [10]

- The multibeam data meet NOS positioning accuracy requirements through the use of the Fugro/Chance Omnistar WADGPS;
- The multibeam data cannot be considered to meet NOS requirements for depth accuracy due to potential double-application of correctors, lack of dynamic draft and loading correctors applied (draft errors up to 0.8m), uncertainty in the sound velocity sampling regime, uncertainty in the data acquisition and processing methods used (no ROS provided), and differences noted in internal data consistency and comparison with overlapping LIDAR data. SWMB should be considered to meet IHO Order 2 requirements for depth accuracy.
- The multibeam data cannot be considered to meet NOS requirements for object detection and full bottom search, since no documentation was provided regarding the data acquisition and processing methods used for the survey and no sensor data were provided to independently assess the adequacy of data acquisition and processing methods.

Therefore, multibeam data should be considered adequate to:

- Chart new shoals and obstructions not previously depicted on NOAA charts
- Depict the general bathymetry and nature of the seafloor; even though data are considered to be outside of NOS HSSDM specifications, given the vintage and sparseness of the charted data, the fact that they compare within IHO Order 2 specifications, and were collected in waters 40 meters deeper, data should be adequate to chart soundings and depth curves in these waters

Multibeam data should not be considered adequate to:

- Disprove charted wrecks, rocks, obstructions, or shoals;
- Supersede shoaler soundings on the chart;

D.3 Automated Wreck and Obstruction Information System (AWOIS) Items

No AWOIS items were located within the limits of survey W00099.

D.4 Chart Comparison and Specific Charting Recommendations

FdM Island Horizontal Positioning:
Radar range and bearing observations were used to position FDM Island approximately 1.1 nautical miles west of its charted position. No specific information was provided for positioning methods or reference positions. NOAA's Marine Chart Division (MCD) corrected the position of FdM on chart 81068 using the .DGN digital smooth sheet and shoreline provided with this survey. Subsequent sounding evaluation and chart comparisons were performed using the updated NOAA .BSB digital raster chart in MapInfo.

Soundings:
Smooth sheet soundings were imported into MapInfo from the survey .DGN smooth sheet file and compared with updated NOAA chart 81068. Soundings on chart 81068 are generally sparse and much of the survey area covered areas on the char without soundings. In general, survey depths greater than 40 meters compared very well with charted depths. Shoaler soundings observed can be attributed to 100% coverage achieved with this survey over complex seafloor bathymetry and features. The smooth sheet selected soundings were imported into Fledermaus for review and comparison with full-density

soundings. Binning and excessing generally represented shoal-biased soundings for features and overall bathymetry at the scale of drawing (1:25,000) and appropriate density for compilation at chart scale (1:45,602).

The blue-tinted area north of FdM annotated "Breaks occasionally" was covered with 100% LIDAR to the operational depth constraint of LIDAR (approximately 39 meters). A small section at the southeast corner was not covered as it was too deep for LIDAR. The blue-tinted area should be replaced with soundings and depth curves from this survey, and the annotation should be retained.[11]

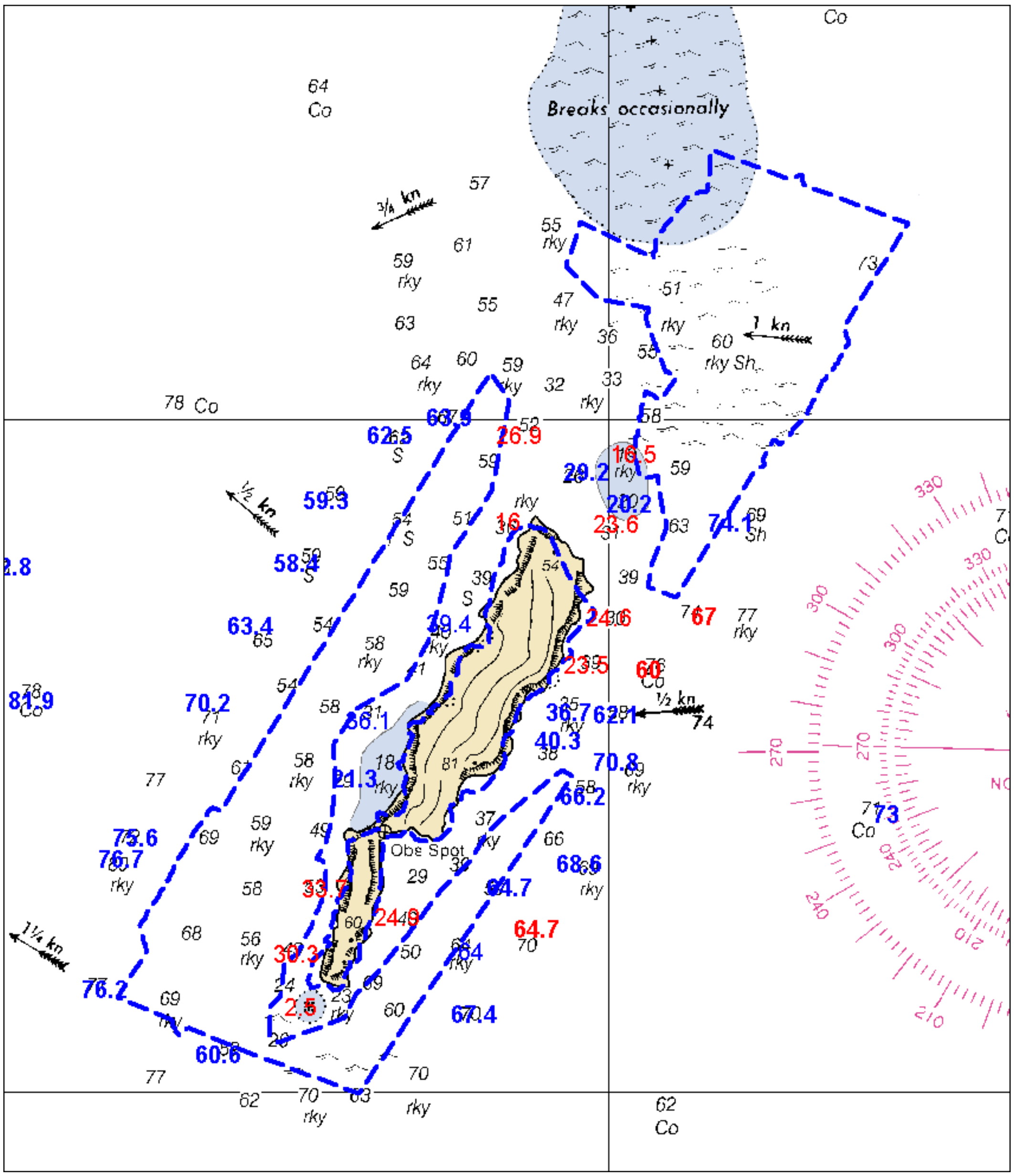

Figure 8: Chart comparison: Significantly shoal soundings are in red. Areas inside blue boundary were not surveyed and should be retained as charted.

Shoreline:
Shoreline provided with the survey is generally consistent with charted shoreline position but differs in detail at scale. Source or survey data used for shoreline compilation was not provided with the survey submission. Initial shoreline used for survey reference purposes was generated from the NIMA DNC (ROS 7.3.1). Shoreline should be retained as charted.[12]

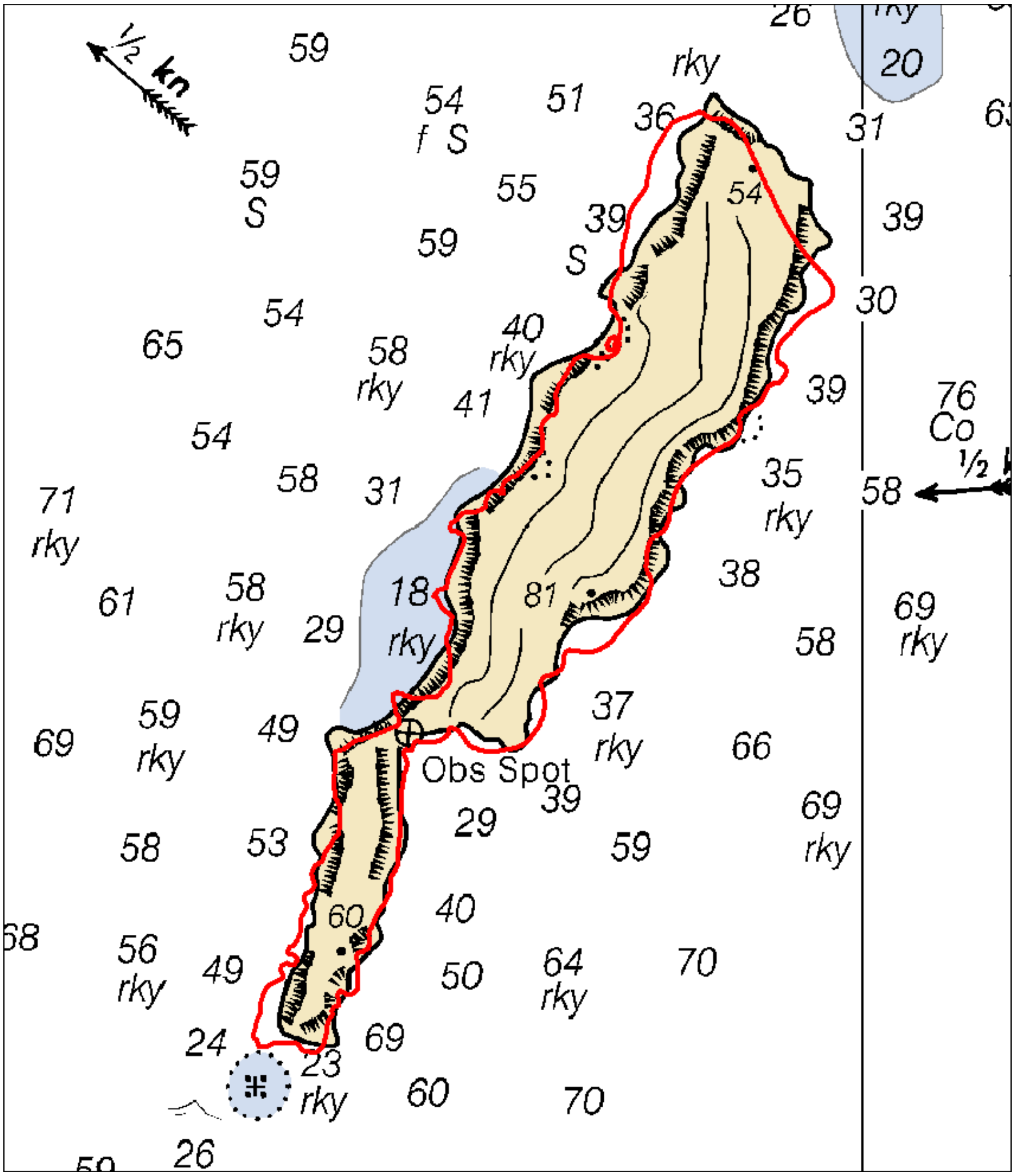

Figure 9: Shoreline comparison

D.5 Miscellaneous

Vessel Traffic:
No commercial or small-craft traffic was observed during survey operations.

E. APPROVAL

Hydrography

All obtained records, reports, and data have been evaluated with regard to survey coverage, survey accuracy, and suitability for nautical charting.

Evaluated by: for
David A. Sinson
Physical Scientist (Hydrographer)
Pacific Hydrographic Branch

Reviewed by:
Lieutenant Edward J. Van Den Ameele, NOAA
Hydrographic Team Leader

Cartography

The evaluated survey has been inspected with regard to delineation of the depth curves, development of critical depths, cartographic symbolization, comparison with prior surveys and verification or disproval of charted data.

Compiled by:
Russ Davies
Cartographer
Pacific Hydrographic Branch

Reviewed by:
Bruce Olmstead
Cartographer
Pacific Hydrographic Branch

Approval

I have reviewed the data and reports. Data are suitable for nautical charting except where specifically recommended in this report.

Approved by: , LCDR/NOAA Date: 6 Oct. 2004
Lieutenant Commander Donald W. Haines, NOAA
Chief, Pacific Hydrographic Branch

Jennifer Sherry

Digitally signed by Jennifer Sherry
DN: CN = Jennifer Sherry, C = US, O = HSD, OU = Operations Branch
Reason: AWOIS/SURF check
Location: Operations Branch, HSD
Date: 2005.08.29 10:28:05 -04'00'

Revisions compiled during cartographic processing and final approval.

[1] And chart 81004

[2] Attached to this report

[3] Attached to this report

[4] Attached to this report

[5] Attached to this report

[6] Attached to this report

[7] Attached to this report

[8] It is recommended that the charted note *DEPTHS IN METERS at approximate lowest low water* be changed on the Farallon De Medinilla panel to *DEPTHS IN METERS AT mean lower low water.*

[9] The lidar data has been applied to the chart in accordance with the evaluator's recommendations.

[10] The multibeam data has been applied to the chart in accordance with the evaluator's recommendations.

[11] Concur, Remove all wave symbols and retain the limit line and notes

[12] Concur

FILE: **WESTPAC LIDAR ROS.DOC**
UPDATED: **25MAY 2004**
BY: **Scott Ebrite SNR**

NAVAL OCEANOGRAPHIC OFFICE
Stennis Space Center, Mississippi

REPORT OF SURVEY

COMMONWEALTH OF THE NORTHERN MARIANNAS (CNMI)
GUAM, SAIPAN, TINIAN, FARALLON de MEDINILLA

Vessel: SHOALS AIRCRAFT

Detachment: SHOALS PROJECT

Dates of Survey: 08 January – 20 March 2001

Archive Number: 00US17

Areas:

Apra Outer Harbor	**1: 10,000**
Apra Inner Harbor	**1: 10,000**
Agat Bay (Dadi and Tipalao beaches (STOIC))	**1: 5,000**
Saipan (inner and outer anchorages)	**1: 25,000**
Saipan Harbor	**1: 10,000**
Tinian (Sunharon Roads)	**1: 25,000**
Tinian Northern Training Area (NTA) (STOIC)	**1: 5,000**
Farallon de Medinilla (FDM) (STOIC) (charting)	**1:5,000/1:25,000**

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Appendix B	Tide Zones
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Appendix F	USNS Sumner EM1002 Assessment of Data Accuracy
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1.0 Introduction

1.1 Purpose of Survey

1.1.1 HSS003, the Hydrographic Survey Specifications for the aforementioned areas, were generated at the request of the primary Functional Customer (COMNAVMARIANAS) in response to DoD/US Navy initiatives. This initiative is to support present and future increased naval activity and usage in WESTPAC as follows.

1.1.2 This Report of Survey specifically addresses the LIDAR portion of the survey and should be considered complimentary to any other reports such as the ROS compiled by the NAVOCEANO Fleet Survey Team (FST). No Report of Survey was written specifically discussing the USNS SUMNER operations. However, USNS SUMNER data acquisition, processing, quality and accuracy are discussed in this report

1.1.3 Naval Station Guam, as a safe haven for major surface and sub-surface Fleet units. Perusal of NOAA Chart 81054 (12th Ed, dated April 10/93, scale: 1:10,000) provides no dates regarding source data other than listing those authorities responsible for charting. It is surmised that the current chart was derived from surveys conducted in the early 1990s. This survey was conducted in order to determine:

a. if the current chart accurately depicts the limits of safe navigable water within Apra Harbor (Inner and Outer)
b. that charted navaids, moorings and bathymetric features are accurately portrayed
c. better control and coastline depiction of the more obvious landforms, navaids and fixing marks
d. the need for a temporary navigation chart (1:10 000 scale) for DoD use only, which covers the transit from Apra Outer Harbor entrance to all berths and wharfage in both Apra Inner Harbor and the commercial facilities in the Cabras Island Channel, until NOAA can formally publish a new chart, or appropriate chart insert, based on data provided from this survey.

1.1.4 Saipan offshore and inshore anchorages including explosives anchorage and harbor, wharves and channels.

a. Support MPSRON-3 ship basing in the anchorages at Saipan
b. Support PACFLT ship utilization of Alpha, Bravo and Charlie wharves in Saipan harbor.
c. The positioning of navaids in Saipan deep-water anchorage and within the harbor itself.
d. Update NOAA charts 81AHA81076 and 81AHA81067, combat chart COMBT805118 and production of a new 1:12,000 NIMA chart of the offshore anchorage.
e. COMNAVMARIANAS request for a STOIC.

f. Support basing of AE ships and expansion of explosives anchorage.

1.1.5 Tinian, Northern Training Area (NTA), southern coastline of the Military Retention area and Sunharon Roads/Tinian harbor and approaches.

a. Support extensive fleet use during major joint exercises and smaller operations including SOF exercises with NSWU-1, EOD, USMC at Unai Chulu and Unai Dankulo.
b. Update NOAA charts 81AHA81071 and 81AHA81067.
c. Update NIMA combat chart COMBT805118
d. STOIC's 11-1 and 11-2 and Annotated Imagery product of Tinian

1.1.6 Farallon de Medinilla (FDM) , an area extremely hazardous to near shore navigation due to a paucity of data and uncharted shoals.

a. Support live bombing exercises by US and Foreign assets.
b. Support NSWU-1, SOF, EOD training.
c. Confirm charted position of FDM.
d. Topography
e. Updating of NOAA chart 81BHA81086.
f. Updating NIMA Combat Chart COMBT808916
g. STOIC and Annotated Imagery products

1.1.7 Agat Bay (Dadi and Tipalao beaches). On scene request by COMNAVMARIANAS for data collection to support anticipated SOF/AMPHIB ops and STOIC.

1.2 **General Survey Specifications**:

1.2.1 Hydrographic Survey Specifications (HSS003) for Apra Harbor, Guam, Archive No. 01US03, generated by the Fleet Survey Team (N45/N4UK), dated 21 December 2000. Due to the short lead-time for this survey, no survey specification was generated for LIDAR or USNS SUMNER operations. LIDAR operations, however, were designed and planned to meet the requirements of IHO Order 1 accuracy standards within the Navy areas of interest. All Navy LIDAR operations are planned and executed to meet IHO Order 1 as a matter of policy. No specific survey specifications exist for areas originally outside the Navy areas. However, some of these areas were developed to meet IHO Order 1, as discussed in section 1.4.

1.3 **Tasking**

1.3.1 FST tasking was for a fairly comprehensive hydrographic survey of Apra Harbor, Guam and NAVAID positioning on Saipan. FST was available within a specific time frame under which they were constrained by follow-on commitments in the Mediterranean. The Apra FST work consisted of single beam sonar coverage in areas not attainable with LIDAR, sidescan sonar coverage of the inner and outer harbors, and NAVAID positioning.

1.3.2 The scope of the LIDAR survey was depth measurement only from the shoreline out to the laser extinction depth, with shoreline delineation, limited beach topography and hazard detection within the capabilities of the system. LIDAR did not perform, nor was one intended, a comprehensive hydrographic survey and no comprehensive survey was done in areas worked solely by LIDAR.

1.4 IHO Standards and Coverage

1.4.1 Most Navy areas on Guam, Saipan, Tinian and FDM covered by LIDAR meet IHO Order 1 specifications for positional and depth measurement accuracy. USNS SUMNER data suffered from an induced heave error due to motion corrections being applied twice. This is discussed in appendix F. The exceptions are:

Only at Saipan and Tinian is USNS SUMNER sounding data expected to meet IHO order 1 accuracy and only in areas deeper than 65 to 70 meters.

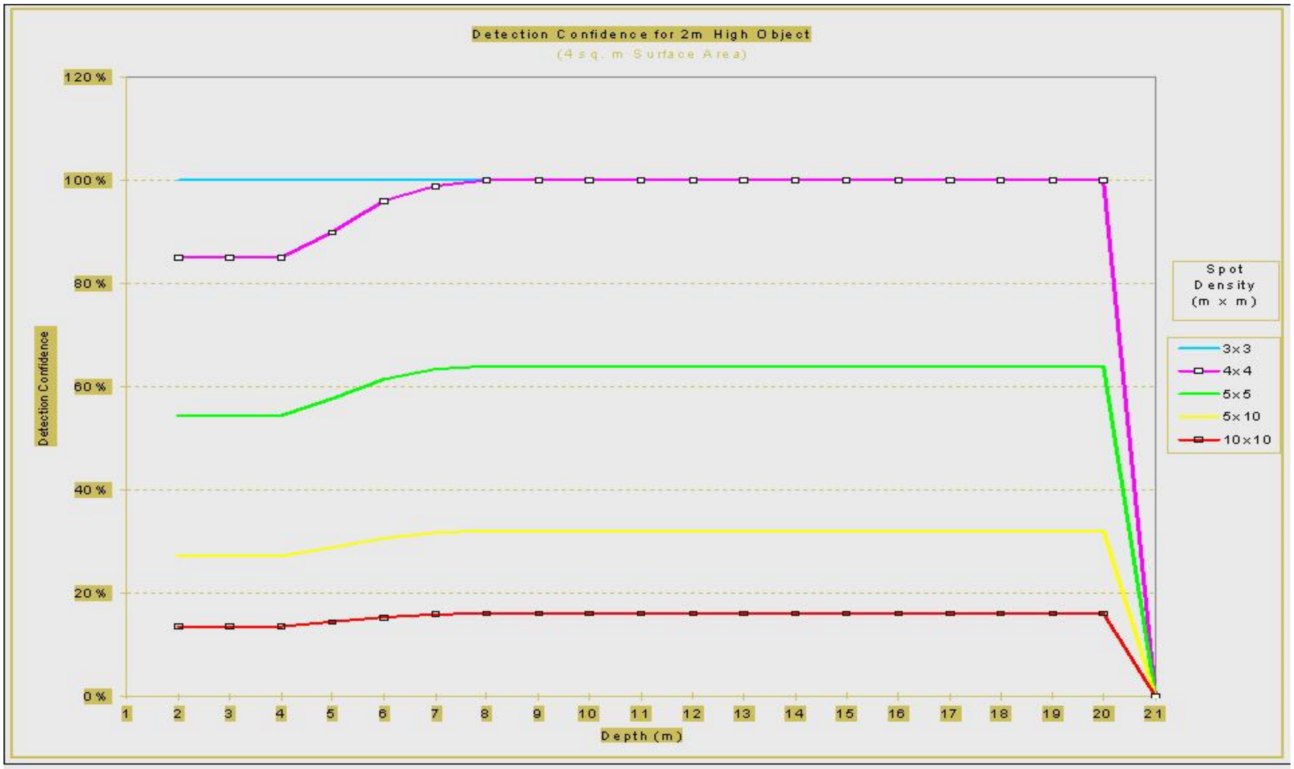
In Guam, Saipan and Tinian the maximum SUMNER sounding error is not expected to exceed 1.5 meters (shoal biased) and only approach this in few occurrences.

In FDM the maximum SUMNER sounding error is not expected to exceed 1.8 meters (shoal biased) and only approach this in few occurrences.

1.4.6 Theoretically, based on target detection probability curves produced by NOAA, Guenther, et al, all Navy areas meet IHO Order 1 target/object detection requirements at the 95% confidence level for depths from 7m to 20m with single-flight coverage. At depths deeper than 20m, signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects less than 2 meters (Figure 1). Multiple-flight coverage will theoretically improve the confidence of target detection capability in the depth range of 2m to 7m, and possibly down to 20m.

1.4.6.1 Lidar positioning at Tinian and FDM did not utilize DGPS due to range limitations of the differential beacon. Lidar positioning at Tinian and FDM utilized GPS operating in SPS mode. Though it is likely the position, in reality, does meet order 1, the advertised accuracy for SPS dictates a claim of order 2.

1.4.7 Subsequent testing of the follow-on CHARTS system, utilizing the same operating principles and algorithms and a lower power laser at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths of 5 to 30 meters. Based on these actual tests the LIDAR system meets IHO Order 1 target detection requirements. Multiple coverage provides a degree of redundancy for this capability.



Theoretical detection confidence vs. depth for a 2m target at different laser spot densities.

Figure 1. Target detection confidence

1.4.8 All Navy WESTPAC areas covered by LIDAR, were surveyed at 4x4 meter spot density and with greater than 200% coverage to ensure a very high confidence of target detection.

Location	Coverage
Guam, Apra Outer Harbor and Agat Bay	>200% LIDAR
NW of Apra jetty covered at 100% by EM1002	
FST single beam sonar in areas too deep for LIDAR	
Saipan, inner and outer anchorage	>200% LIDAR
The western third of the outer anchorage was covered at	100% by EM1002
	100% EM1002 > 40m
Saipan , Garapan Harbor channel	>500% LIDAR
Saipan, coastal	>200% LIDAR
Tinian, Sunharon Roads, Coastal	>200% LIDAR
	100% EM1002 > 40m

FDM, coastal	>200% LIDAR
FDM, surrounding sea	100% EM1002 > 40m

1.5 **Extraneous Activities Affecting the Survey**

1.5.1 In Apra Harbor commercial fishing boats, mostly Japanese, regularly transited the survey area, along with larger scheduled military and commercial traffic. A commercial submarine operation, "Atlantis III", operated off Gabgab Beach in Apra Outer Harbor. Additionally, military pre-positioned ships moored in the harbor caused some initial data holidays in the coverage; fortunately a short time period when the mooring was unoccupied allowed for the infill of missing coverage. Other large military and merchant traffic was again regular and predictable. Leisure traffic consisted largely of jet skis, small motor launches and occasional sailboats.

1.5.2 No significant commercial vessel or small craft traffic was observed at Saipan and Tinian, while none was observed at FDM. Only birds like FDM.

1.6 **Weather**

1.6.1 The survey was conducted during Guam's dry season, a term that is strictly relative, there being very few days when some precipitation did not occur at some stage. Ripples on the nearby ITCZ created slightly unsettled conditions resulting in partially cloudy skies (Cu/StCu) for approximately 80% of the period and scattered showers, the majority of which fell during the mid-forenoon. As the diurnal temperature (range: about 10^{o} C) rose so conditions generally stabilized, with most afternoons remaining sunny, warm and generally cloud-free. Of note was the consistency of wind direction: very few periods of calm (<5kn) conditions were experienced; wind strength ranged from 10-30kn but invariably from a NE or ENE direction. This phenomenon would serve to create, in Apra Outer Harbor in particular, a mass transport of water out of the harbor and cause both a temporal shift to HW and LW times and a phase eccentricity in the predicted tidal curve (later HW; early LW). Often, swells entering the harbor opening combined with a chop driven by the NE and ENE winds created a significant chop and standing waves within the harbor. This was particularly apparent at the harbor entrance. While not a concern for commercial ship traffic waves and chop could be a concern to small craft.

1.6.2 The survey areas of Saipan, Tinian and FDM are exposed to the open sea. Surf and rough seas were significant, but had relatively little impact on LIDAR data collection or quality, only creating breaking waves on the fringing reefs, breakwaters and shorelines. Data coverage suffered some against the shorelines and on top of reefs due to surf in some areas.

2.0 Geodetic Control

2.1 **Horizontal Datum**: WGS-84
Projection: Transverse Mercator
Spheroid: World Geodetic System of 1984
Grid: Universal Transverse Mercator (Zone 54: CM 147^{o} East)

2.2 **Vertical Datum**: Land Leveling Datum is NAVD88, to which the existing primary benchmark for the southern half of the island, located at the Airport in Agana, was referenced. Chart Datum is Mean Lower Low Water: the relationship between this and NAVD88 was deduced through analysis of tidal data over a 19-year national tidal datum epoch by NOAA which generated values for MSL, and hence (from further harmonic analysis) MLLW.

2.3 **Sounding Datum**: Mean Lower Low Water. The NOAA-maintained automatic tide gauge, located at 13^{o} 26' 37.4" N, 144^{o} 39' 24.2" E (Apra Harbor, Guam) was sited on a small concrete platform, the approach to which had been subject to considerable erosion over a period of time. The nearest benchmark to the site, designator 163-0000 No. 11, rests on a large concrete plinth which itself did not appear to have been disturbed. However, it is questionable, given Guam's location in the path of regular typhoon activity, whether this mark (and indeed the tide gauge platform) can be considered stable and permanent in their current state. Because this type of gauge cannot be physically leveled to, a check waterline measurement was made to ensure that data downloaded from the gauge agreed with the calculated tidal height. Subsequent perusal of the tidal curve prior to the final reduction of soundings against predicted curves again confirmed that data gleaned from the gauge was fit for purpose.

2.4 **Time**. The time standard is UTC (GMT).

2.5 **Existing and New Control**. On Guam, the primary geodetic mark for the LIDAR survey DGPS reference station is the benchmark for the Apra Harbor NOAA tide station. On Saipan, the primary geodetic mark for the DGPS reference station was located on the roof of the harbor master building. Tinian and FDM were not surveyed using DGPS due to range limitations of the beacon. Positioning on Tinian and FDM was GPS

2.6 **Datum Shifts**. No datum shifts were applied.

2.7 **Horizontal Control Reports**. No horizontal control reports were generated.

2.8 **Station Descriptions/Recovery Forms**. No station descriptions/recovery forms were completed or issued.

3.0 Digital Survey System

3.1 **SHOALS GPS Positioning Systems**. ASHTECH Z-12 L1/L2 GPS receivers (2 total) were used during the survey in order to verify 1st Order geodetic control points obtained from local sources and to provide navigational control in the survey platform in the DGPS and kinematic mode (Guam) through the use of radio modem links from the established control point ashore to the SHOALS survey suite.

3.1.1 **USNS SUMNER GPS Positioning System**. USNS SUMNER utilized the Fugro/Chance Omnistar Wide Area DGPS. Accuracy analysis for the area, conducted by Fugro/Chance, indicated radial positioning errors of 2.0 to 2.5 meters (1 sigma), on average with spurious error spikes of 5 to 8 meters. See section 8.

3.2 **SHOALS Lidar data acquisition system**. The SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system consists of an airborne laser transmitter/receiver capable of measuring 400 soundings per second. Lidar is an acronym for LIght Detection And Ranging. The system operates from a deHavilland DHC-6 Twin Otter flying at altitudes between 300 and 400 meters with a ground speed of about 104 knots. The SHOALS system also includes a ground-based data processing system for calculating accurate horizontal position and water depth. The system operates by emitting a pulse of light that travels from an airborne platform to the water surface where a small portion of the laser energy is reflected back to the airborne receiver. The remaining energy at the water's surface propagates through the water column and reflects off the sea bottom and back to the airborne detector. The time difference between the surface return and the bottom return corresponds to water depth. The maximum depth the system is able to sense is related to the complex interaction of radiance of bottom material, incident sun angle and intensity, and the type and quantity of organic material or sediments in the water column. As a rule-of-thumb, the SHOALS system is capable of sensing bottom to depths equal to two or three times the Secchi depth.

3.2.1 The airborne system conducts all the data collection and is divided into three subsystems:

1) Acquisition, control and display,
2) Transceiver, and
3) Positioning and auxiliary sensors.

3.2.2 **Acquisition, Control and Display Sub-System (ACDS)**. The ACDS is the primary component through which all data are collected and recorded, system integrity and self-checks conducted, and operator monitoring of key real-time system and survey information. All airborne data are recorded on Exabyte 8-mm dual tape drives at a rate of approximately 300 Kbytes per second. These tape drives were selected over other possible data storage media because of their proven performance and reliability in aircraft. The data tape is the only link between the airborne data collection system and the data processing system. It also provides the ability to load survey flight information for each survey mission into the airborne system prior to each flight.

3.2.3 The survey operator’s interface with the system is through the ACDS. Real-time information is provided so that the operator can accomplish two tasks, first as the surveyor to ensure that the planned mission is successfully implemented and completed and second, as the Lidar system operator to monitor system status during the mission to ensure that the system operates within expected parameters. The main indicator of survey status and progress is from real-time depths provided to the operator at 100 Hz. These real-time depths are not corrected for tides or water surface waves, but they do provide an estimate of project depths to within approximately +/- 1 m.

3.2.4 The ACDS also provides survey navigation information to the pilot such as the required altitude, speed, and position along a selected survey line, necessary to conduct the planned mission and produce the desired sounding density. The operator selects the flight line and the ACDS converts its position and other flight parameters to navigation information and presents this to the pilot on a small video monitor mounted in the cockpit.

Transceiver

3.2.5 The Transceiver is mounted over a window in the belly of the aircraft. The main component is the laser, which operates at 400 Hz. There are four receiver channels, two for detecting the water surface and two for detecting the sea bottom. The two water surface channels include the IR return from which the surface location is determined. The second channel is to ensure a water surface return by detecting the Raman scattering. The two bottom channels are used to detect returns from shallow and deep depths.

3.2.6 Included is a gyro-stabilized scanner, which directs each laser pulse to a predetermined location on the sea surface. An inertial reference system provides aircraft attitude information allowing the scanner to compensate for aircraft motion and measures accelerations necessary for accurately resolving the sea surface location during post-flight data processing. The width of the scan is nominally equal to half the altitude of the aircraft. At a speed of 120 knots and an altitude of 200 m, this yields a uniform sounding spacing of 4 m x 4 m. the sounding density can be altered by flying higher/lower and faster/slower and also by selecting a different scan width.

Aircraft Positioning And Auxiliary Sensors Sub-System (APASS).

3.2.7 The APASS consist of DGPS and a video camera. DGPS is used for horizontal positioning of the aircraft and the differential correction is available through Fugro's Omnistar system. The other function of the APASS is to record a video image of the area being scanned by the laser. This provides a visual and audio record of each survey mission and a record for the data processor/hydrographer conducting the data processing to check or evaluate any anomalies that may be encountered during data processing, such as algae on the water surface or over-flight of an island.

3.3 SHOALS System Calibration

3.3.1 To ensure accuracy of the system, SHOALS requires both a hard target test and a calibration flight for calibration of the system. The hard target test is accomplished through firing the laser against a known baseline distance. The test is performed for each receiver of the surface and bottom channels. Any observed error is nulled out through adjustment of appropriate parameters.

3.3.2 The SHOALS system undergoes an in-flight calibration for the determination of the small offsets of the scanner mirror frame relative to the optical axes of the system, in the roll, pitch and heading directions as defined by the Inertial Navigation System. Critical to this calibration is locating and flying a calm, flat area in the field. To calculate the angular offsets an average of the water surface is derived by the system, then a special calibration program developed by the National Ocean Service derives these small angular offsets assuming that the sea surface is flat. The offsets are folded back into the collected standard data and the successful plotting of a flat-water surface shows that the angles were correctly derived.

3.3.3 In the first six years of SHOALS operation, a standard survey line was used to derive these small angular offsets. In early 2000 is was thought that a wider excursion of the scanner forward angles would result in better calibration values and a raster scanner pattern became the standard operational procedure. Either procedure raster or standard pattern is acceptable as long as the resulting angular corrections produce a flat-water surface. (Carswell; Optech, Inc. 2002)

3.4 **SHOALS Positioning Quality Control.** The operator continuously monitors position quality in the air. Flight lines are re-flown if any of the following specifications are exceeded:

PDOP exceeds 4. The PDOP is recorded as a field within the data.

The semi-major axis of the positional error ellipse exceeds 3.5m at the 95% confidence level.

The DGPS correction age exceeds 10 seconds.

The minimum number of satellites being tracked for continued sounding is less than 4 healthy SV's.

The minimum elevation for SV is less than 10°angle from the horizontal.

3.5 **SHOALS Lidar data processing system**. Hydrographic Data Processing utilized the SHOALS data processing suite; data tapes from the aircraft are read in and the depth derived from the processed laser pulse. The algorithms utilized in the SHOALS processing suite were developed at NOAA by Gary Guenther, et al. Time tagged position and depth, the *.out file and laser waveform files were then transferred to the NAVOCEANO system. Data quality control, additional editing and validation were carried out using the NAVOCEANO Area Based Editor running under LINUX. Upon return to NAVOCEANO, the data underwent further analysis and refinement using 3D visualization tools (Fledermaus) and application of NOAA verified tides.

3.5.1 **Ground Processing Environment** All processing, cleaning and product generation is carried out on off-the-shelf NT workstations using software developed by Optech, Inc. specifically for SHOALS.

3.5.2 **Processing Of Data, General Principles.** All survey data collected are field processed, verified and validated concurrent with survey operations. Verification methods include comparison of collected data to existing charts and prior surveys. Discrepancies discovered in field processing are resolved immediately. Discrepancies requiring significant additional operational time and effort to resolve are brought to the attention of the Operations Manager, for decision.

3.5.3 **Post Processing Lidar Data**. SHOALS Lidar data is processed by an NT-based automated processing software package that includes automated post-flight depth extraction procedures, various calculation and utility programs, and a manual processor operator interface that provides access to individual waveforms for display and editing. The suite maximizes throughput by recognizing and handling most problems routinely, minimizing the amount of human interaction with the raw data.

3.5.4 After the data is extracted from the flight tape and input into the database, it is processed by an automated routine consisting of a lidar waveform processor and sounding position determination algorithm. The main function of the automated processor is to obtain inputs from the raw data; calculate depths, positions, and other products; correct for tides and waves; and write the outputs back to file database. It runs at a 1:0.1 time ratio with data collection and data processing.

3.5.5 All data is then manually edited for obvious anomalies. Where such anomalies are clearly due to fish, or similar causes, they will be flagged as invalid returns; any other anomalies resembling bottom hazards will require investigation of the waveform in order to determine whether the feature is real and should be retained in the data set. In cases of doubt, such features will be marked for further investigation through re-flight of the area in question.
The processed data is then output as an ASCII (*.xyz) file which can either be input directly into Hypack, or converted to Fugro Binary Format (*.fbf) for input into Starfix.Proc for review, QC and ultimately subsequent mapping and product generation. This process is outlined in Figure 6.

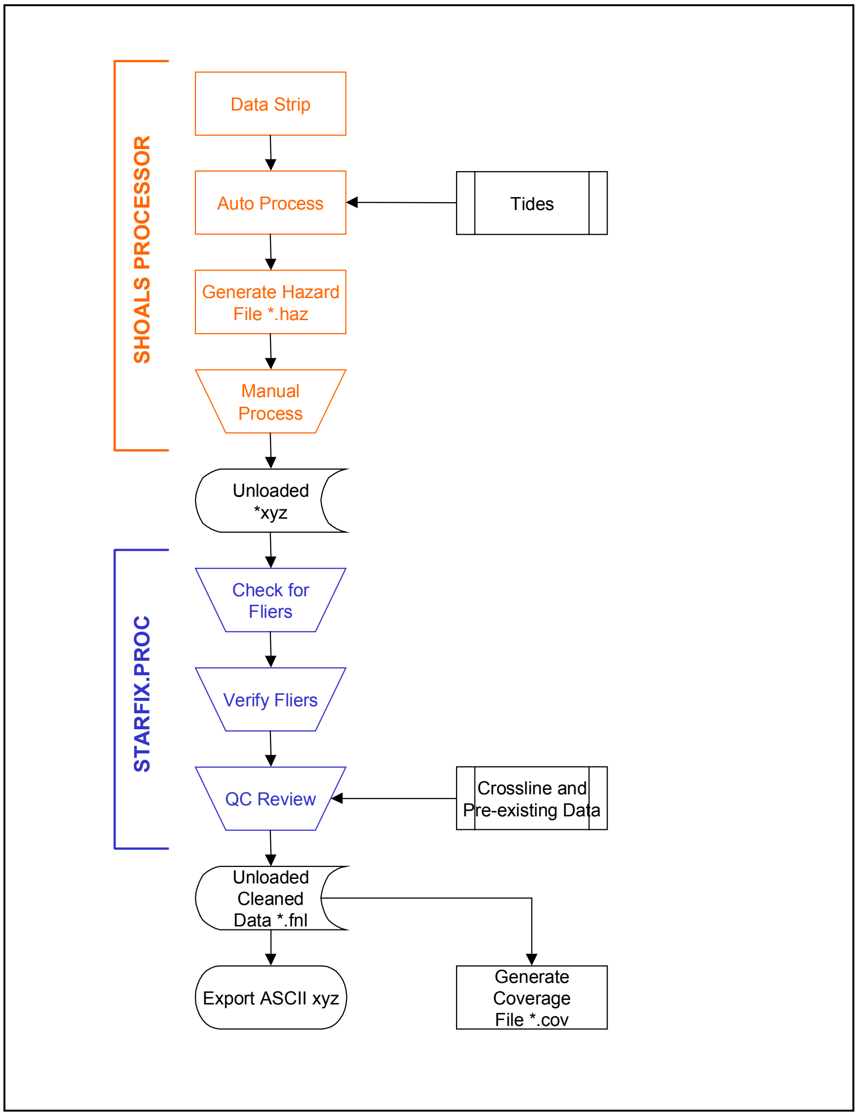


Figure 6: Data Processing Flow

3.5.6 **Data Review and Inspection.** Output xyz data from the processor is transformed to the appropriate projection using Corpscon or GeoCoordinator and then input into Starfix.Proc where the process of spatial review and comparing each data set to expected values is performed. Each dataset is compared with any available pre-existing charts, maps or other information data; overlapping datasets are also compared to each other to make sure each falls within the systems limitations. The data is then plotted out on paper with a contour interval 1 or 2 m in order to identify any further anomalies that may not have been apparent from inspection of individual flightlines and only become evident in a broader spatial context. Any such anomalies will then be resolved through reference back to the waveforms.

3.5.7 **Second Depth Description and Methodology.** The laser waveform from the bottom return is capable of having two valid returns (second depths) for a single sounding. Multiple returns can be from any object suspended in the water column, sharp drops in the bottom topography, or objects rising above the bottom. The initial processing of the data picks the more shallow depth for that particular sounding. The post processing software allows for viewing of all soundings with multiple returns and evaluation by the hydrographer to determine the validity of the return. The hydrographer is allowed to keep, swap or kill the return based on the waveform analysis and review of the surrounding and overlapping data. The keep option will keep the sounding as it was initially calculated by the post processing algorithm. The swap option allows the hydrographer to change the sounding to the second of the valid returns calculated by the software. The kill option allows the hydrographer to kill the sounding so that the sounding is not reported in the final cleaned xyz data. A report of this process is output from the post processing software and details the status of each second depth return as either keep, swap, or kill. See appendix "F" for second depth report for this project. Soundings reviewed here are kept unless there is valid evidence to support change.

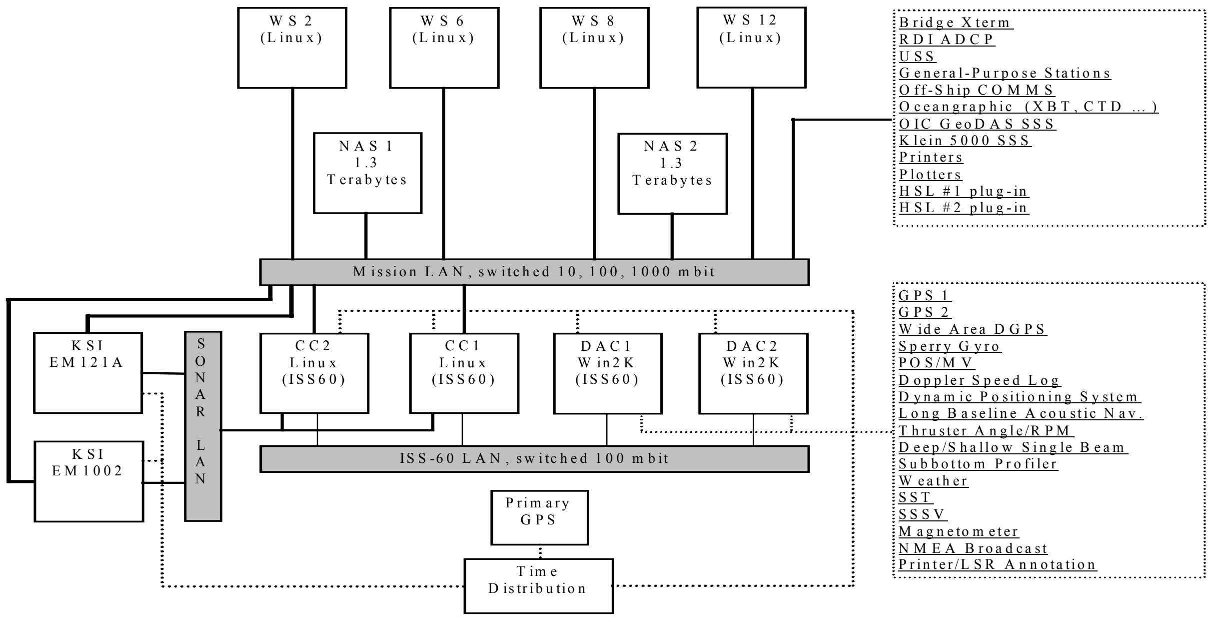
3.5.8 **Flier Description and Methodology.** Possible fliers are listed within Starfix.Proc and output to a log file. The timestamps listed in this log file are then reviewed in the post processing software by the hydrographer to determine the validity of the return. The analysis is similar to that of the second depths in that adjacent and overlapping data are reviewed in conjunction with the waveform. A report of these fliers is then compiled with the action taken (either keep or kill) for each sounding. See appendix "G" for the flier report. As with the second depths all soundings are kept unless valid evidence exist to support killing of the sounding.

3.5.9 **Area Investigation and Review.** In areas where soundings are killed due insufficient energy return, or areas where the second depth and / or flier review produce questions to the validity of the sounding, re-flights are performed. The field hydrographer is responsible for determining which areas are to be re-flown based on the client's maximum gap in coverage requirements.

3.5.10 **Data Mapping**. The final cleaned xyz files are then binned using a 4m by 4m bin size to help reduce the size of the files. This file is the final delivered xyz file. The final mapping is performed using MicroStation and Inroads. These programs produce maps in DGN format. The contour files produced by Inroads where derived from a reduced data set of xyz files. The reduced data set was produced by HyPack's point reduction program. After mapping in the DGN format the files were exported to a DXF format for the final deliverable.

3.6 USNS SUMNER data acquisition system.

USNS SUMNER data acquisition system is shown in block diagram below.



The SIMRAD EM1002 is a 150 beam, 150 degree multibeam sonar system. Several operating modes are available; 150 degree swath, 120 degree swath, equal-angle (EA) and equal-distant (ED). In EA mode the beams are formed such that the beams are an equal and consistant angle apart across the swath. This results in the bottom footprints getting progressively further apart toward the outer swath. In ED mode the beams are formed such that the beam footprints are an equal distance apart on the bottom. ED mode provides consistent coverage across the swath.

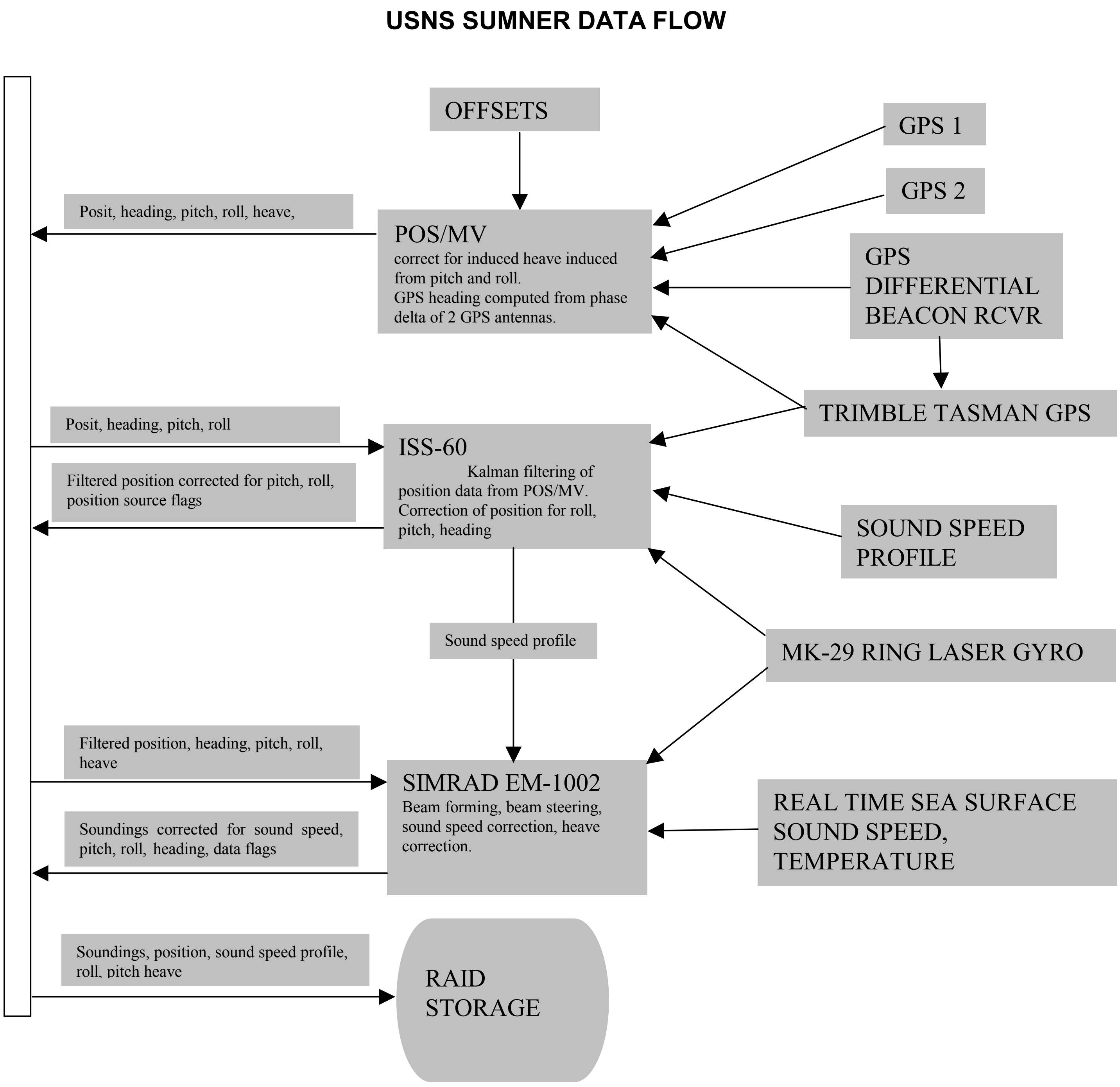
Extensive NAVOCEANO testing has shown that beams in excess of 60 degrees off nadir (beams outside a 120 degree swath) are subject to substantial refractive errors no matter how accurate the sound speed profile of the sound speed at the transducers. These outer beams do not meet accuracy requirements.

The standard NAVOCEANO mode of operation for this system is ED mode with a 150 degree swath (to ensure outer swath object detection). This was the setup on USNS SUMNER.

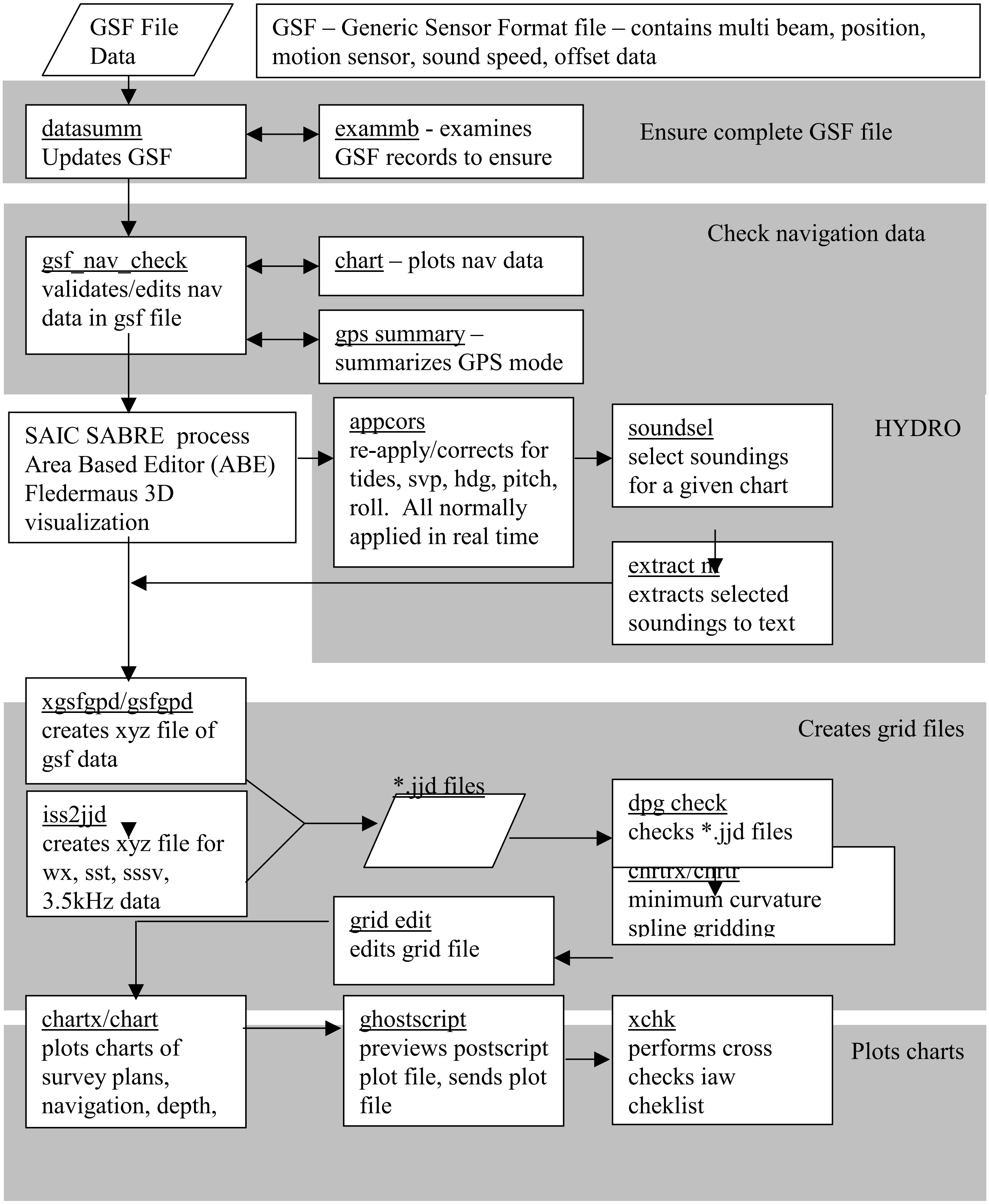
Because of the inaccuracies of the those beams in excess of 60 from nadir, beams outside of this envelope are discarded during processing and these soundings are not part of the final sounding selection.

3.7 USNS SUMNER Data Flow

USNS SUMNER data flow is described in block diagram below



3.8 **USNS SUMNER data processing system**



4.1 **Positioning Systems**. No formal calibrations of the Ashtech Z-12 receivers operating in the DGPS mode were conducted in the field. However, internal accuracy (precision) of the system was monitored by the SHOALS system utilizing standard positional QC (HDOP, PDOP, SNR data) techniques. Overall accuracy was not checked against independent (terrestrial) navaids, but crossline, swath overlap and multiple flights over kinematically positioned features such as pier ends/corners and NAVAIDS and comparison checks on the sounding data did allow a high degree of trust in positional integrity to be reached. Fugro/Chance personnel received daily solar storm forecasts and activity reports. Data collection during periods of high solar activity was avoided. During processing, graphical analysis of LOP data indicated no problems with the positioning system. With the vast majority of cross-checks and overlapping swaths showing good agreement however, both sounding reduction and navigational accuracy were assessed as adequate for the survey.

4.2 **SHOALS System Calibration**. To ensure accuracy of the system, SHOALS requires both a hard target test and a calibration flight for calibration of the system. The hard target test is accomplished through firing the laser against a known baseline distance. The test is performed for each receiver of the surface and bottom channels. Any observed error is nulled out through adjustment of appropriate parameters.

4.2.1 The SHOALS system undergoes an in-flight calibration for the determination of the small offsets of the scanner mirror frame relative to the optical axes of the system, in the roll, pitch and heading directions as defined by the Inertial Navigation System. Critical to this calibration is locating and flying a calm, flat area in the field. To calculate the angular offsets an average of the water surface is derived by the system, then a special calibration program developed by the National Ocean Service derives these small angular offsets assuming that the sea surface is flat. The offsets are folded back into the collected standard data and the successful plotting of a flat-water surface shows that the angles were correctly derived.

4.2.2 In the first six years of SHOALS operation, a standard survey line was used to derive these small angular offsets. In early 2000 is was thought that a wider excursion of the scanner forward angles would result in better calibration values and a raster scanner pattern became the standard operational procedure. Either procedure raster or standard pattern is acceptable as long as the resulting angular corrections produce a flat-water surface. (Carswell; Optech, Inc. 2002)

4.3 **Survey System Offsets/Alignment**. The laser system and motion sensors are optically aligned and the offsets measured with respect to the phase center of the GPS antenna. This is done at every system or component installation. The measured offsets are contained in what is called the "STATIC" file. This file is written to the survey plan and, during initialization of the data collection system, written to the daily data tape. During processing the offset values are stripped from tape along with the data applied during post processing (SHOALS NT processor). During processing tide corrections are applied. In the event of a kinematic survey the KGPS derived positions and ellipsoid to MSL offset is also applied. For surveys covered in this report no kinematic data collection was conducted.

4.4 **Deep Bias Offset Correction**

4.4.1 There has been a suspected deep bias present in SHOALS 400 data. This bias has never been quantifiable due to a lack of suitable ground truth data. The SHOALS-400 algorithm applied a constant bias to make the SHOALS derived depths shallower by 12 cm. This was based on the original Sarasota data and also the later Tampa Bay data. Recent testing of the follow-on Lidar system, SHOALS 1000, or CHARTS, the NAVOCEANO term for the system, at the South Florida Test Facility (SFTF) operated by the Naval Surface Weapons Center off Dania Beach Florida has allowed for the quantifying of this deep bias error. True, the deep bias error has been quantified with the SHOALS 1000 system, it is applicable to the SHOALS 400 system because the physics involved is the same as are the algorithms utilized to derive depth from the laser shots.

4.4.2 All of the SHOALS 400 data has been corrected for a depth bias that was discovered during the ground truth tests for the CHARTS system at the South Florida Test Facility. The equation used is as follows:

```
if (out.au.reported_depth > 7.0)
{
   correction = 0.17235 - 0.02485 * out.au.reported_depth;

   out.au.tide_cor_depth -= correction;
   out.au.reported_depth += correction;
   out.au.result_depth += correction;
   out.au.sec_depth += correction;
}
```

4.4.3 The equation represents the difference between the historical depth bias corrector (SHOALS-400) that was applied to the data and the new depth bias corrector taken from the SFTF data. The equation was derived by Grant Cunningham of Optech. This information came in an email (10/10/03) from Paul LaRocque of Optech. Note that the 12cm bias mentioned in the email was not depth dependent and was not removed from the data.

0 cm effect at 7 m
8 cm effect at 10 m
20 cm effect at 15 m
32 cm effect at 20 m
57 cm effect at 30 m
82 cm effect at 40 m.

The SHOALS-400 algorithm applied a constant bias to make the SHOALS derived depths shallower by 12 cm. This was based on the original Sarasota data and also the later Tampa Bay data. The following new recipe will make the SHOALS-400 data even shallower by the amounts stated in table above.

To apply the newest depth bias corrector to older (i.e., SHOALS-400) data, the following equation should be used:

delta_depth = 0.0 m, for reported_depths < 7 meters
delta_depth = [0.17235 - (0.02485 * reported_depth)] m, for
reported_depths >= 7 meters

This delta_depth should be ADDED to the older values of the reported_depth,
as below:
new_reported_depth = (old_reported_depth + delta_depth)

Therefore, at 40 meters old_reported_depth this will make the new_reported_depth shallower by about 82 cm.

5.0 **Side Scan Sonar**

5.1 **Requirements**. A side scan requirement existed only for Apra Harbor, Guam. This requirement was completed by NAVOCEANO's Fleet Survey Team (FST) and is discussed in the FST Report of Survey.

5.2 **Equipment**. N/A

5.3 **Coverage**. N/A

6.0 **Tides and Water Levels**.

6.1 **General Requirements**. Tidal zoning shall be constructed and tidal data observed and recorded such that derived tidal corrections to the sounding data meet 0.5 meter accuracy standards. The survey area shall be sufficiently zoned and tide gauges strategically located to ensure tidal corrections meet accuracy requirements.

6.2 **Tide Gauges**

6.2.1 **Apra Harbor, Guam**. The primary NOAA tide gauge (163-0000) for the Apra Harbor, Guam port area was located (13^{o} 26' 37" N, 144^{o} 39' 24.3" E), within the Apra Outer Harbor.

6.2.2 **Saipan, Tinian, FDM**. The primary NOAA tide gauge (163-3227) for Saipan, Tinian and FDM was located within Tanapag Harbor at Garapan, Saipan.

6.2.3 **Additional Gauges**. Due to the difficulties discussed in section 6.5.2, an additional NAVOCEANO tide gauge, a simple non-integrating pressure-recording gauge water level logger, was installed in a fabricated stilling well mounted adjacent to the NOAA gauge adjacent to the NOAA gauge as a backup to NOAA gauge failure or down time. Data from this gauge was not used to correct data.

6.3 **Preliminary Tidal Zoning**.

6.3.1 Tidal zones for Guam, Saipan, Tinian and FDM were developed by NOAA CO-OPS.

6.4 **Final Tidal Zoning**

6.4.1 Tidal zones for Guam, Saipan, Tinian and FDM were developed by NOAA CO-OPS. The only adjustment to the zones was at Saipan.

6.4.2 For operations at Saipan, Tinian, and FDM, NAVO determined the Saipan gauge (163-3227) would be more appropriate for the immediate area. NAVO modified the zones and adjusted the correctors slightly to utilize the Saipan gauge. NOAA verified NOAA tides from the NOAA tide gauge on Saipan were used as the reference. Zones were altered as follows:

MAR300	0 min	1.0
MAR301	6 min	1.0
MAR302	6 min	1.0
MAR303	0 min	0.97
MAR400	0 mim	0.93

6.4.3 Zones MAR300 and MAR301 are split from Ushi Pt., Tinian to N 15-10', E 145-30'

6.4.4 With reference to Saipan 163-3227 Saipan is corrected with no phase or amplitude correctors applied. Tinian west, 6 minute phase delay with no amplitude correction. Tinian east, no phase delay with a 0.97 amplitude correction. FDM, no phase delay with a 0.93 amplitude correction.

.

6.5 **Tidal Data Collection, Scope of Work**.

6.5.1 The primary NOAA tide gauge (163-0000) for the Guam port area had been recently serviced and checked by NOAA CO-OPS. The primary tide gauge at Saipan (163-3227) was installed by NOAA CO-OPS specifically to support these survey operations. NOAA CO-OPS was tasked with installation, maintenance and technical support of the gauges. Also NOAA CO-OPS was responsible for posting preliminary unverified tidal data on the CO-OPS web site, tidal data processing and verification, posting of verified data to the web site and tidal zoning.

6.5.2 Difficulty was experienced initially in obtaining continuous data (at 6-minute intervals) from this gauge on the NOAA CO-OPS website. It was found that the main up-link antenna to which the data was transmitted by the gauge was badly obscured by vegetation and aimed to a very low elevation satellite that may have been masked by mountains to the east of the harbor. As a result, data coming across onto the site was very sporadic. This was overcome by obtaining data directly from the gauge from a dial-in facility made known to us by Mr. Frank Wells, a National Weather Service (NWS) employee and the NOAA tide observer on Guam. It is considered that NOAA should take action to remedy this shortfall in their services so that all marine traffic in Guam could benefit from the data as required, especially given the heightened importance of the Naval Base to the US Navy and their desire to increase traffic and size of vessels entering Guam waters.

6.6 Tidal Corrections

6.6.1 Guam - NOAA CO-OPS derived tide zones and applicable correctors are shown in Appendix B. Guam data was corrected using the Apra Harbor tide gauge, 163-0000. NOAA CO-OPS verified tides from this gauge were applied to the Apra Harbor and Agat Bay data according to the NOAA CO-OPS zones.

6.6.2 Saipan, Tinian and FDM - NOAA CO-OPS derived tide zones and applicable correctors were initially applied according to the NOAA CO-OPS zoning scheme using Apra, Guam (163-000) as the reference. Due to the distance of Saipan, Tinian and FDM from the reference gauge in Apra Harbor, Guam and the availability of tide data in the immediate area from the Saipan gauge (163-3227), it was determined that the local gauge would better represent the tidal signal and locally induced distortions of this tide. Accordingly, tide zone boundaries for MAR300 and MAR301 were altered slightly and the correctors adjusted for all the Saipan, Tinian and FDM zones to allow for the application of Saipan tide data to the surrounding waters. Data were corrected using NOAA CO-OPS verified tide data from the Saipan tide gauge, 163-3227, with appropriate adjustments made to the zonal time shift and amplitude corrector appropriate to the Saipan gauge as per section 6.4.2

6.7 Application of Tides.

6.7.1 The NAVOCEANO processing system does not utilize “tide correctors”, per se. The NOAA CO-OPS zoning scheme partitioned the survey areas into zones referenced to a reference tide gauge. For each zone there is a phase and amplitude correction, also referenced to the reference tide gauge. NAVOCEANO’s processing system handles tide correction by creating a tide file for each zone by applying zonal corrections to the reference gauge tides. The processing software identifies in which zone a sounding falls and applies that zone’s tide to the sounding.

6.8 Currents and Tidal Streams

6.8.1 **Apra Harbor , Guam**. Currents were not observed to exceed 0.5 knots at any time during the harbor survey.

6.8.2 **Saipan**. Three Acoustic Doppler Current Profilers (ADCP's) were deployed within the

Saipan survey area. The ADCP locations and current data are summarized in Appendix E. Currents within the Saipan survey area are seen to be heavily influenced by tide and wind forcing.

7.0 Data Collection and Field Work

7.1 **Units**. All soundings are in meters.

7.2 **Corrections to Soundings**. Alignments, offsets and verified tides were applied during appropriate stages of data collection and processing.

7.3 Hydrography

7.3.1 **Source of Shorelines**. The shoreline source was initially generated from the vector shoreline used in the DNC of the area; this should be revised using high resolution shoreline derived from the zero contour obtained from the LIDAR datasets as the charted shoreline accuracy could use some improvement.

7.4 Sounding Development and Coverage

7.4.1 **Guam**. The LIDAR survey consisted of 200% coverage of the entire inner and outer harbors. Flight lines were oriented E-W over the outer harbor and N-S over the inner harbor. Depth and water clarity limitations of the system prohibited attaining 100% bottom detection. Areas not covered by LIDAR were surveyed by the Fleet Survey Team and consist of single beam and sidescan sonar coverage. Coastal areas of Guam, surveyed per USACoE, USGS and USF&W requirements consist of 100% coverage. These areas were not tidal zoned, and therefore have had no tides applied. These areas were not flown for charting purposes. However, with appropriate zoning and application of verified tides this data would meet IHO Order 1 requirements.

7.4.2 Apra Harbor, Guam is quite deep with most of the bottom outside the operational range of the LIDAR system. Therefore, LIDAR coverage in the outer portion of Apra Harbor, Guam was limited to the shorelines and reef areas to depths of 20 to 35 meters, deeper toward the mouth of the harbor where water clarity is greatest. LIDAR coverage in the inner portion of Apra Harbor was fairly good. However the inner harbor is quite shallow, of limited circulation and bounded in the south and east by mangroves where freshwater runoff is prevalent. Additionally, any vessel traffic stirs up the bottom quite a bit. As a result, due to a large amount of false bottom returns and significant pulse stretching, confidence in the LIDAR data in the inner harbor is quite low and all LIDAR sounding data for the inner harbor has been discarded. The exception is in the channel from the outer harbor to the inner harbor where water clarity was acceptable and shoreline definition was accomplished along the eastern shore and the piers. Coverage consists of a combination of LIDAR and FST single beam sonar data and is shown in Appendix D.

7.4.3 **Apra Outer Harbor**. Measuring some 2.5 miles long and 1.2 miles wide, Apra Outer Harbor is very complex in nature. The western portion is mostly uniform and relatively deep, whilst the eastern end contains a more convoluted shoreline, several shallow reefs, some large wrecks and numerous shoals on an altogether irregular seabed. It is home to a plethora of marine flora and fauna and as such is a particularly sensitive environment. The approaches to the outer harbor were surveyed by USNS Sumner utilizing a SIMRAD EM1002 multibeam sonar system.

7.4.4 **Apra Inner Harbor**. With an average depth of 10 meters this triangular body of water possesses a much more regular and mostly featureless seabed. The narrow (275 meter) channel connecting the inner and outer harbors was similarly configured.

7.4.5 **Cabras Island Channel**. Leading from Apra Outer Harbor to the main commercial wharves, this channel under consideration within the limits of the HI included important terminals used both by commercial and military ships alike. Although dredging reportedly takes place in the area, evidence from both the chart and that found during surveying suggests that this activity is somewhat sporadic, indicating that the area is not prone to regular silting.

7.4.6 **Saipan**. Coverage consisted of 200% LIDAR in depths less than 35-40 meters supplemented with 100% multibeam sonar data in areas deeper than 40 meters and the western third of the offshore anchorage. See Appendix D.

7.4.7 **Tinian**. Coverage consisted of 200% LIDAR in depths less than 35 - 40 meters supplemented with 100% multibeam sonar data in the deeper areas off Sunharon Roads. Numerous holidays, for reasons unknown, exist in the SUMNER SWMB data. See Appendix D.

7.4.8 **FDM**. Coverage consisted of 200% LIDAR in depths less than 35 meters immediately around FDM and over the shoal area to the north of FDM, supplemented with 100% multibeam sonar data in the deeper areas. Additionally, there is a coverage gap close in and surrounding FDM in an area too deep for LIDAR and too hazardous and close to FDM for ship operations. See Appendix D.

7.4.9 **Sounding Selection**. NAVOCEANO area-based, shoal-biased sounding selection algorithm.

7.5 Data Quality Control

7.5.1 **Processing Methodology**. Graphical examination/evaluation of LOP time series data and deletion of bad data. Graphical examination/evaluation of roll, heading, vertical acceleration time series. 3D visualization of data as a sun-shaded surface colored by depth, line or file. Visualization of data with color and gray scale palette. Visualization of data from any view angle, elevation or lighting position. Visualization of the sun shaded statistical, minimum, average and maximum surfaces. Area based editing of data. Data can be rotated. Multiple and overlying data can be compared. Complete 3D editing capability through the Area Based Editors. Overlay of GeoTif chart images with sounding sheets.

7.5.2 **Cross check/swath overlap agreements**

7.5.3 Cross check lines consisting of single beam sonar data were run in Apra Harbor. This provided data check capability along with system-to-system comparisons. Additionally, adjacent LIDAR swath overlap provides an excellent data check capability. Excellent agreement was seen with overlapping LIDAR swaths. Good agreement with the main development lines was generally observed between LIDAR and FST single beam data. However, several disparate results indicated the degree of difficulty in obtaining definitive geo-referenced depths due to equipment configuration and steeply sloping bottom topography. Perusal of these points indicated large differences in depth (6-8 meters) for corresponding positions. While this appears a problem initially, it serves as a good indicator that such discrepancies can and will occur, even with DGPS-positioned platforms, using single beam echosounders (9-15 degree beamwidth) in water depths up to 55 meters over very steep seabed gradients, and with azimuth and orientation derived only from historic GPS positions. Notwithstanding these few anomalies, the vast majority of cross-check deviations were well within IHO standards. Cross check agreement over flat bottom areas, where beam geometry has minimal effect, was excellent.

7.5.4 At Saipan, Tinian and FDM, due to the rapid nature of bottom drop-off close to shore, LIDAR swath overlap was primarily utilized as a data check tool with excellent agreement noted. Where there was enough nearshore bottom extent cross-checks were run and agreement was excellent.

7.6 **Agreement With Existing Charts**.

NOAA Chart 81054 (12^{th} Ed 10/93) was used in determining survey agreement.

> General bathymetry agreed well in all but a few areas. Navigational buoyage in Apra Harbor and Saipan was also observed to be at variance with the chart.

NOAA Chart 81067 (Saipan, Tinian) Generally good agreement considering the age of the survey data on the charts.

NOAA Chart 81076 (Saipan Harbor) Shoaling at the entrance of Garapan harbor appears evident in the data. Numerous bathymetric featurs near the channel entrance are evident in the data. These features are not evident on the charts.

NOAA Chart 81071 (Sunharon Roads, Tinian) Generally good agreement considering the age of the survey data on the charts.

7.7 **Agreement with prior surveys**. No recent prior surveys were available. Soundings on existing charts were, normally, derived from World War II era surveys.

8.0 Accuracy and Resolution of Soundings

8.1 **LIDAR Positional Accuracy.** Positions were obtained from the Ashtech Z-12 GPS receiver onboard the survey aircraft. The system was operated in GPS stand alone SPS mode (FDM, Tinian), DGPS mode (Saipan) ans kinematic mode (Guam).

8.1.1 For the Guam survey, the system was operated in kinematic mode. The reference station was setup over the tidal station benchmark in Apra harbor. In kinematic mode, sub-meter accuracy is attained.

8.1.2 Correction data for Saipan were received from temporary beacons set at established geodetic reference mark on the roof of the harbor master building. The receiver was set up in the DGPS mode and received, via VHF radio modem Online system performance indicated that navigational accuracy of the order of 2-4 meters (95% probability) was achieved. It is assumed therefore that, combined with the potential offset latency mentioned above, the absolute navigation error (the position of the transducer) did not exceed +/-5 meters.

8.1.3 Due to range limitations of the VHF beacon transmitters, Tinian and FDM were surveyed using GPS in SPS mode. Positioning may meet order 1 standards, but published GPS SPS performance dictates a claim of order 2 for positional accuracy

8.1.4 The error budget discussed below pertains to the positioning system operating in differential mode.

Based on the following:

System measurement circular error:	1.0 m
Slope error (variable, 1.0 m flat bottom)	1.0 m
Navigational System accuracy:	4.0 m
Heading error	0.5 m
Roll/Pitch error (beam pointing error) (less than 0.05 degrees, less than 26 cm @ 300 meters altitude)	0.26 m

8.1.5 The cumulative effects of the above errors (RMS) would be: +/- 4.16 meters: allowing for the navigational accuracy of +/- 5 meters, the total RMS value for sounding positional accuracy is +/- 5.13 meters.

8.1.6 IHO Positional Accuracy (Order 1) requires +5m +5% of depth, which equates to an allowable error of:

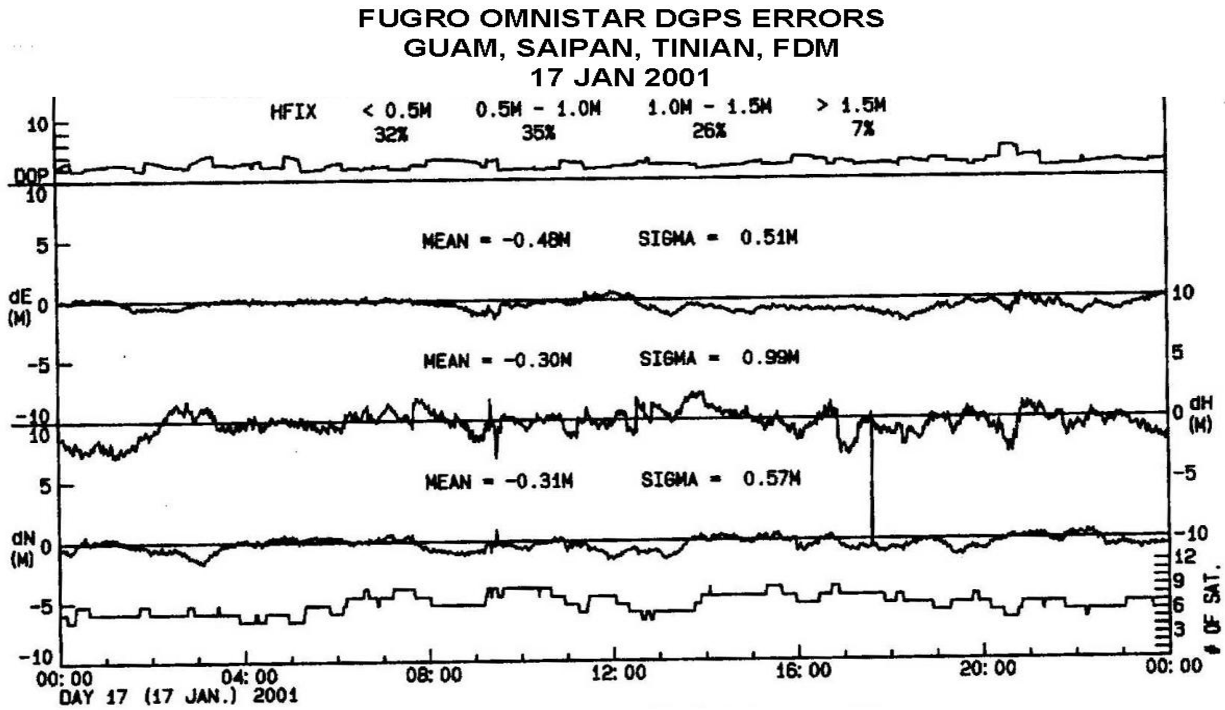
5.25 m   in 5 m depth

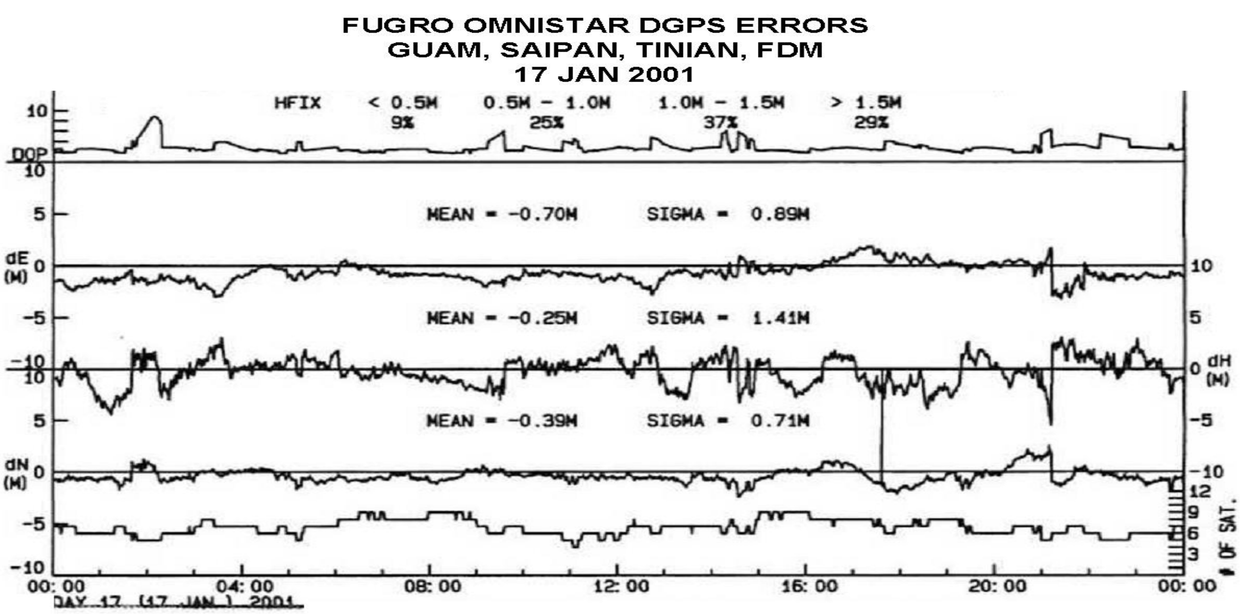
5.50 m	in 10 m depth
5.75 m	in 15 m depth
6.00 m	in 20 m depth

IHO 1st order positional accuracy is therefore considered to have been met in all areas throughout the survey. In areas of steeply sloping or high bottom variability deeper than 15 m IHO 1st order positional accuracy is considered to have been met.

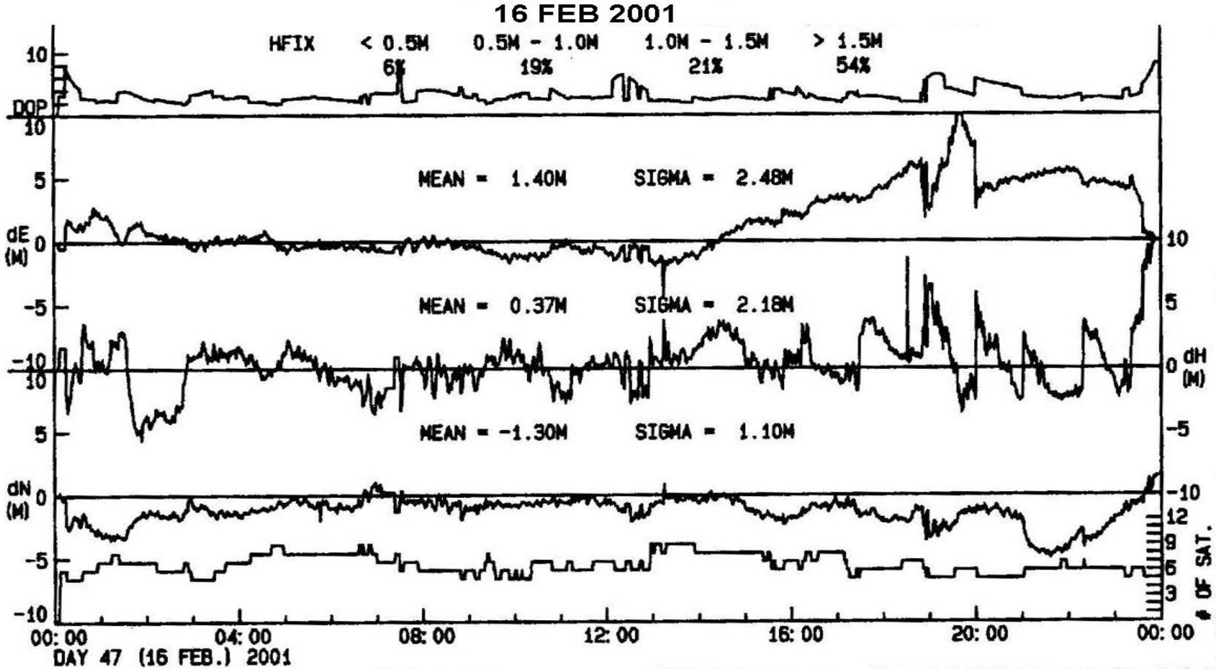
8.2 USNS SUMNER Positioning Accuracy

8.2.1 Positional Accuracy. USNS SUMNER utilized the Fugro/Chance Omnistar DGPS system. Error predictions for the WESTPAC survey errors are shown below.

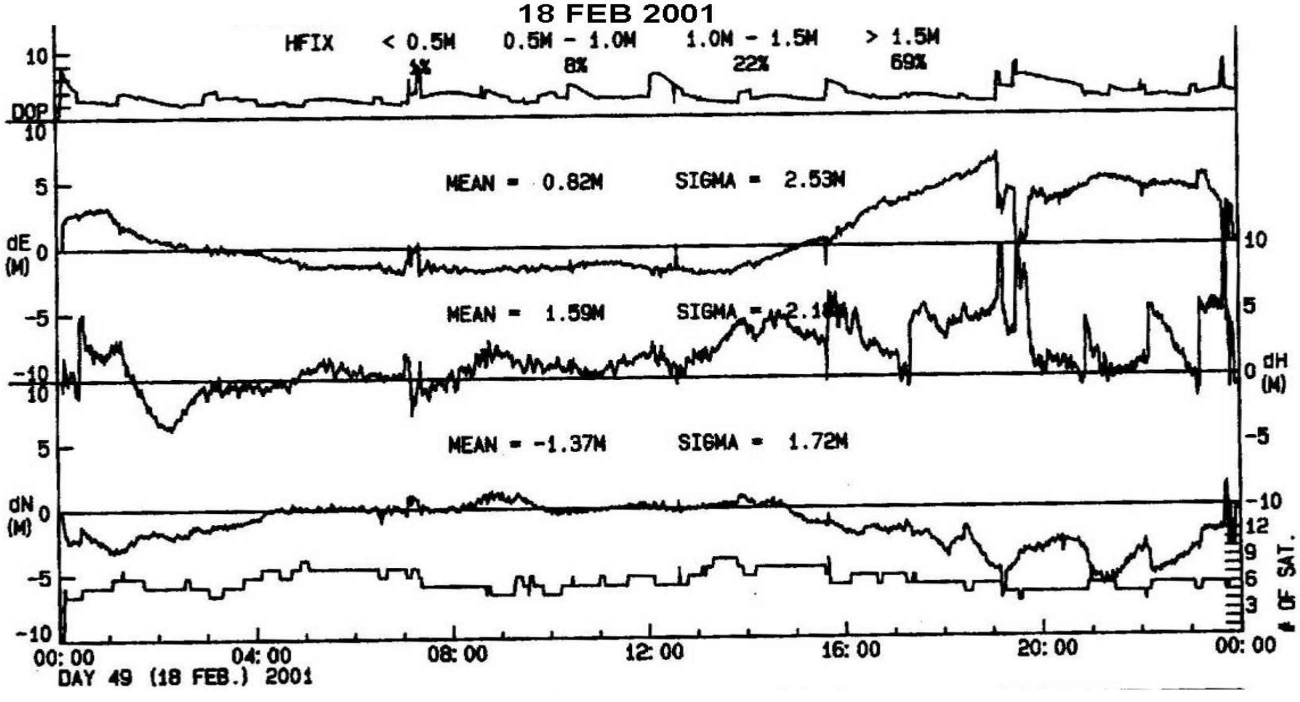




FUGRO OMNISTAR DGPS ERRORS
GUAM, SAIPAN, TINIAN, FDM
16 FEB 2001



FUGRO OMNISTAR DGPS ERRORS
GUAM, SAIPAN, TINIAN, FDM
18 FEB 2001



8.3 Accuracy of Soundings - Assessment and Evaluation

8.3.1 **LIDAR**. Assessment of the accuracy of LIDAR soundings entails an evaluation of the following:

a. LIDAR zero mark (water surface)	+/- 0.10 m
b. Depth measurement (system accuracy)	+/- 0.10 m
c. Laser propagation velocity error	+/- 0.05 m
d. Roll, pitch, heading	+/- 0.00 m
e. Vertical motion (heave)	+/- 0.00 m
f. Tidal Measurement	+/- 0.02 m
g. Co-tidal corrections	+/- 0.10 m
h. seabed slope	+/- 0.0 – 0.25 m

8.3.2 **LIDAR zero mark** (a) The zero or reference mark for Lidar data is not the platform or sensor, it is the water surface while operating in DGPS mode or the GPS antenna while operating KGPS mode. The accuracy of the zero reference is very dependent on the surface model utilized to compensate for wave and swell. The accuracy of the surface reference is considered to be 0.1 meters on a normal ocean surface. The surface reference accuracy improves over calm seas and in protected waters. A nominal value of 0.10 meters has therefore been accepted as typical.

8.3.3 **Depth Measurement error** (b) (Instrument Accuracy/Error).
System accuracy (depth resolution) for the LIDAR is 0.1 meters RMS. A nominal value of 0.10 meters has therefore been accepted as typical, given the relatively shallow water nature of this survey.

8.3.4 **Speed of Light Correction**. (c) In any medium light travels more slowly than it does in a vacuum. The velocity of light in a medium is equal to the velocity of light in a vacuum divided by the refractive index of the medium. The refractive index of light in air is 1.00028 and, for our purposes, is not significantly different from that in a vacuum, 1.00 by definition. The refractive index of water, though it varies slightly with temperature, salt concentration and wavelength, may be regarded as 1.33 for all natural waters. Assuming a velocity of light in a vacuum of 300,000,000 m/s, the velocity in water is about 225,000,000 m/s. The refractive index variability in natural waters is negligible, as is the speed. Therefore variation in light speed is not a limiting factor for LIDAR data and errors attributed to velocity of light variability can be considered non-existent.

8.3.5 **Roll, Pitch, Heading** (d) Roll, Pitch and Heading are sensed by an onboard POS/AV. Roll, pitch and heading are fully compensated for in real time through direct interfacing to the laser/scanner servo control system. Servo compensation within the limits of +/- 20 degrees of motion ensures the scanning mirror is referenced to nadir at all times. All out-of-tolerance motion results in system warnings and discarded Lidar pulses. Roll, pitch and heading errors are considered negligible.

8.3.6 **Vertical Motion Corrections**. (e) Not applicable for LIDAR data because the zero reference is not the platform or sensor, it is the water surface (when operating in DGPS mode) or the GPS antenna (when operating in KGPS mode). However, aircraft platform motion is compensated for by an aircraft mounted inertial motion system (POS/AV). This resolves undulations in the flight path. Aircraft movement outside of normal parameters result in "jerk" flags and rejected data.

8.3.7 **Tide corrections**. (f), (g) Tide correction errors consist of the actual observation errors at the tide gauge and any errors resulting from a tidal zoning schema or cotidal analysis. Observation errors from the NOAA tide gauges are known to be very low. The estimated error for observed tides is 0.025 meters (1 SIGMA). A similarly small margin of error for co-tidal corrections (0.35 meters) was calculated from comparison of a gauge installed on the leeward sides of Oahu and Kauai and the zone corrected reference tide station data. The standard deviation between the observed tide at these locations and the tide derived from the zoning was 0.179 meters. A similarly small margin of error for co-tidal corrections is based on the range and extent of the survey area in relation to the reference tidal stations and minimal shallow water effects due to the deep surrounding ocean water.

8.3.7.1 Incidentally, the three-day period when there was 0.35 meter difference between the observed tide and the NOOA COOPs cotidal zoned tide on the west coast of Oahu, no data was being collected in the area at this time. This error was strictly an observation and part of the tidal zone validation.

8.3.8 **Sea bed slope** (h) Slope error is normally related to footprint size at the sea floor. Directly related to beam spreading, the Lidar footprint is approximately 0.5 times the water depth. In 25 meters of water the footprint size is about 8 meters across. Normally, this would induce significant error on a sloping bottom due to the shallower part of the footprint reflecting back before the deeper edge of the footprint. This error is significantly reduced with the use of a narrow field-of-view (FOV) receiver telescope. The Lidar receiver telescope FOV is approximately 1.0 meters in diameter. Regardless of the actual beam spreading, only the 1 meter diameter area in the center of the beam is actually received. The leading edge of the return pulse, that which would be received from the shallowest part of the footprint, is not where the depth is computed. Depth determination utilizes a centroid of mass method within the 1 meter receiver FOV. Induced error estimates due to seafloor slope are based on the narrow receiver FOV footprint size.

8.4 **SHOALS Lidar Sounding Error Budget**

The resultant theoretical error budget is tabulated below representing typical shallow, mid-water and deepest values in the survey area

Source of Error		At 10m	At 25m	At 50m
a LIDAR zero reference (surface mark)		0.10	0.10	0.10
b system measurement accuracy		0.10	0.10	0.10
c laser propagation velocity error		0.05	0.05	0.05
e roll, pitch (this is positional error)		0.0	0.0	0.0
f tidal measurements		0.025	0.025	0.025
g co-tidal corrections (maximum 0.35m, STDEV 0.179m)		0.179	0.179	0.179
h seafloor slope 0		0.0	0.0	0.0
seafloor slope 1:4		0.0625	0.0625	0.0625
seafloor slope 1:2		0.125	0.125	0.125
seafloor slope 1:1		0.25	0.25	0.25
Combined total $(\Sigma(a^2 + \ldots l^2)^{1/2})$	flat bottom 1:4 bottom slope 1:2 bottom slope 1:1 bottom slope	0.235 0.25 0.354 0.500	0.235 0.25 0.354 0.500	0.235 0.25 0.354 0.500
IHO Cat 1 Requirement $[+/-(a^2 + (b*d)^2)^{1/2}]$		0.502m	0.509m	0.542m
Standard Met?		YES	YES	YES

8.4.1 As an adjunct to the standard calibration procedures approximately 200 tide corrected lead line observations were collected over a flat sand bottom and flat seas. Comparison of the lead line data to LIDAR data indicated agreement within a maximum of 0.06 meters with a mean agreement of 0.04 meters. Very close agreement with the lead line observations allows a very high confidence in the accuracy of LIDAR soundings.

8.4.2 **IHO Standards**. The accuracy for Order 1 allowable error (95% or 2 SIGMA) for depths from 0 to 50 meters is +/- 0.5 meters to +/- 0.542 meters. The calculated error for the motion-corrected LIDAR data and observed tides (see comments above) for this survey has a maximum value of approximately 0.354 meters and is therefore within the IHO accuracy limits for Order 1 surveys. As has been discussed, it is considered that the accuracy's estimated are both realistic and pragmatic; in no way do they negate the quality of the survey data so rendered nor do they serve to provide critical comment on the methods and equipment used in the survey. Indeed, the error could probably be reduced a bit with tide gauges installed on all sides of the islands.

8.5 **SHOALS LidarTarget Detection** Theoretically, based on target detection probability curves produced by NOAA, all Navy areas meet IHO Order 1 target/object detection requirements at the 95% confidence level for depths from 7m to 20m with single-flight coverage. At depths deeper than 20m signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects less than 2 meters (Figure 1). Multiple-flight coverage will theoretically improve the confidence of target detection capability in the depth range of 2m to 7m, and possibly down to 20m. Subsequent testing of the follow-on CHARTS system utilizing the same operating principles and algorithms, targets of 2 meters and larger were detected 100% of the time in depths of 5 to 30 meters. Based on actual tests the LIDAR system meets IHO Order 1 target detection requirements. Multiple coverage greatly improves this capability.

8.5.1 Subsequent testing of the follow-on CHARTS system, utilizing the same operating principles and algorithms and a lower power laser, at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths of 5 to 30 meters. Based on these actual tests the LIDAR system meets IHO Order 1-target detection requirements. Multiple coverage provides a degree of redundancy for this capability. The results of these tests have not yet been formally documented.

9.0 USNS SUMNER Errors Assessment

USNS SUMNER error assessment is discussed in Appendix F

10.0 **Navigational Aids**

10.1 Positions of navigational aids were obtained using 2 TRIMBLE Model 4700 geodetic receivers operating in kinematic mode.

10.2 On Guam one Trimble 4700 receiver was used by the NAVOCEANO FST to position a new geodetic point atop the EOD Tower, within the confines of the naval base, and was operated from the commencement of survey operations until completion of all field surveying (kinematic and DGPS survey phases). Post-processing of this positional data included use of GPS information from the Continuously Operating Reference Station (CORS) located at the USGS Observatory (designation "GUAM") to establish the primary benchmark as a geodetic control point and to refine positions obtained in the field during the kinematic survey of the area. Based on 95% probability, centimeter accuracies were achieved during the geodetic survey.

10.3 On Guam, navigational aids and features were kinematically positioned by the NAVOCEANO FST utilizing a Trimble 4700 GPS receiver. Positioning accuracy is within the IHO standards for Order 1 surveys (fixed features 2 meters, floating features 10 meters).

10.4 On Saipan, an existing geodetic mark atop the harbor masters office served as the reference position. The position of this mark was verified via a 2-hour observation period. Fixed and floating navigational aids pertinent to commercial harbor operations were positioned kinematically using two Trimble 4700 GPS receivers.

10.3 Some of the privately maintained navigational aids located off Garapan in the vicinity of N 15 12' were positioned.

10.4 Sea conditions at Saipan were very rough during this tasking. The harbormaster boat received damage when it was rolled into a buoy, while a NAVOCEANO person was on the buoy, and the emergency light rack was knocked off the top of the boat. Further offshore positioning tasks were abandoned in the interest of safety. Time did not permit additional effort.

11.0 **Sailing Directions**

11.1 **General**. Not verified due to the nature of the survey.

11.2 **Coastal Pollution**

Apra Harbor, Saipan, Tinian and FDM are areas of great marine diversity and home to many species of plants, fish, crustaceans, mollusks, birds and mammals. As such it is a particularly fragile and sensitive environment. However, no slicks, effluent or sewage were encountered throughout the survey period.

11.3 **Anchorage and Moorings**. Designated Naval, explosives and special anchorages are annotated on NOAA Chart 81054 (Guam) and described in Publication 126. No additional effort was made in surveying these anchorages in any greater detail than that prescribed for the rest of the survey area. The numerous moorings in the area were occupied and positioned using a Trimble 4700 GPS receiver operating in the PPK mode.

11.4 No anchorage and mooring positing efforts were conducted on Tinian due to a lack of suitable vessel, weather and time constraints.

11.4 **Photography**. FST photographed all NAVAIDS in Apra harbor. Aerial photos of Apra Harbor and Tipallao and Dadi beaches, Guam were shot from the aircraft. Also, aerial photos of all of Tinian shoreline were shot as was FDM and portions of Saipan.

12.0 **Charted and Uncharted Wrecks and Obstructions**.

12.1 **Guam**. Numerous man-made and natural obstructions were found during the course of this survey, most of which were uncharted. Generally small (10 meters or less) in size, with heights initially estimated from sidescan sonar and later confirmed by echo sounder to be in the order of 1 meter, the contacts were scattered throughout the outer harbor. These small wrecks are the remains of aircraft, LCMs, tracked military and commercial vehicles and other materiel chiefly from the WWII and post-WWII eras. The vast majority listed in the Wrecks and Obstructions database are not considered dangerous to surface navigation; nevertheless their existence should be annotated on the chart.

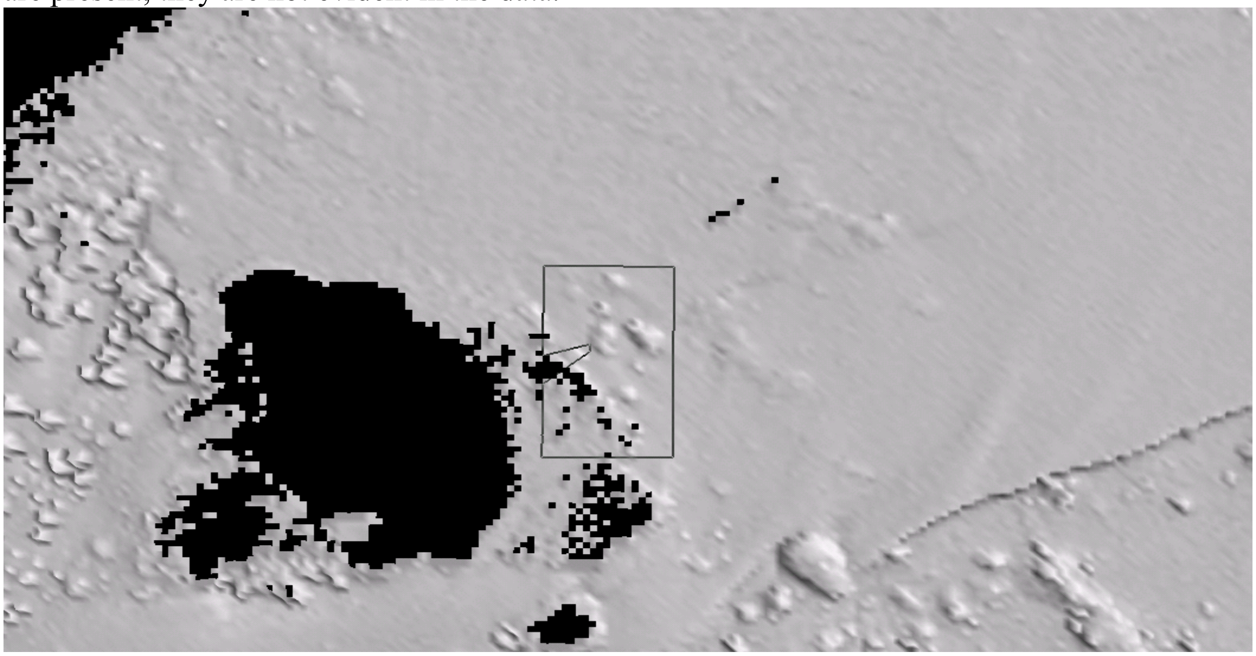
12.1.1 Charted Wrecks and Obstructions. Some, but not all of the charted wrecks and obstructions are evident in the data.

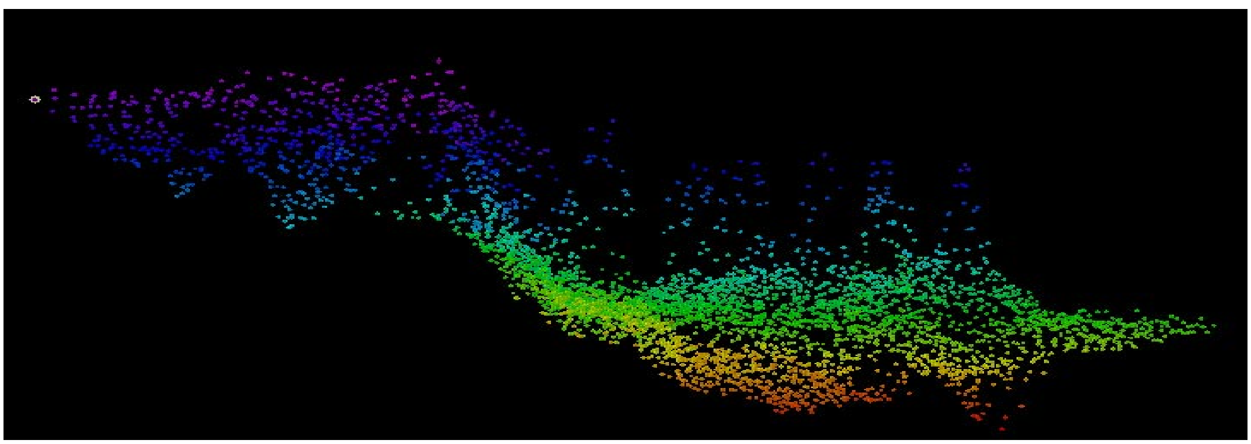
12.1.2 Uncharted Wrecks and Obstructions. None observed.

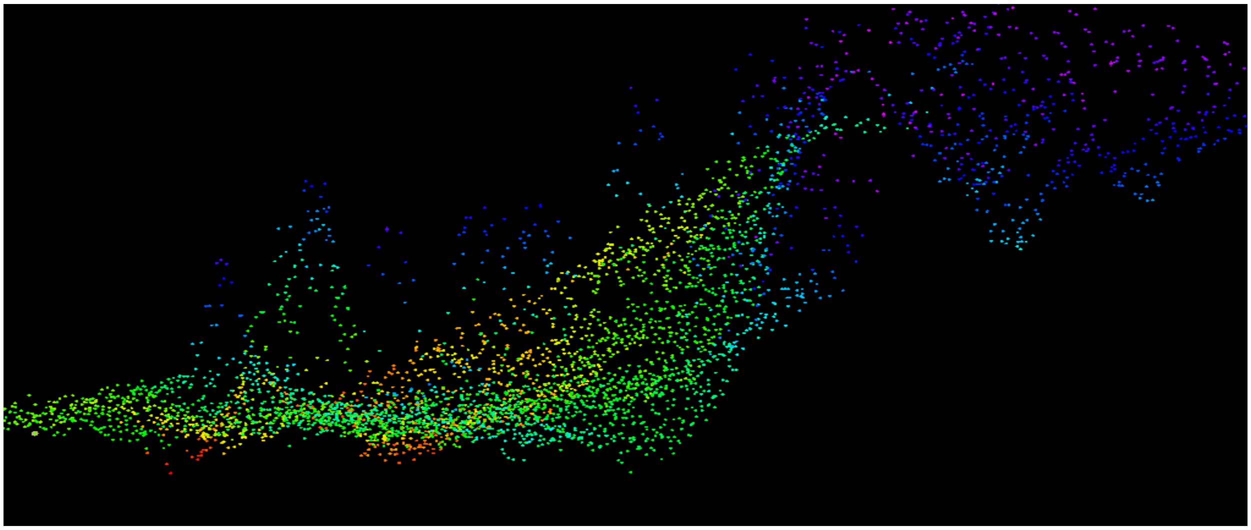
12.1.3 Guam wrecks and obstructions are discussed in the Fleet Survey Team RoS.

12.2 **Saipan**. Charted wrecks are in reference to NOAA chart 81076, 9th ed. Sept. 19/98.

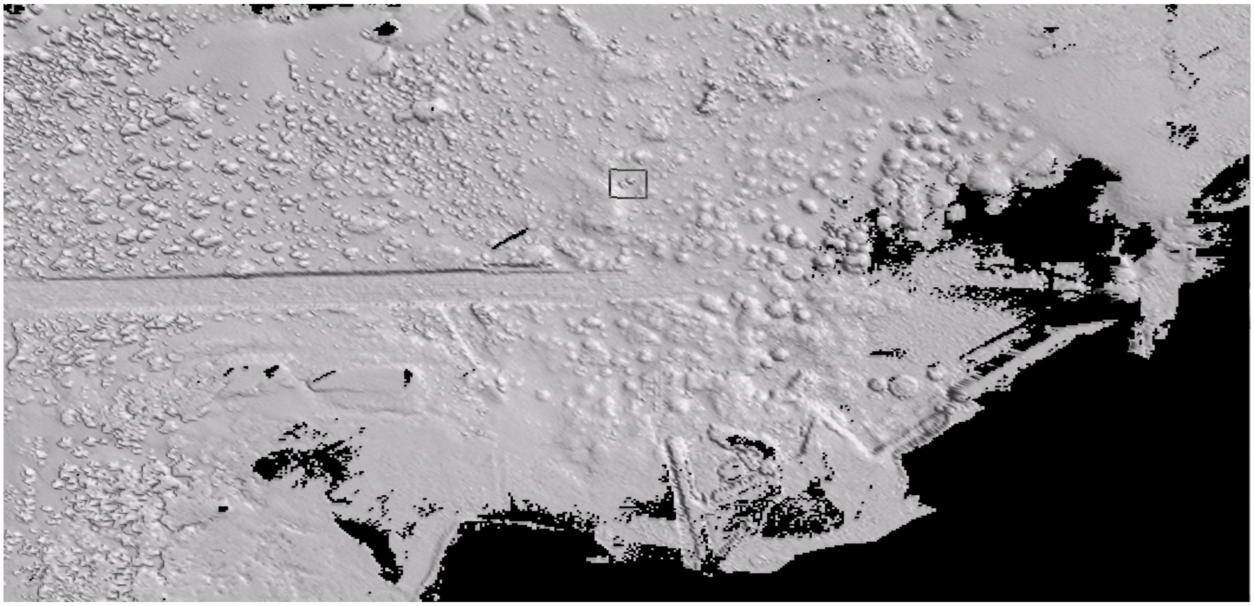
12.2.1 Two wrecks are charted just to the east of Isleta Managaha at approximately N 15 14.52' E 145 42.9'. Lidar data tends to support coral heads in this area. If the two wrecks are present, they are not evident in the data.

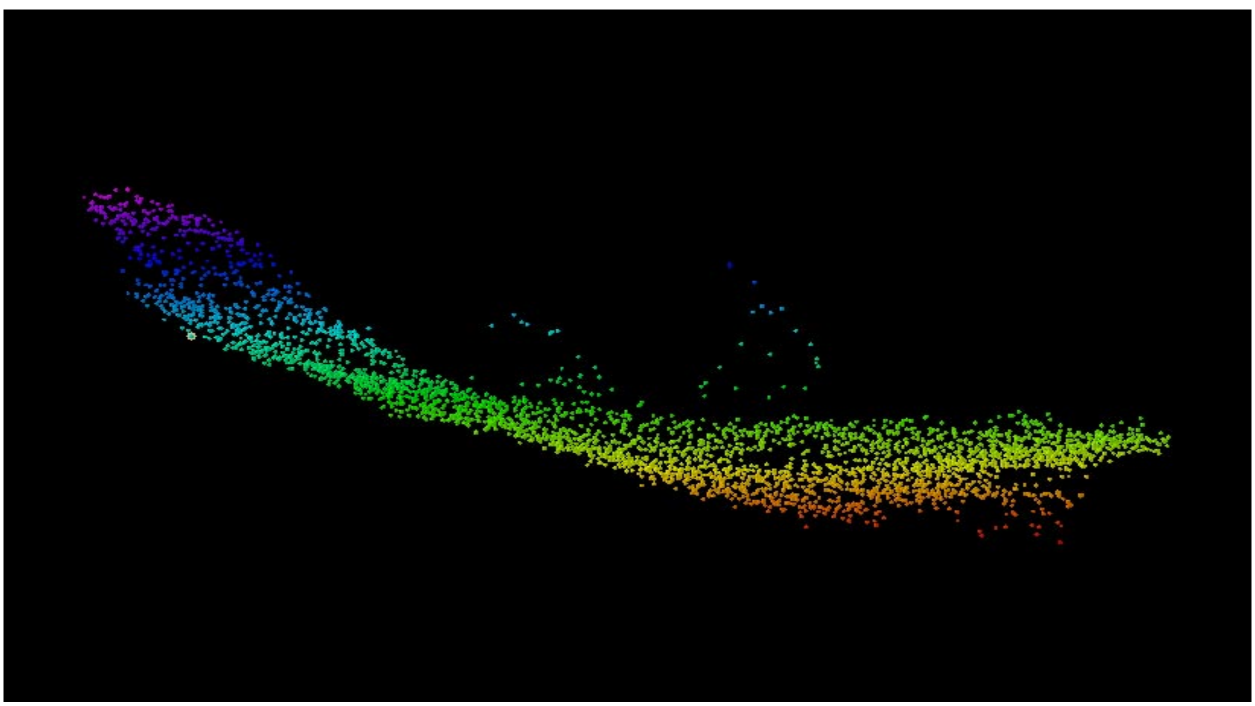




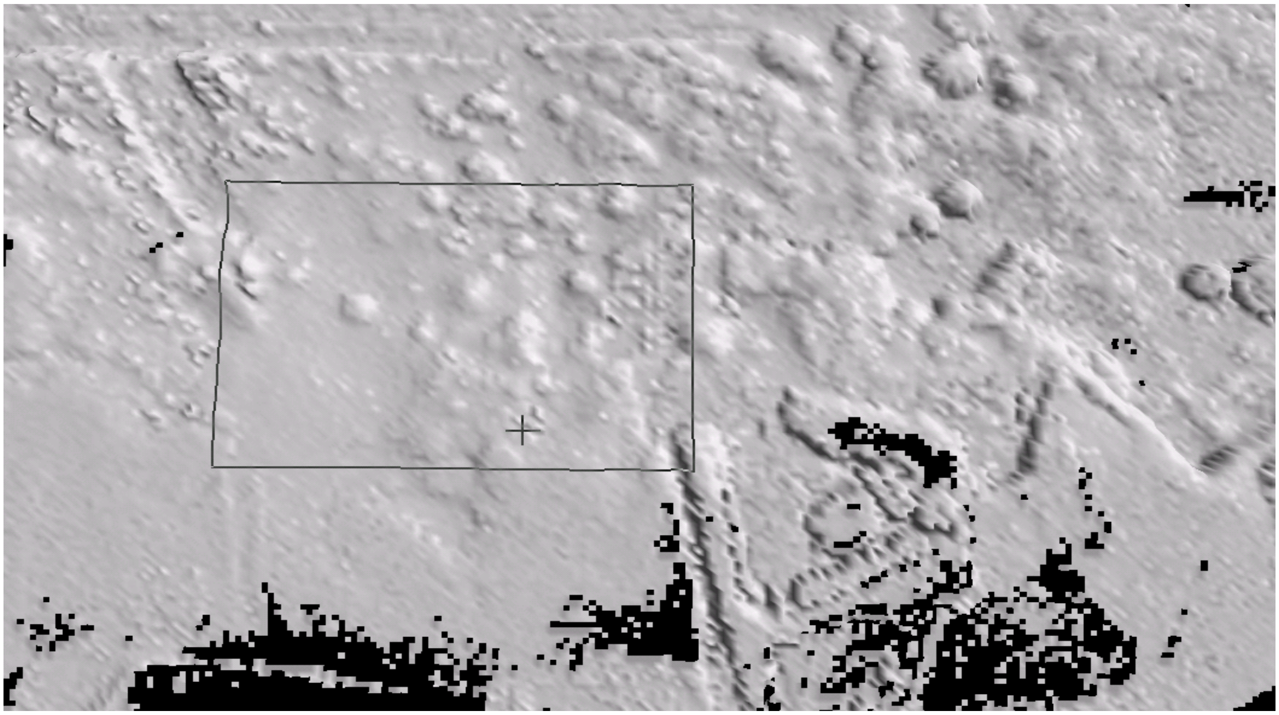


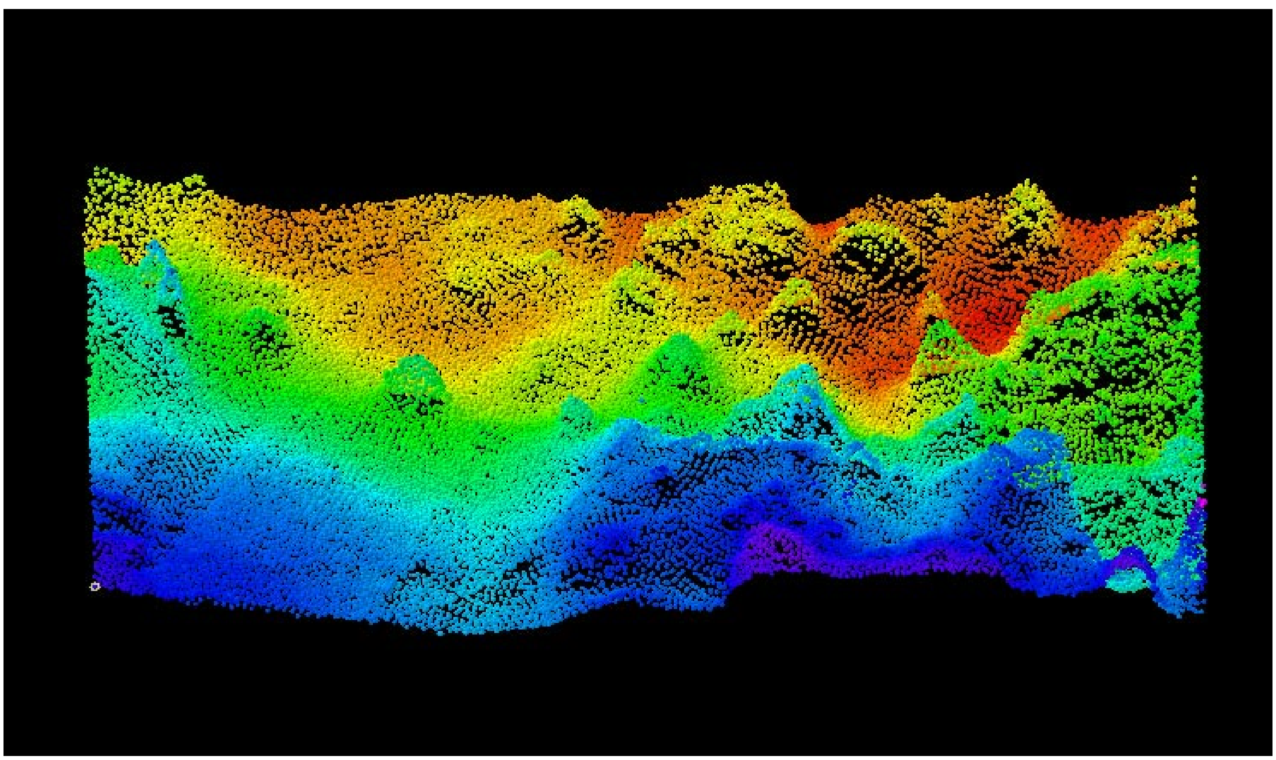
12.2.2 A charted wreck just to the north of Garapan Harbor Channel at approximately N 15 13.9653 E 145 43.3175, appears to be evident in the data with a minimum corrected Lidar depth of 5.88 meters.





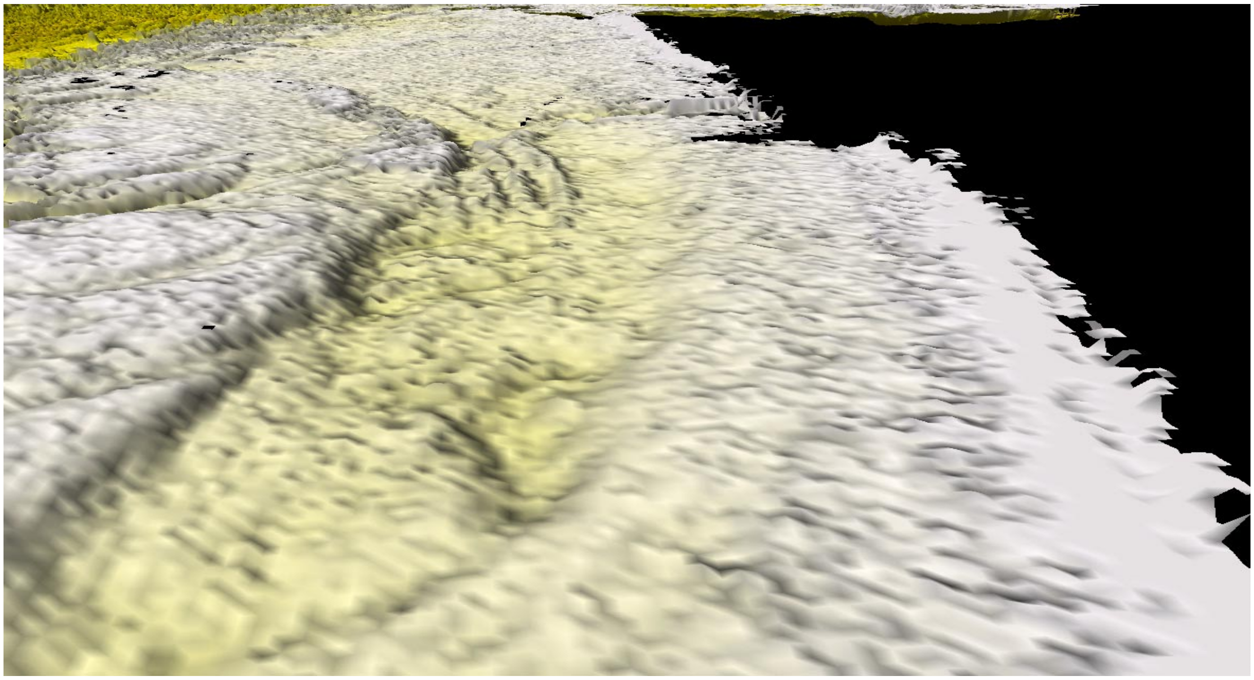
12.2.3 Eighteen charted wrecks south of Garapan Harbor channel between E 145 43’ and eastward toward the harbor are not evident in the data.

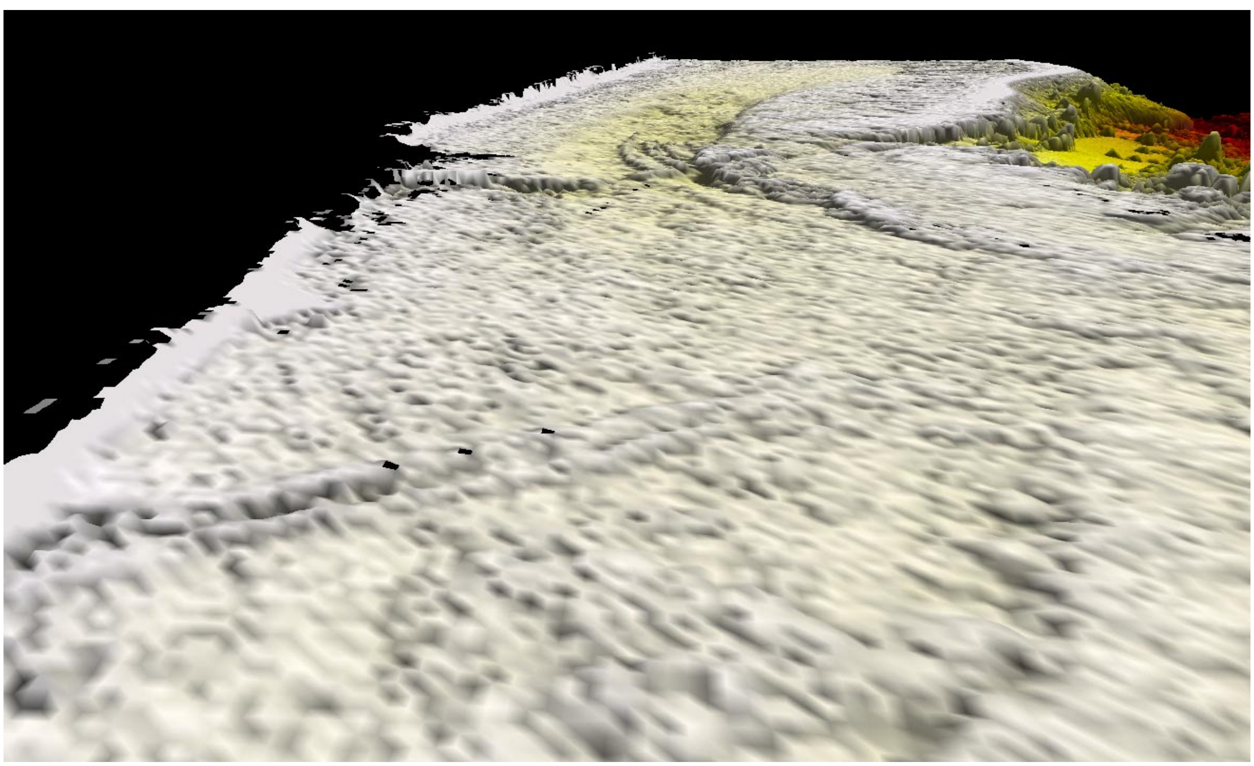


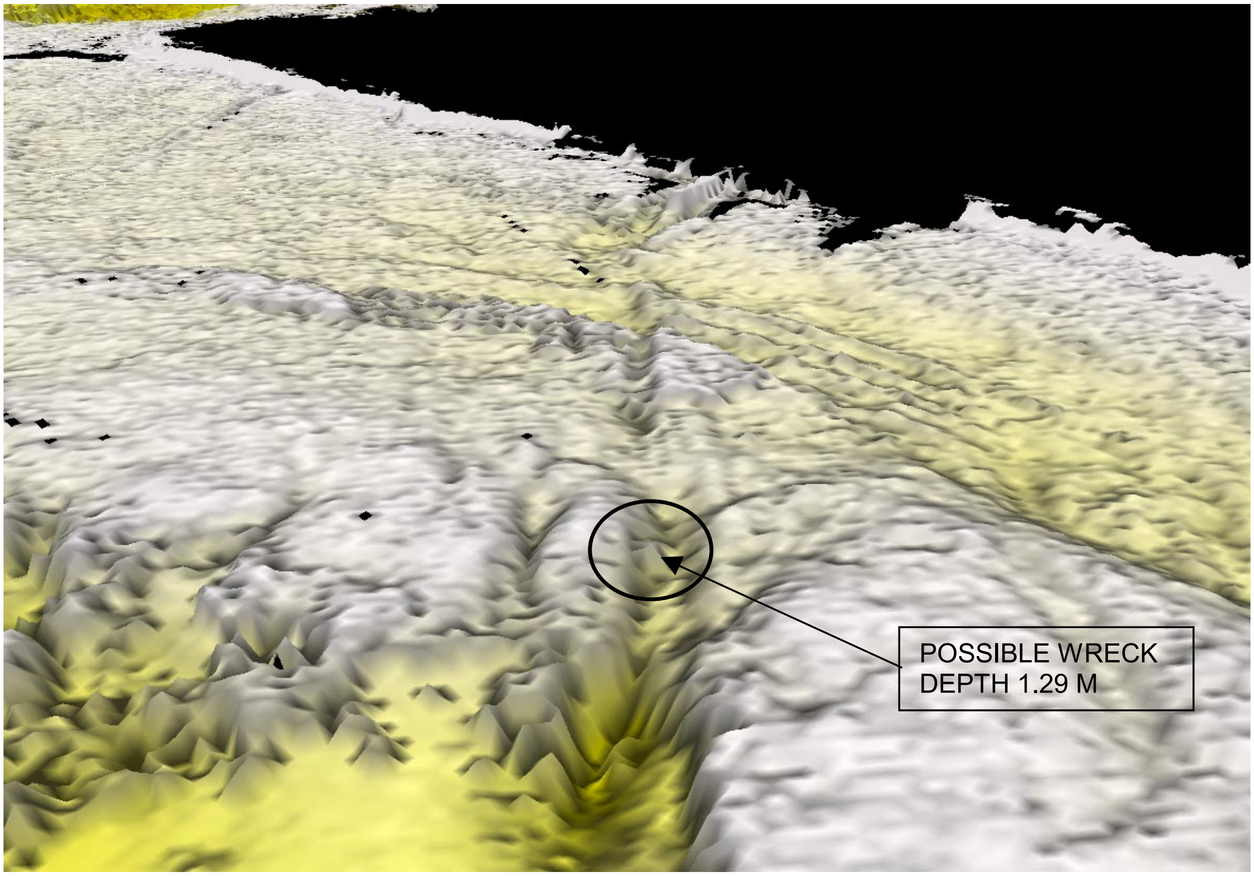


12.2.3 Two wrecks charted against a reef at N 15 13.55’ E 145 42.6’ are not evident in the data.

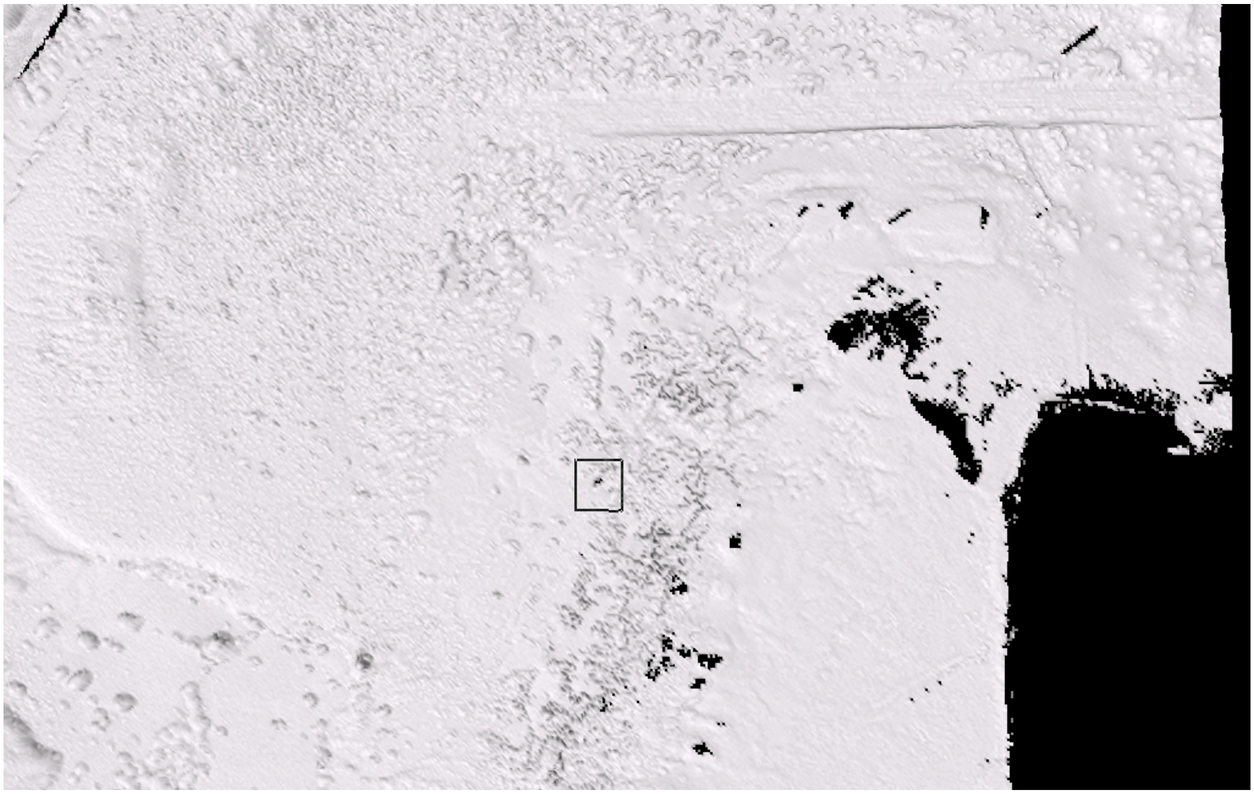
12.2.4 Twenty three wrecks are charted off the Garapan government pier and out to the reef between N 15 11.7’ and N 15 12.5’. None of these wrecks are evident in the data. However, there may still exist a wreck in the channel through the reef at N 15 11 53.72, E 145 42 32.95 with a depth of 1.29 meters

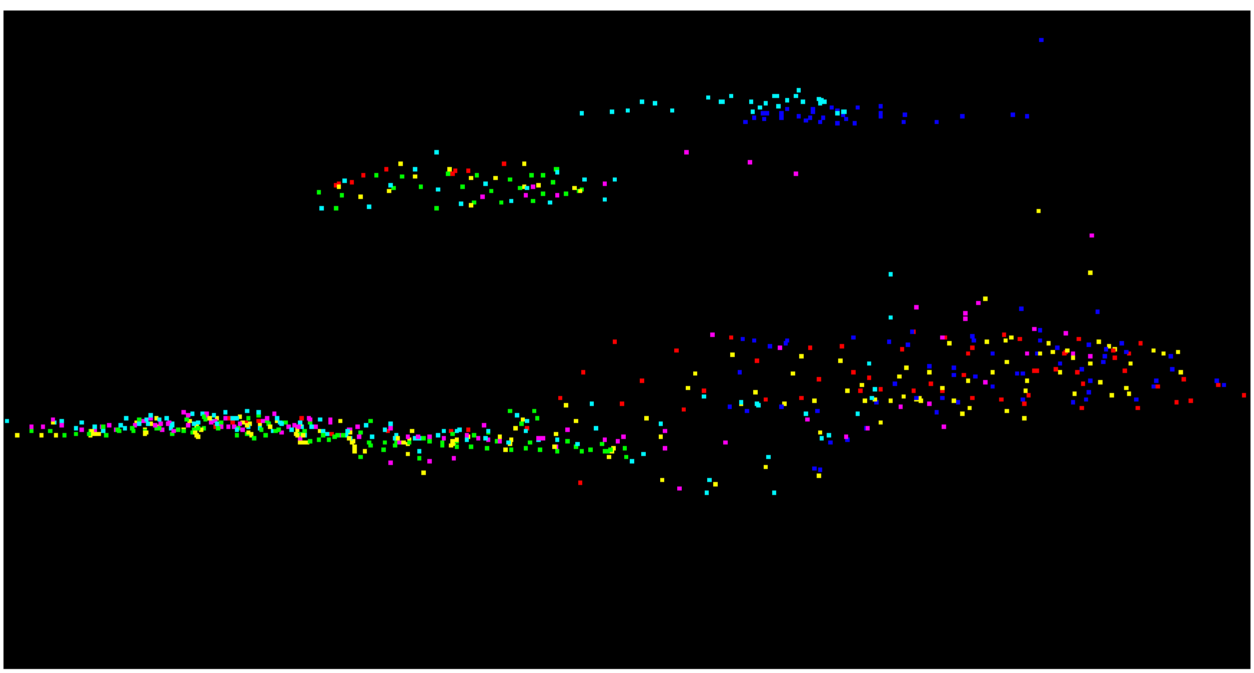





POSSIBLE WRECK
DEPTH 1.29 M

12.2.5 Charted wreck located at N 15 13’ 02.44” E 145 42’ 14.65” is visible. This wreck is approximately 100 meters long, orientated NE-SW. Much of the deck is awash and visible with breaking waves often evident. The maximum Lidar detected height of 2.4 meters above the tidal datum of MLLW is located at N 15 13’ 02.8” E 145 42’ 14.74”.





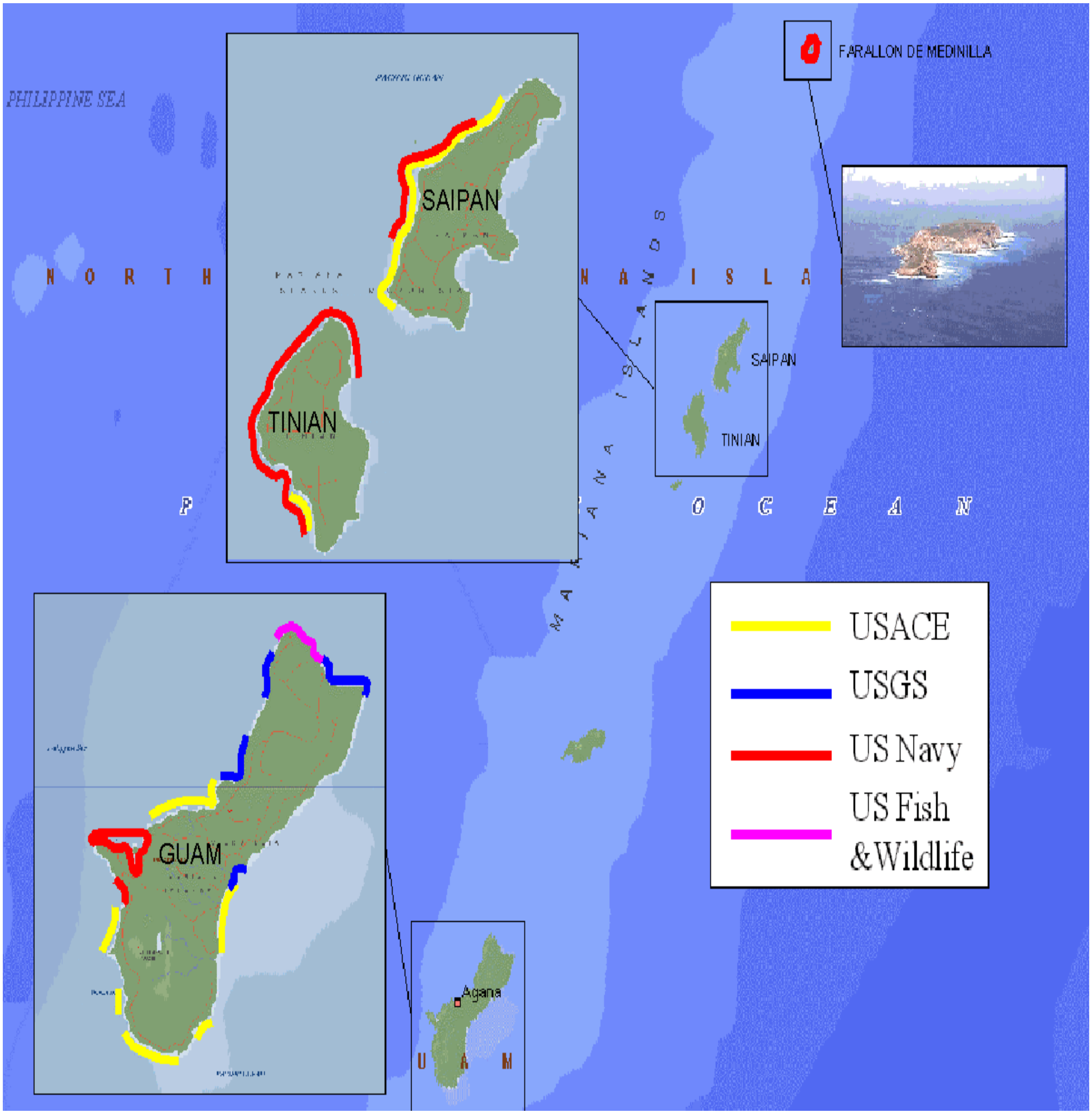
12.3 **Tinian**. Wrecks and obstructions are in reference to NOAA chart 81071, 6th ed., Apr 27/91.

12.3.1 No evidence of any wrecks or significant obstructions are evident in the Lidar data.

12.4 **Farallon de Medinilla**. No evidence of ant wrecks or obstructions are evident in the Lidar data.

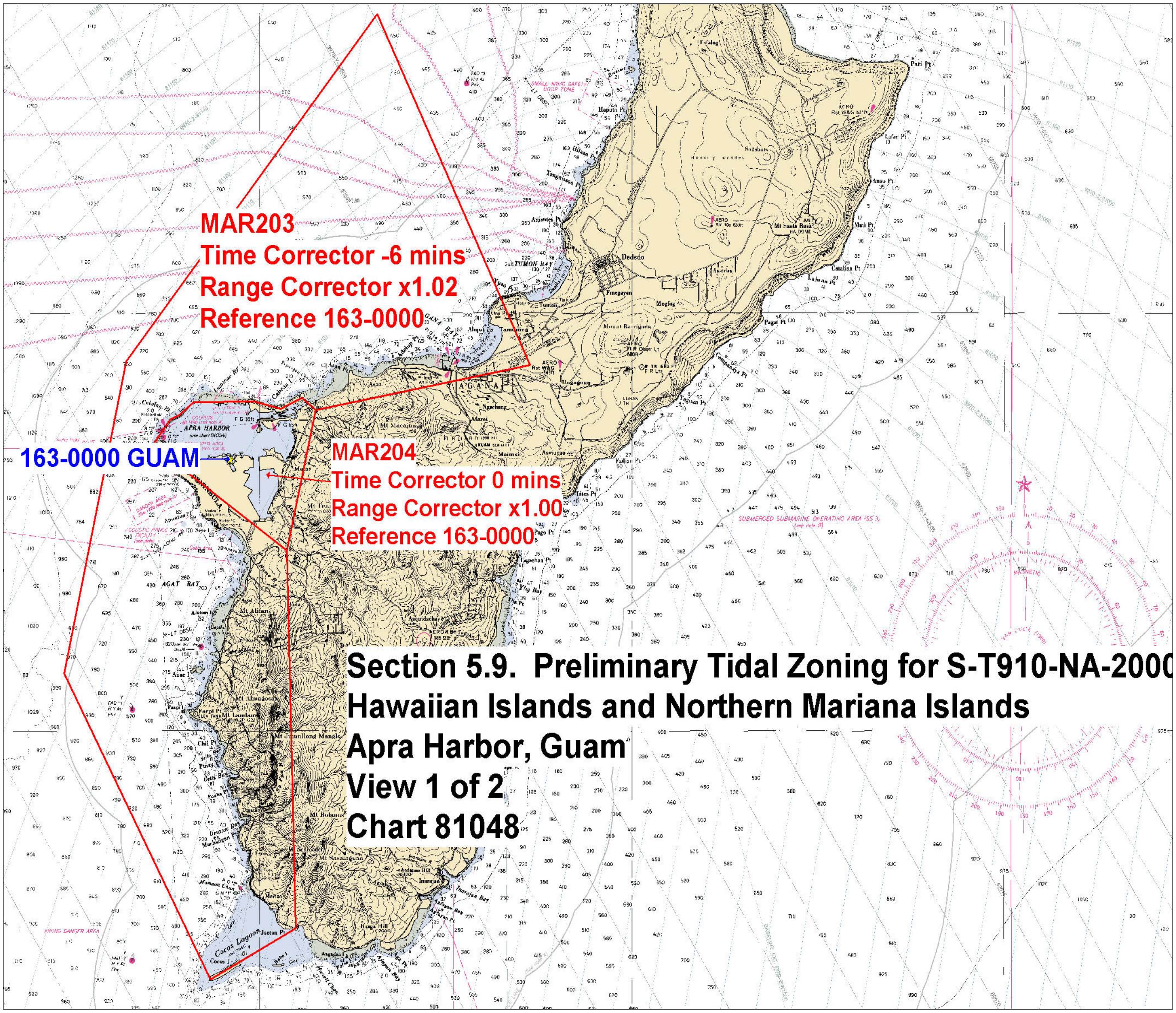
APPENDIX A

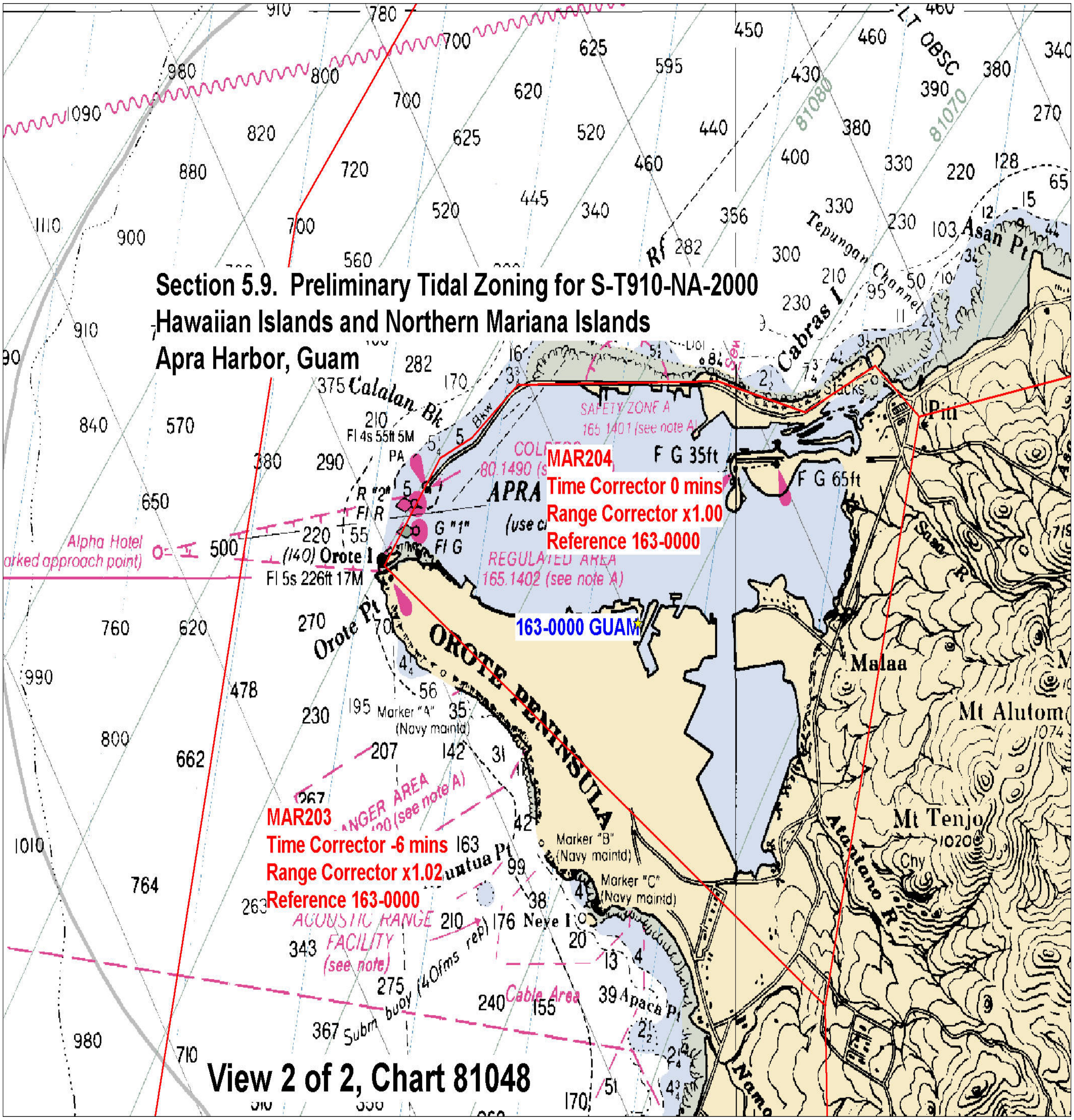
GUAM, SAIPAN, TINIAN, FDM SURVEY AREAS



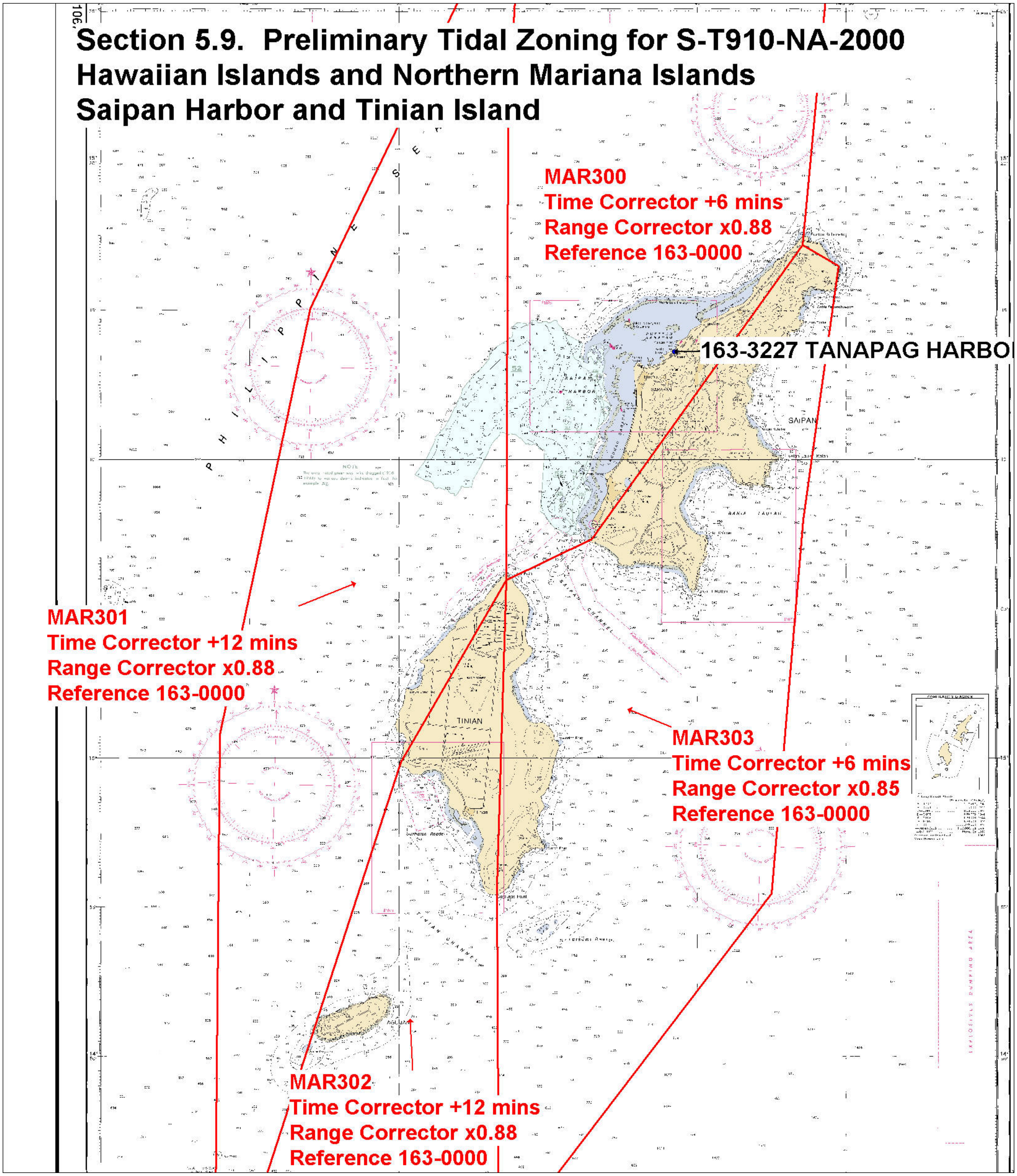
APPENXIX B

GUAM, SAIPAN, TINIAN, FDM TIDE ZONES

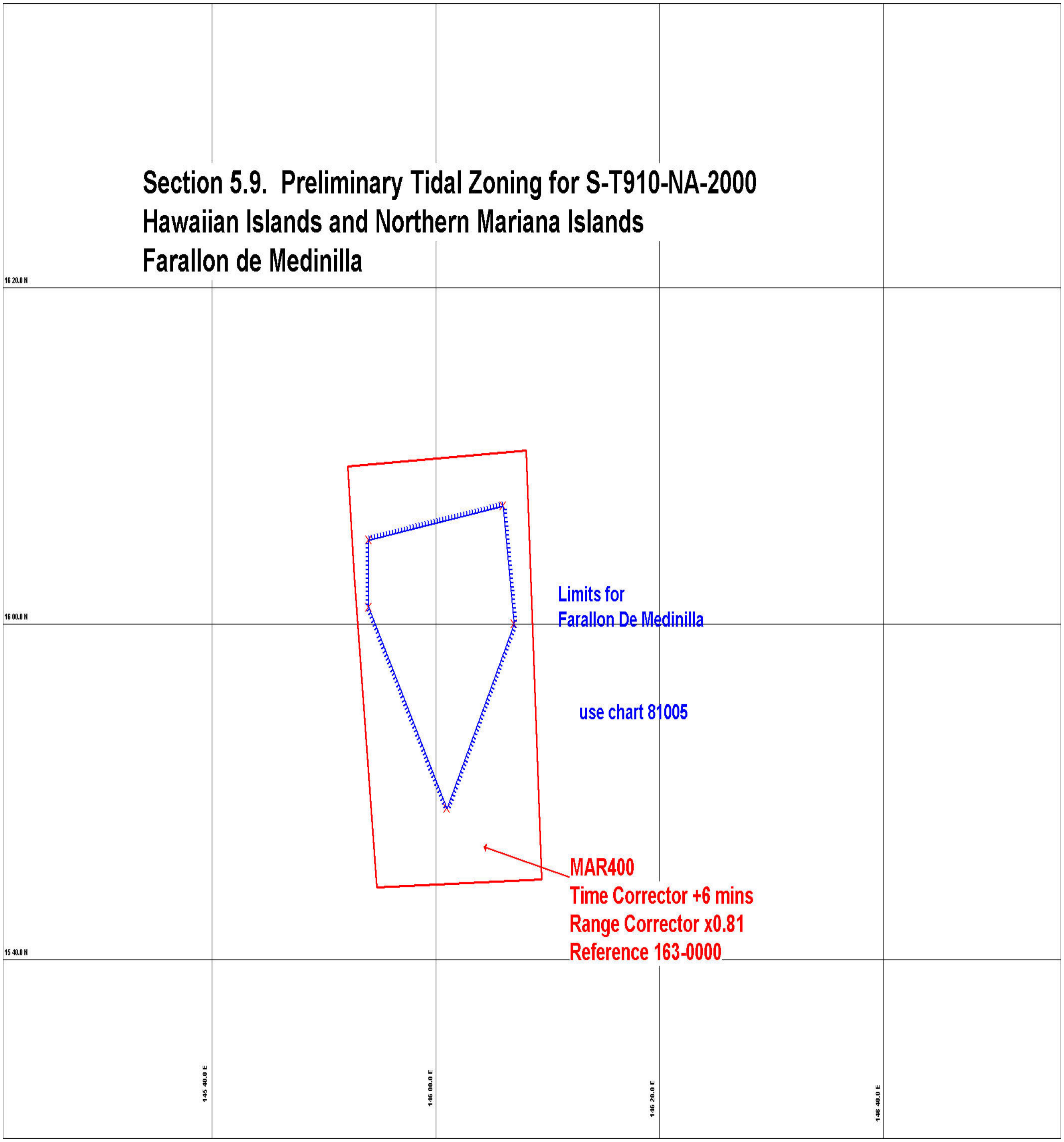



Section 5.9. Preliminary Tidal Zoning for S-T910-NA-2000
Hawaiian Islands and Northern Mariana Islands
Apra Harbor, Guam
MAR204
Time Corrector 0 mins
Range Corrector x1.00
Reference 163-0000
163-0000 GUAM
MAR203
Time Corrector -6 mins
Range Corrector x1.02
Reference 163-0000
View 2 of 2, Chart 81048

Section 5.9. Preliminary Tidal Zoning for S-T910-NA-2000
Hawaiian Islands and Northern Mariana Islands
Saipan Harbor and Tinian Island



Section 5.9. Preliminary Tidal Zoning for S-T910-NA-2000
Hawaiian Islands and Northern Mariana Islands
Farallon de Medinilla



APPENDIX C

TIDE STATIONS

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID:	1630000	PUBLICATION DATE:	08/30/2000
Name:	GUAM, APRA HARBOR 0		
NOAA Chart:	81054	Latitude:	13ø 26.5' N
USGS Quad:	APRA HARBOR	Longitude:	144ø 39.2' E

To reach the tidal bench marks, from the Guam airport travel east on Chalan Passajeros (Route 10A) for 2.9 km (1.8 mi) where it dead ends at Marine Drive (Route 1), turn left and proceed on Marine Drive for approximately 19 km (12 mi) until you reach the main gate of the Naval Station Guam. Obtain a visitor's pass and continue on Marine Drive for 2.9 km (1.8 mi) until you reach San Luis Road, turn right (east) and follow to the boat channel on your right to its entrance. The bench marks are located between Small Boat Channel and Fleet Landing Channel. The tide house is located on the east corner of the entrance to the Sunny Cove Marina boat harbor.

T I D A L   B E N C H   M A R K S

PRIMARY BENCH MARK STAMPING: NO 4 1949
DESIGNATION: 163 0000 TIDAL 4

MONUMENTATION:	Tidal Station disk	VM#:	1684
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID#:	TW0041
SETTING CLASSIFICATION:	Concrete valve box		

The primary bench mark is a disk set in the NW side of a 2 m x 4 m (6 ft x 12 ft) concrete valve box with steel plates projecting 0.15 m (0.5 ft) in the center of road between remains of Fleet Post Office Building and Fleet Landing Channel, 81 m (266 ft) south of the NE corner of the remains of the building, 24.17 m (79.3 ft) NW of the last light pole along the SE bulkhead, and 7.92 m (26.0 ft) NW of the SE bulkhead of the old Fleet Landing Channel. Note: A white square is painted around mark.

BENCH MARK STAMPING: NO 5 1949
DESIGNATION: 163 0000 TIDAL 5

MONUMENTATION:	Tidal Station disk	VM#:	1685
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID#:	TW0042
SETTING CLASSIFICATION:	Concrete bulkhead		

The bench mark is a disk set inside a 6-inch diameter iron pipe handhold at the end of Small Boat Channel, about 29 m (95 ft) west of Fleet Landing Channel bulkhead, 1.98 m (6.5 ft) SW of east corner of boat channel, and 0.21 m (0.7 ft) below level of concrete bulkhead.

Station ID: 1630000 PUBLICATION DATE: 08/30/2000
Name: GUAM, APRA HARBOR
0
NOAA Chart: 81054 Latitude: 13ø 26.5' N
USGS Quad: APRA HARBOR Longitude: 144ø 39.2' E

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: NO 6 1949
DESIGNATION: 163 0000 TIDAL 6

MONUMENTATION: Tidal Station disk VM#: 1686
AGENCY: US Coast and Geodetic Survey (USC&GS) PID#: TW0043
SETTING CLASSIFICATION: Concrete culvert headwall

The bench mark is a disk set in top of the south end of a concrete culvert headwall on the south side of San Luis Road, 95.40 m (313.0 ft) south of bench mark NO 5 1949, 82.30 m (270.0 ft) east of the centerline of Marine Drive, 12.19 m (40.0 ft) south of the centerline of San Luis Road, and 9.14 m (30.0 ft) north of telephone pole 2-H-22-6-19-2.

BENCH MARK STAMPING: NO 11 1964
DESIGNATION: 163 0000 NO 11

MONUMENTATION: Tidal Station disk VM#: 1688
AGENCY: US Coast and Geodetic Survey (USC&GS) PID#: AA4394
SETTING CLASSIFICATION: Concrete foundation

The bench mark is a disk set in concrete foundation which used to support a - now destroyed - walkway to tide house, 12.80 m (42.0 ft) south of the NE end of Pier K, 4.03 m (13.2 ft) east of SE corner of tidehouse, 0.91 m (3.0 ft) west of the steel piling bulkhead on the west side of Fleet Landing Channel, and 0.29 m (1.0 ft) SE of the SE corner of the concrete step that used to lead to the - now destroyed - walkway.

Station ID: 1630000 PUBLICATION DATE: 08/30/2000
Name: GUAM, APRA HARBOR
0
NOAA Chart: 81054 Latitude: 13ø 26.5' N
USGS Quad: APRA HARBOR Longitude: 144ø 39.2' E

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: NO 12 1974
DESIGNATION: 163 0000 NO 12

MONUMENTATION: Tidal Station disk VM#: 1689
AGENCY: National Ocean Survey (NOS) PID:
SETTING CLASSIFICATION: Concrete patio slab

The bench mark is a disk set flush in SW corner of the elevated 9 m x 6 m (28 ft x 21 ft) concrete patio supporting a yellow flammable storage house of the U.S. Naval Sea Cadets Headquarters, 57 m (187 ft) west of the west side of the Fleet Landing Channel, 18.75 m (61.5 ft) east of the east side of the small boat channel, and 7.32 m (24.0 ft) south of a flagpole.

BENCH MARK STAMPING: TIDAL BM 13 1975
DESIGNATION: 163 0000 TIDAL BM 13

MONUMENTATION: Tidal Station disk VM#: 1690
AGENCY: National Ocean Survey (NOS) PID:
SETTING CLASSIFICATION: Concrete apron slab

The bench mark is a disk set in the concrete apron fronting the double door entrance to the Communication Security Material Issuing office, 70 m (230 ft) NW of the centerline of the intersection of San Luis Road and Marine Drive, 42 m (139 ft) west of a fire hydrant, 7 m (24 ft) north of the south wall of the office, and 0.85 m (2.8 ft) east of the office.

Station ID: 1630000 PUBLICATION DATE: 08/30/2000
Name: GUAM, APRA HARBOR
0
NOAA Chart: 81054 Latitude: 13ø 26.5' N
USGS Quad: APRA HARBOR Longitude: 144ø 39.2' E

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: 0000 K TIDAL BM 1978
DESIGNATION: 163 0000 TIDAL BM K

MONUMENTATION: Tidal Station disk VM#: 1691
AGENCY: National Ocean Survey (NOS) PID:
SETTING CLASSIFICATION: Concrete base of a flagpole

The bench mark is a disk set in the NW corner of the concrete base of a flagpole at the Sumay Cove Marina, 61 m (200 ft) east of bench mark NO 6 1949, 19.96 m (65.5 ft) east of the SE corner of the Marina Building (#1985), 14.02 m (46.0 ft) east of east edge of a 6 m x 18 m (20 ft x 60 ft) old concrete foundation used for drydocking small boats, 6.10 m (20.0 ft) west of the eastern-most edge of a wooden plank deck along west side of Sunny Cove, and 3.05 m (10.0 ft) south of a small concrete floored picnic shelter.

BENCH MARK STAMPING: USN BM 1
DESIGNATION: 163 0000 USN BM 1
ALIAS: 14

MONUMENTATION: Bench Mark disk VM#: 1692
AGENCY: U.S. Department of Defense (DOD) PID:
SETTING CLASSIFICATION: Concrete bulkhead

The bench mark is a disk set inside a 6-inch diameter iron pipe handhold at end of Small Boat Channel, 38.10 m (125.0 ft) west of the Fleet Landing Channel bulkhead, 11.77 m (38.6 ft) SW of the inside east corner of the Small Boat Channel, 10.00 m (32.8 ft) SW of bench mark NO 5 1949, and 0.21 m (0.7 ft) below the level of concrete bulkhead.

Station ID: 1630000 PUBLICATION DATE: 08/30/2000
Name: GUAM, APRA HARBOR
0
NOAA Chart: 81054 Latitude: 13ø 26.5' N
USGS Quad: APRA HARBOR Longitude: 144ø 39.2' E

T I D A L B E N C H M A R K S

BENCH MARK STAMPING:
DESIGNATION: 163 0000 TIDAL 7
ALIAS: TIDAL 7 PIE

MONUMENTATION: Bolt VM#: 1693
AGENCY: Unknown PID#: TW0044
SETTING CLASSIFICATION: Concrete culvert headwall

The bench mark is a bolt set flush in the north end of a concrete culvert headwall at the SW corner of the intersection of Marine Drive and San Luis Road, 21.34 m (70.0 ft) south of the centerline of San Luis Road, 10.97 m (36.0 ft) west of the centerline of Marine Drive, and about 4 m (12 ft) north of a protruding concrete post labeled "Buried Cable".

BENCH MARK STAMPING: 0000 N 1994
DESIGNATION: 163 0000 N

MONUMENTATION: Tidal Station disk VM#: 12702
AGENCY: National Ocean Service (NOS) PID:
SETTING CLASSIFICATION: Concrete slab

The bench mark is a disk set flush in the SE corner of a 5 m x 8 m x 1 m (16 ft x 26 ft x 3 ft) utility access pad, 0.2 km (0.1 mi) west of the intersection of Marine Drive and San Luis Road, 30 m (98 ft) east of the Trans-Pacific Cable Station sign, 14.50 m (47.6 ft) SE of a 2.5 m x 2 m x 1 m (8 ft x 7 ft x 3 ft) concrete bunker, 11.75 m (38.5 ft) SW of utility pole "JB-61-9", 10.85 m (35.6 ft) north of the centerline of San Luis, and 1.24 m (4.1 ft) above the natural grade of the hill.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 1630000 PUBLICATION DATE: 08/30/2000
Name: GUAM, APRA HARBOR
0
NOAA Chart: 81054 Latitude: 13ø 26.5' N
USGS Quad: APRA HARBOR Longitude: 144ø 39.2' E

T I D A L   D A T U M S

Tidal datums at GUAM, APRA HARBOR based on:

LENGTH OF SERIES:	19 YEARS
TIME PERIOD:	January 1960 - December 1978
TIDAL EPOCH:	1960-1978
CONTROL TIDE STATION:	

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (08/28/1992)	= 1.338
MEAN HIGHER HIGH WATER (MHHW)	= 0.732
MEAN HIGH WATER (MHW)	= 0.695
MEAN TIDE LEVEL (MTL)	= 0.442
MEAN SEA LEVEL (MSL)	= 0.430
MEAN LOW WATER (MLW)	= 0.186
MEAN LOWER LOW WATER (MLLW)	= 0.000
LOWEST OBSERVED WATER LEVEL (12/21/1968)	= -0.683

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
NO 4 1949	2.618	1.923
NO 5 1949	1.032	0.337
NO 6 1949	1.987	1.292
NO 11 1964	2.447	1.752
NO 12 1974	2.641	1.946
TIDAL BM 13 1975	3.295	2.600
0000 K TIDAL BM 1978	2.156	1.461
USN BM 1	0.988	0.293
163 0000 TIDAL 7	2.715	2.020
0000 N 1994	13.369	12.674

Station ID: 1630000 PUBLICATION DATE: 08/30/2000
Name: GUAM, APRA HARBOR
0
NOAA Chart: 81054 Latitude: 13ø 26.5' N
USGS Quad: APRA HARBOR Longitude: 144ø 39.2' E

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned.
Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

Station ID: 1633227 PUBLICATION DATE: 04/09/2001
Name: TANAPAG HBR, SAIPAN, N MARIANAS ISLAND 0
NOAA Chart: 81067 Latitude: 15ø 13.6' N
USGS Quad: ISLAND OF SAIPAN Longitude: 145ø 44.2' E

To reach tidal bench marks from Saipan International Airport, proceed north 3.4 km (2.1 mi) along an unnamed road. As the road terminates, turn left (west) onto Cross Island Road (Note: there are no road signs in Saipan). Turn right (north) on Middle Road (first large intersection with traffic light) and proceed for 8 km (5 mi). Turn left (west) immediately after the WESTPAC building (located on the west side of Middle Road). The unnamed road will bend to the south, turn right (west) just past the Port of Saipan Building (two story concrete building painted beige). Proceed through the parking toll booth and turn right toward the NNE side of the port facility. The bench marks were located on the Port of Saipan facility. The tide gauge was located where east parking lot meets with the east face of Delta Dock.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING:
DESIGNATION: 163 3227 UH-2C

MONUMENTATION: Bolt VM#: 16316
AGENCY: University of Hawaii (UH) PID:
SETTING CLASSIFICATION: Concrete deck

The primary bench mark is a 9/16" SS hex head bolt set in the concrete deck where the east face of Delta Dock (Delta -3) meets the east face of the parking lot (CPA-2) fronting the port building, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), 2.83 m (9.3 ft) SSE of the SE corner of a diesel containment wall, 2.56 m (8.4 ft) NNE of utility pole #7, and 1.13 m (3.7 ft) west of the east pier face (CPA-2).

BENCH MARK STAMPING:
DESIGNATION: 163 3227 CPA-1

MONUMENTATION: Bench Mark disk VM#: 16317
AGENCY: U.S. Geological Survey (USGS) PID:
SETTING CLASSIFICATION: Concrete deck

The bench mark is a disk set flush in the concrete deck in the extreme NW corner of the port, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), 70.01 m (229.7 ft) north of the south end of Able Dock, 0.58 m (1.9 ft) south from the north edge of Baker Dock, and 0.55 m (1.8 ft) east of the west edge of Able Dock.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 1633227 PUBLICATION DATE: 04/09/2001
Name: TANAPAG HBR, SAIPAN, N MARIANAS ISLAND
0
NOAA Chart: 81067 Latitude: 15ø 13.6' N
USGS Quad: ISLAND OF SAIPAN Longitude: 145ø 44.2' E

T I D A L B E N C H M A R K S

BENCH MARK STAMPING:
DESIGNATION: 163 3227 CPA-2

MONUMENTATION: Bench Mark disk VM#: 16318
AGENCY: U.S. Geological Survey (USGS) PID:
SETTING CLASSIFICATION: Concrete bullrail

The bench mark is a disk set flush in the concrete bull rail in the extreme WSW corner of the port, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), 70.01 m (229.7 ft) south of the north edge of Baker Dock, 1.60 m (5.2 ft) east of the west end of bull rail, 0.19 m (0.6 ft) north of the south end of bull rail, and 0.33 m (1.1 ft) above the pier deck.

BENCH MARK STAMPING:
DESIGNATION: 163 3227 UH-1

MONUMENTATION: Bolt VM#: 16319
AGENCY: University of Hawaii (UH) PID:
SETTING CLASSIFICATION: Concrete deck

The bench mark is a disk embedded in the NE corner of Delta Dock, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), 18.71 m (61.4 ft) east of the NW corner Delta Dock, 0.47 m (1.5 ft) west of the east pier face (Delta-3) of Delta Dock, and 0.42 m (1.4 ft) south of the north pier face (Delta-2) of Delta Dock.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 1633227 PUBLICATION DATE: 04/09/2001
Name: TANAPAG HBR, SAIPAN, N MARIANAS ISLAND
0
NOAA Chart: 81067 Latitude: 15ø 13.6' N
USGS Quad: ISLAND OF SAIPAN Longitude: 145ø 44.2' E

T I D A L B E N C H M A R K S

BENCH MARK STAMPING:
DESIGNATION: 163 3227 UH-3B

MONUMENTATION: Bolt VM#: 16320
AGENCY: University of Hawaii (UH) PID:
SETTING CLASSIFICATION: Concrete deck

The bench mark is a 1/4" SS square headed pin marker set in the concrete deck, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), below the Mobile Gas sign, near the SW corner of Delta Deck, where the west face of Delta Dock (Delta-1) meets the north face of the parking lot (CPA-1) fronting the port building.

BENCH MARK STAMPING:
DESIGNATION: 163 3227 UH-4B

MONUMENTATION:	Bolt	VM#:	16321
AGENCY:	University of Hawaii (UH)	PID:	
SETTING CLASSIFICATION:	Concrete foundation for flagpole		

The bench mark is a 9/16" SS hex head bolt set in the flag pole base north of the port building, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), 46.53 m (152.7 ft) west of the east pier face (CPA-2), 42.21 m (138.5 ft) south of the north pier face (CPA-1), and 0.67 m (2.2 ft) north of the center flag pole.

Station ID:	1633227	PUBLICATION DATE:	04/09/2001
Name:	TANAPAG HBR, SAIPAN, N MARIANAS ISLAND 0		
NOAA Chart:	81067	Latitude:	15ø 13.6' N
USGS Quad:	ISLAND OF SAIPAN	Longitude:	145ø 44.2' E

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING:
DESIGNATION: 163 3227 UH-5B

MONUMENTATION:	Bolt	VM#:	16322
AGENCY:	University of Hawaii (UH)	PID:	
SETTING CLASSIFICATION:	Concrete deck		

The bench mark is a 1-1/4" SS square headed pin marker set in the concrete deck near the SE corner of Charlie Dock where the east face of Charlie Dock (Charlie-2) meets the north face of the parking lot (CPA-1) fronting the port building, located at the Commonwealth Port Authority (CPA) facility in Saipan Harbor (aka Tanapag Harbor), 20.56 m (67.5 ft) south of the SE most large bollard on Charlie dock, 5.35 m (17.6 ft) north of Charlie-2 and CPA-1 corner, and 0.19 m (0.6 ft) west of the east face (Charlie-2) of Charlie Dock.

Station ID:	1633227	PUBLICATION DATE:	04/09/2001
Name:	TANAPAG HBR, SAIPAN, N MARIANAS ISLAND 0		
NOAA Chart:	81067	Latitude:	15ø 13.6' N
USGS Quad:	ISLAND OF SAIPAN	Longitude:	145ø 44.2' E

T I D A L   D A T U M S

Tidal datums at TANAPAG HBR, SAIPAN, N MARIANAS ISLAND based on:

LENGTH OF SERIES:	5 MONTHS
TIME PERIOD:	October 2000 - February 2001
TIDAL EPOCH:	1960-1978
CONTROL TIDE STATION:	1630000 GUAM, APRA HARBOR

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER (MHHW)	=	0.683
MEAN HIGH WATER (MHW)	=	0.644
MEAN TIDE LEVEL (MTL)	=	0.414
MEAN SEA LEVEL (MSL)	=	0.400
MEAN LOW WATER (MLW)	=	0.184
MEAN LOWER LOW WATER (MLLW)	=	0.000

Bench Mark Elevation Information   In METERS above:

Stamping or Designation	MLLW	MHW
163 3227 UH-2C	2.075	1.431
163 3227 CPA-1	2.373	1.729
163 3227 CPA-2	2.621	1.977
163 3227 UH-1	2.122	1.478
163 3227 UH-3B	2.010	1.366
163 3227 UH-4B	2.390	1.746
163 3227 UH-5B	1.854	1.210

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID:	1633227	PUBLICATION DATE:	04/09/2001
Name:	TANAPAG HBR, SAIPAN, N MARIANAS ISLAND 0		
NOAA Chart:	81067	Latitude:	15ø 13.6' N
USGS Quad:	ISLAND OF SAIPAN	Longitude:	145ø 44.2' E

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at
National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at National Geodetic Survey.

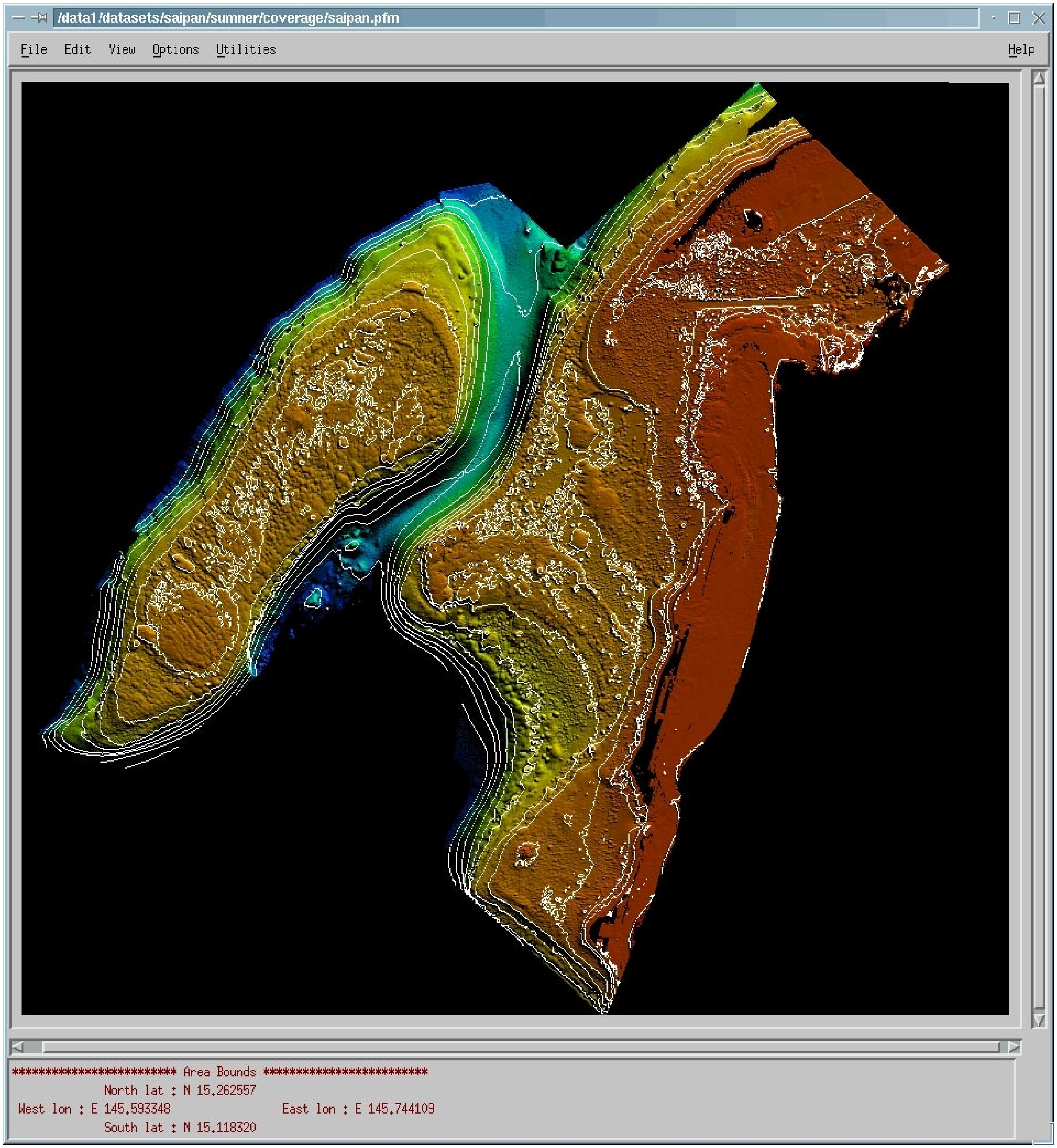
NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned.
Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

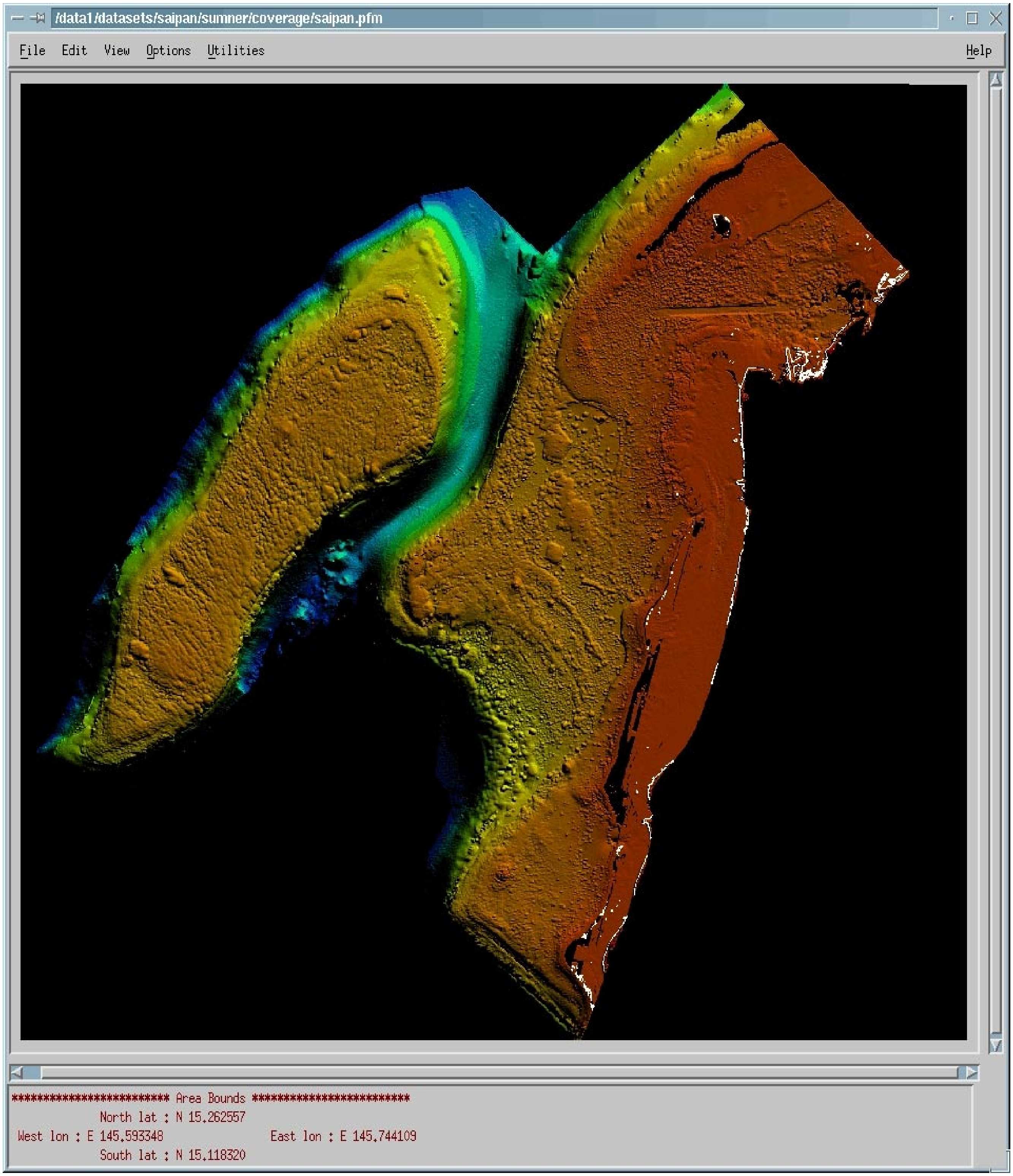
The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

APPENDIX D

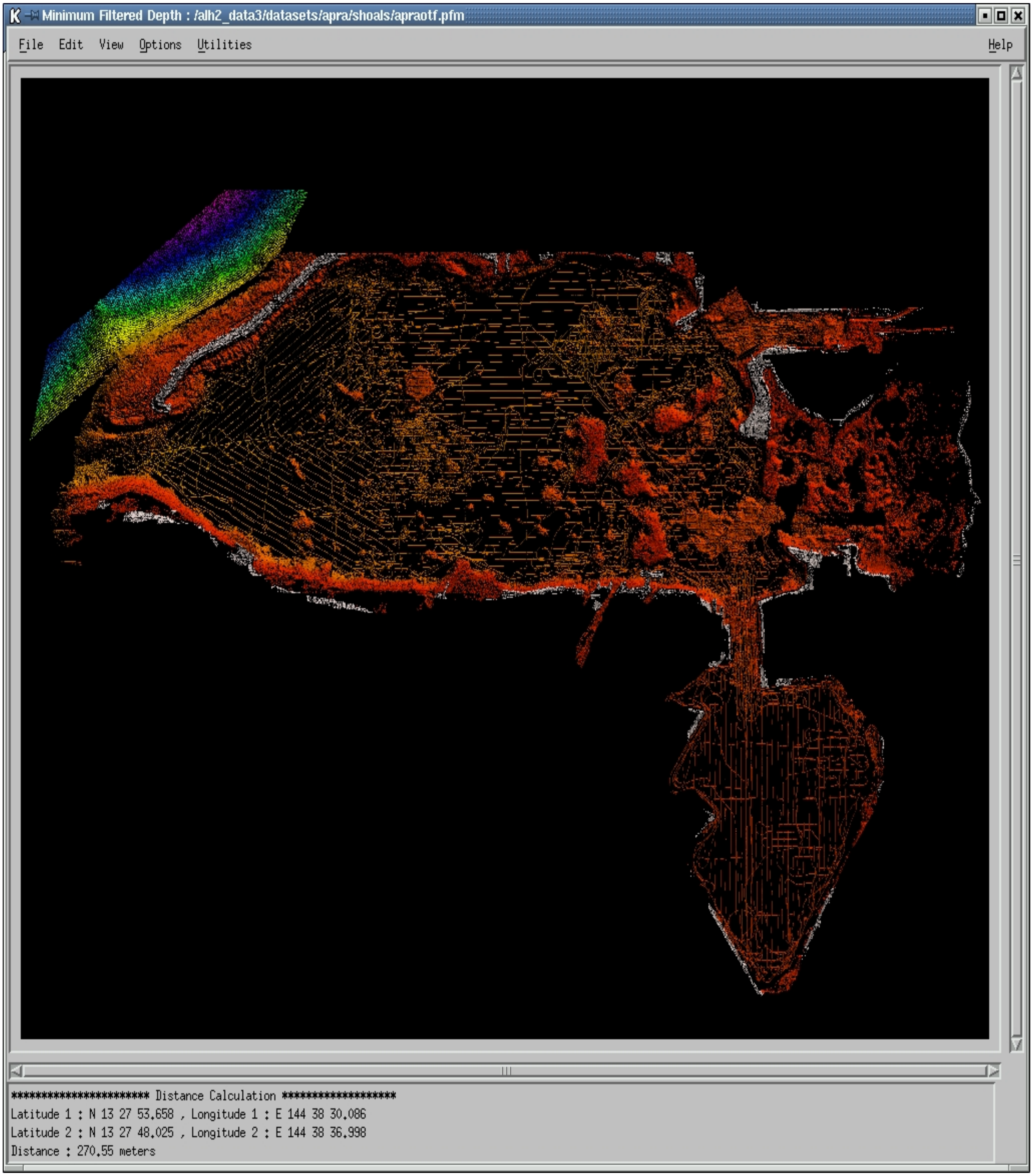
COVERAGE



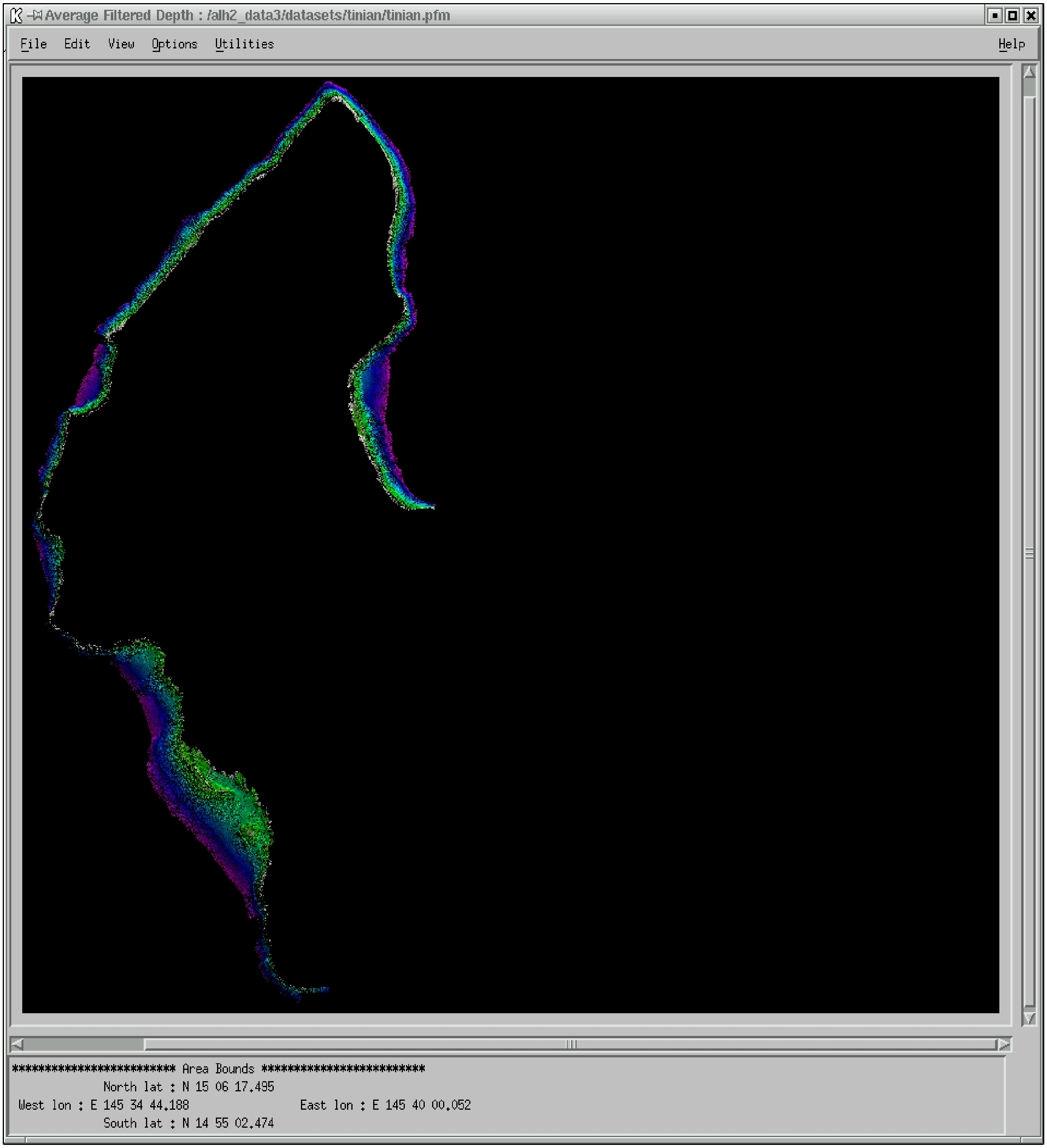
SAIPAN


/data1/datasets/saipan/sumner/coverage/saipan.pfm
File Edit View Options Utilities
Help
************************** Area Bounds **************************
North lat : N 15.262557
West lon : E 145.593348
East lon : E 145.744109
South lat : N 15.118320

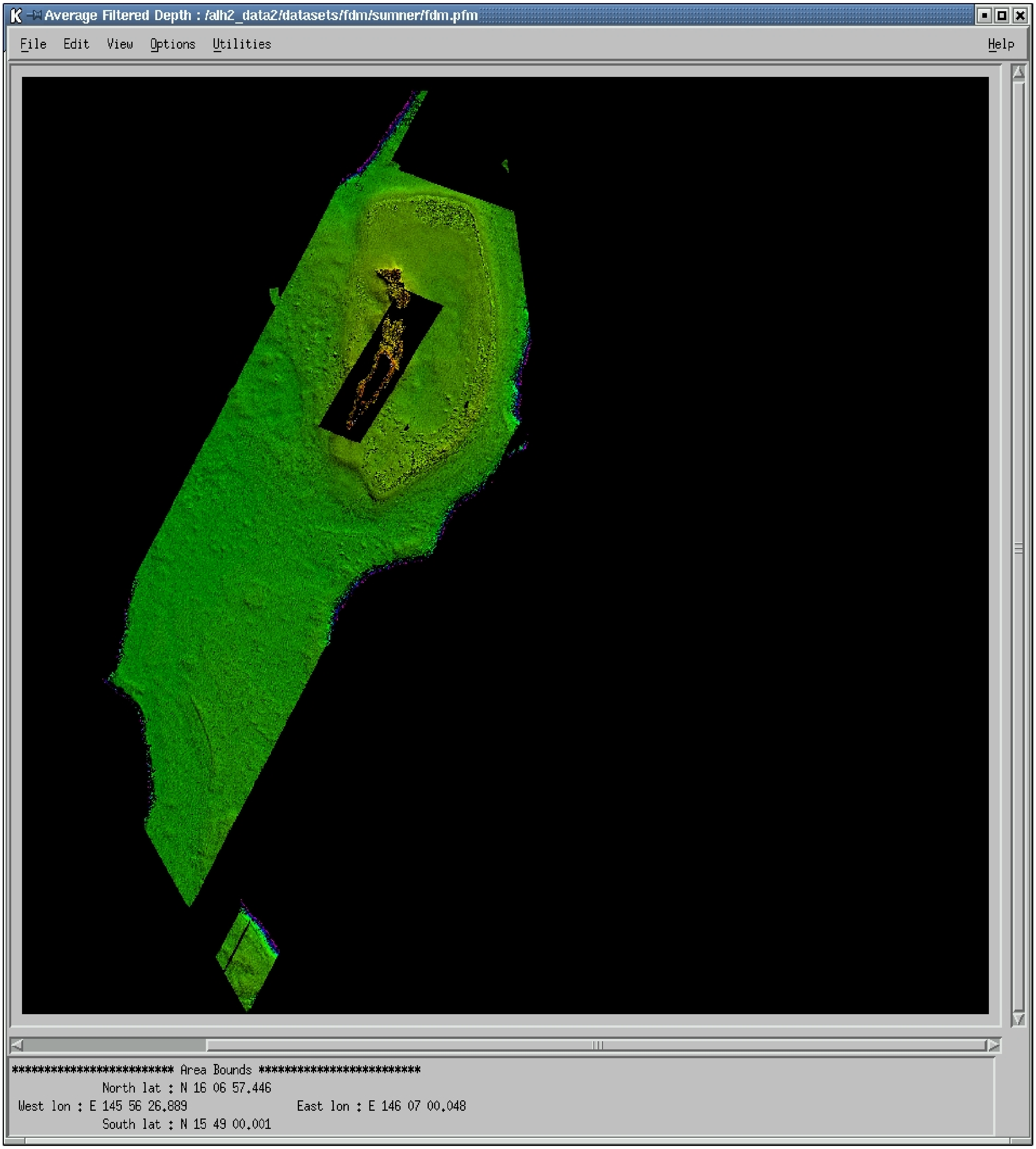
SAIPAN


Minimum Filtered Depth : /alh2_data3/datasets/apra/shoals/apraotf.pfm
File Edit View Options Utilities
Help
*********************** Distance Calculation *******************
Latitude 1 : N 13 27 53.658 , Longitude 1 : E 144 38 30.086
Latitude 2 : N 13 27 48.025 , Longitude 2 : E 144 38 36.998
Distance : 270.55 meters

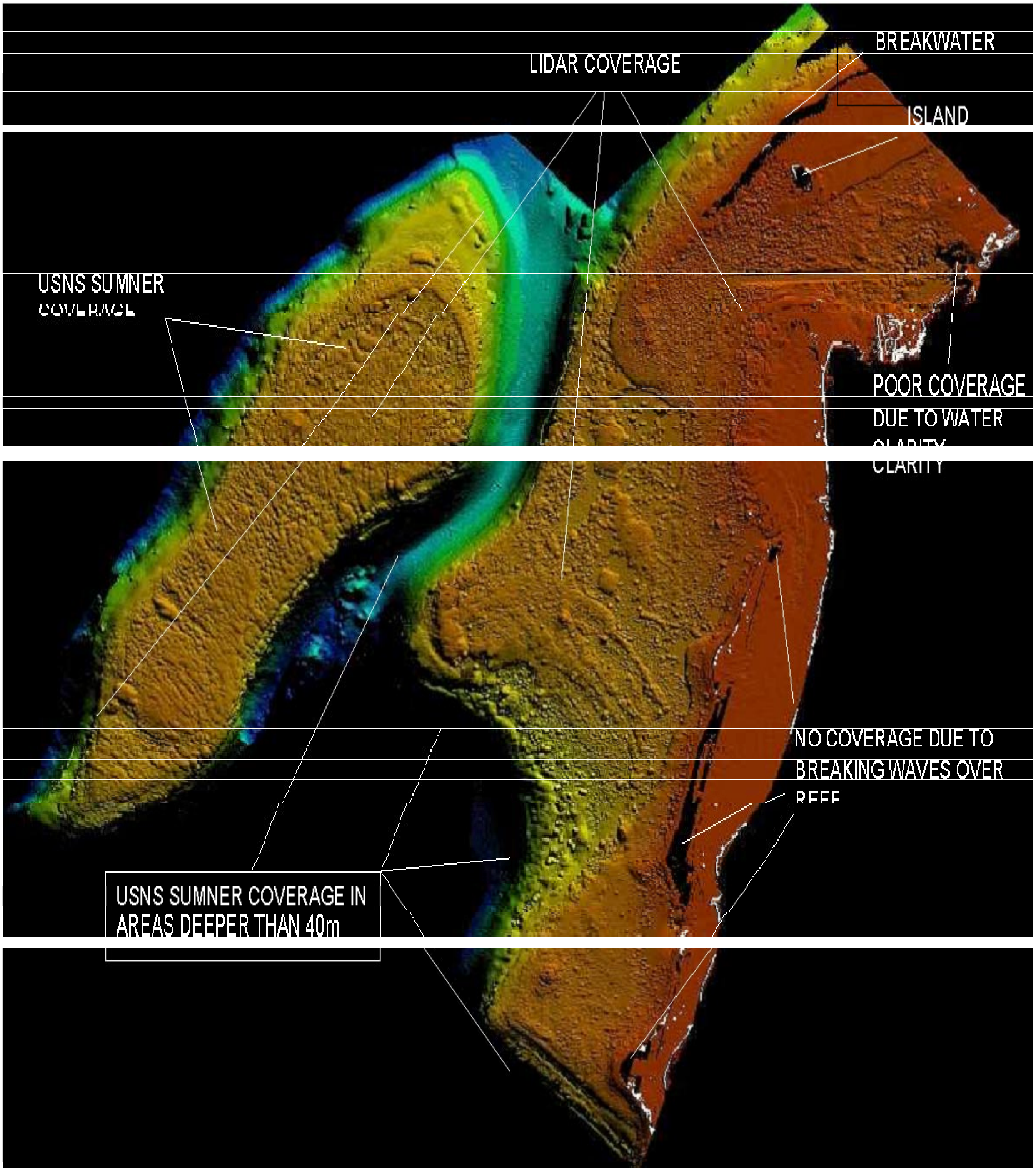
APRA HARBOR

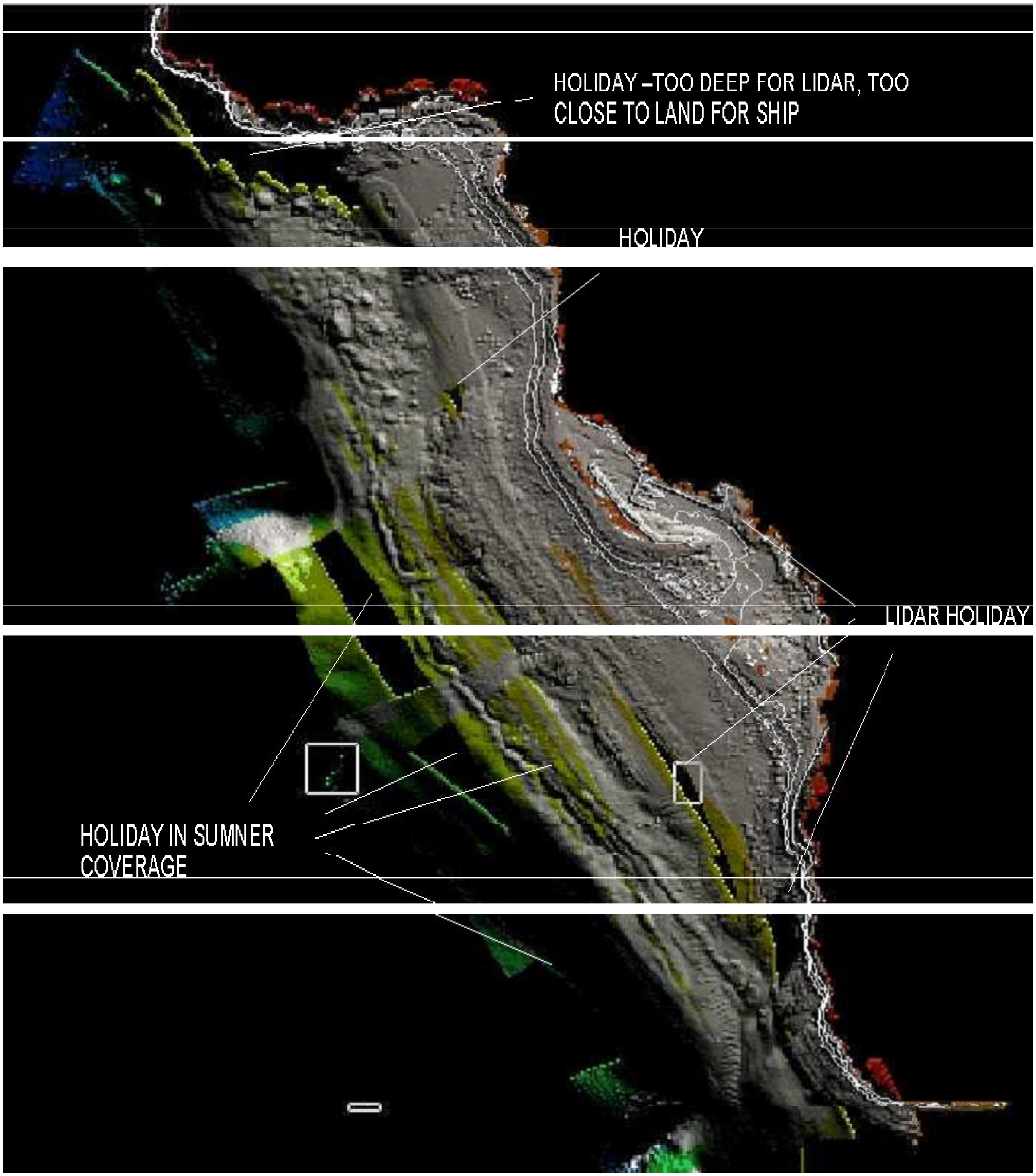

Average Filtered Depth : /alh2_data3/datasets/tinian/tinian.pfm
File Edit View Options Utilities
Help
************************ Area Bounds ************************
North lat : N 15 06 17.495
West lon : E 145 34 44.188
East lon : E 145 40 00.052
South lat : N 14 55 02.474

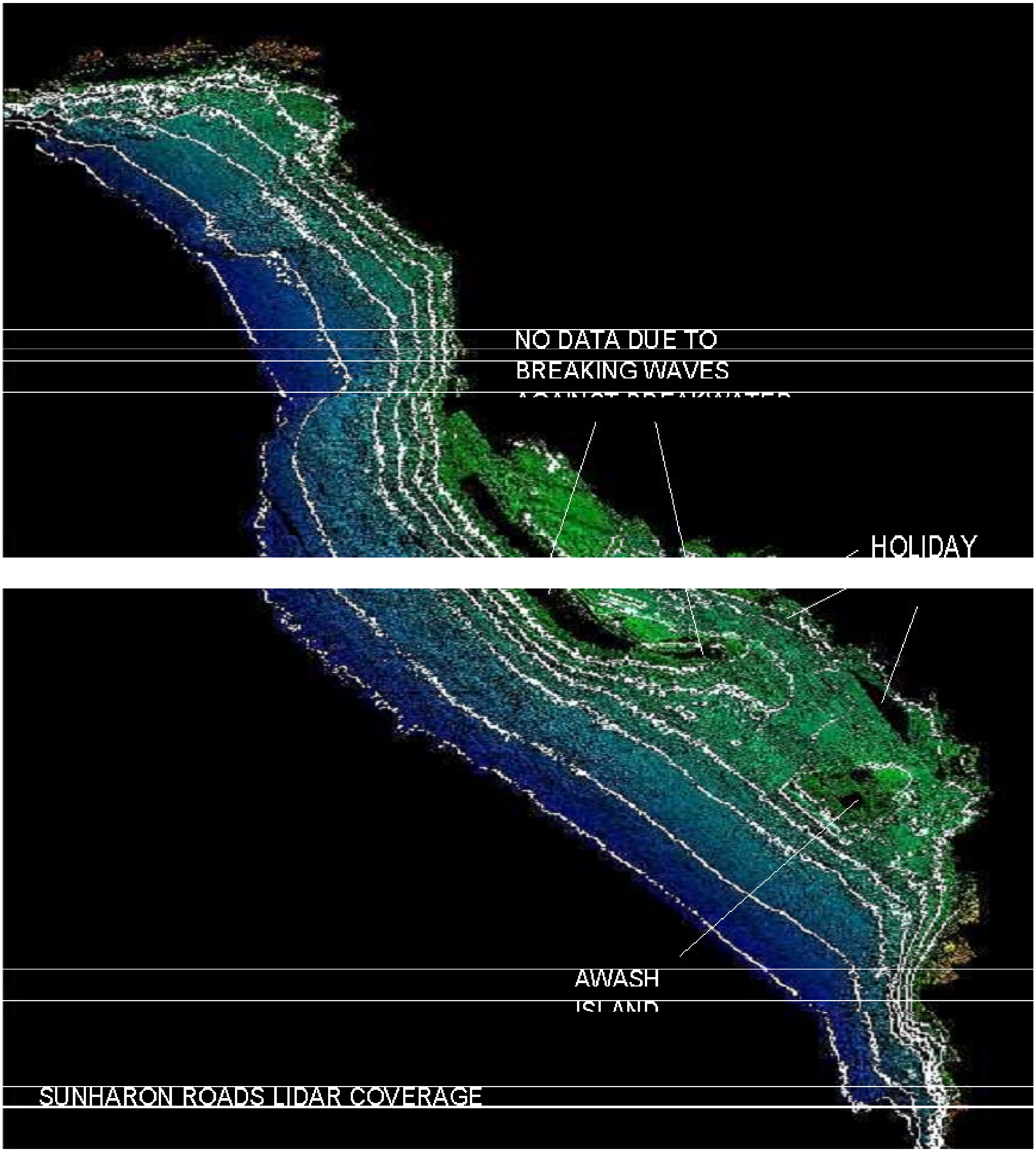
TINIAN



FARALLON de MEDINILLA


BREAKWATER
LIDAR COVERAGE
ISLAND
USNS SUMNER
COVERAGE
POOR COVERAGE
DUE TO WATER
CLARITY
NO COVERAGE DUE TO
BREAKING WAVES OVER
REEF
USNS SUMNER COVERAGE IN
AREAS DEEPER THAN 40m


HOLIDAY –TOO DEEP FOR LIDAR, TOO
CLOSE TO LAND FOR SHIP
HOLIDAY
LIDAR HOLIDAY
HOLIDAY IN SUMNER
COVERAGE


NO DATA DUE TO
BREAKING WAVES
HOLIDAY
AWASH
SUNHARON ROADS LIDAR COVERAGE

APPENDIX E

SAIPAN NAVAIDS

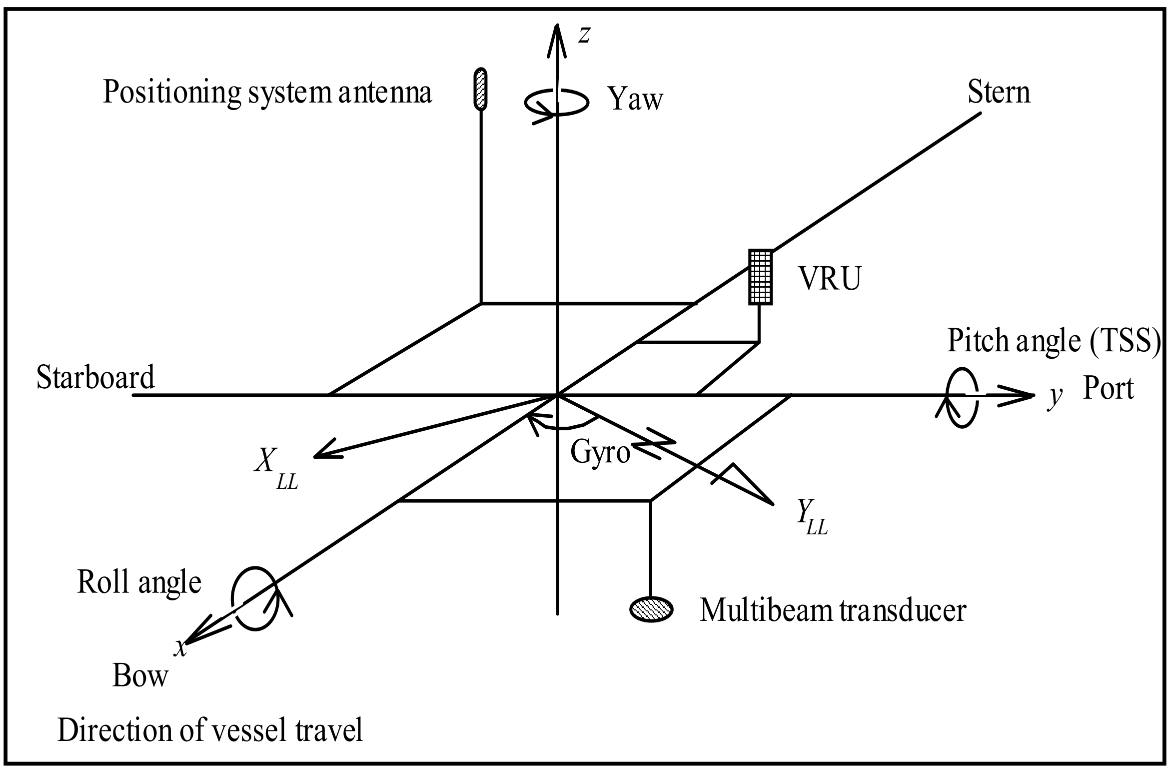
POLICE DOCK	15 13 2.002 N,	145 43 26.255 E	62.37
GREEN 7	15 13 40.500 N,	145 43 3.117 E	61.64
RED 6	15 13 44.815 N,	145 43 2.673 E	56.34
RED 4	15 13 44.543 N,	145 42 36.623 E	60.61
GREEN 3	15 13 39.650 N,	145 42 14.221 E	64.89
RED 2A	15 13 43.659 N,	145 42 8.782 E	61.41
RED 2	15 13 31.316 N,	145 41 43.236 E	61.14
MANAGAHA DK NW	15 14 26.553 N,	145 42 38.271 E	61.35
MANAGAHA DK SW	15 14 26.240 N,	145 42 38.262 E	61.36
MANAGAHA FXAID	15 14 25.572 N,	145 42 44.534 E	61.41
LIGHT HOUSE	15 11 50.374 N,	145 42 31.080 E	60.80
LITTLE GREEN 3	15 11 58.523 N,	145 42 38.829 E	60.43
LITTLE GREEN 5	15 12 1.124 N,	145 42 42.038 E	60.41
LITTLE GREEN 9	15 12 7.321 N,	145 42 47.822 E	60.40
LITTLE RED 10	15 12 8.204 N,	145 42 47.129 E	60.40
LITTLE DOCK NW	15 12 9.069 N,	145 42 53.680 E	60.92
LITTLE DOCK SW	15 12 8.512 N,	145 42 53.682 E	60.93
BASESP	15 12 29.466 N,	145 44 59.267 E	316.66
POLICE DK DAY 2	15 13 1.985 N,	145 43 26.121 E	61.53
10RED	15 13 44.869 N,	145 44 10.889 E	60.40
1 OR MOORING BUOY	15 13 58.591 N,	145 43 30.346 E	59.96
8 RED	15 14 5.507 N,	145 43 26.499 E	59.67
2 WH MOORING BUOY	15 13 52.026 N,	145 43 28.903 E	60.82
7 GREEN	15 13 40.536 N,	145 43 3.108 E	60.74
5 GREEN	15 13 38.061 N,	145 42 19.489 E	368.12
1 GREEN	15 12 43.266 N,	145 41 44.949 E	60.23
RED LAND LIGHT	15 13 20.312 N,	145 43 24.246 E	62.66
POLICE END DAY2	15 13 1.982 N,	145 43 26.133 E	62.11
DOCK1	15 13 48.798 N,	145 44 20.140 E	61.07
DOCK1SOUTH	15 13 47.530 N,	145 44 20.188 E	61.07
RANGEMARK1	15 13 45.553 N,	145 44 25.683 E	63.39

APPENDIX F

USNS SUMNER ERROR ANALYSIS

USNS SUMNER error analysis is facilitated by use of an Microsoft Excel based numerical model where all known errors from all sensors are propagated to a final positional and sounding error estimate.

The coordinate reference frame for the USNS SUMNER and all sensor offsets are first described.



General	
Vessel	USNS Thomas H Sumner
Vessel Number	T-AGS-61
Vessel noise (dB)	45
Heave sensor	POS/MV 320
Roll and Pitch sensor	POS/MV 320
Heading sensor/gyro	POS/MV 320
Positioning system	WADGPS
Surface sound speed sensor	AML
Sound speed profile sensor	SBE 11

Sensor coordinate offsets	
Positioning X (m)	-6.120
Positioning Y (m)	2.120
Positioning Z (m)	29.890
Heave sensor X (m)	1.260
Heave sensor Y (m)	-0.950
Heave sensor Z (m)	2.830
Transducer X (m)	19.880
Transducer Y (m)	-0.020
Transducer Z (m)	-3.310
Transducer Draft (m)	6.086
Roll offset angle of transducer (deg)	0.060
Pitch offset angle of transducer (deg)	1.460
Heading offset angle of transducer (deg)	0.540

Then the known and measurable sensor errors are defined.

Sensor coordinate offset errors	
Positioning X (m)	0.005
Positioning Y (m)	0.005
Positioning Z (m)	0.005
Heave sensor X (m)	0.005
Heave sensor Y (m)	0.005
Heave sensor Z (m)	0.005
Transducer X (m)	0.005
Transducer Y (m)	0.005
Transducer Z (m)	0.005
Dynamic draught error (m)	0.070
Roll (deg)	0.050
Pitch (deg)	0.050
Yaw (deg)	0.050

Positioning errors	
Positioning system error (m) drms	2.00
Speed error (m/s)	0.20
Latency	
Positioning time lag (ms)	0.00003
VRU time lag (s)	0.00100
Transducer time lag (s)	0.00100
Latency (s)	0.00000
Total latency error (s)	0.001
Depth mode and coverage	
Automatic (calculated from depth)	S
Manual override	S
Angular coverage (deg)	150
Manual override	150
Approximate cross-track (m)	701.0
Computed angular coverage	150.0

Auxilliary sensor errors	
Heave - fixed error (m)	0.05
Heave (% error of heave Amplitude)	5.00
Roll (deg)	0.02
Pitch (deg)	0.02
Heading error (deg)	0.02
Surface sound speed sensor	0.05
Sound speed profile sensor	0.50

Intermediate error calculations are performed.

Intermediate calculations	
Roll offset angle (rad)	0.001
Roll meas. error (rad)	0.0003
Total Roll error (rad)	0.0009
Pitch offset angle (rad)	0.025
Pitch meas. error (rad)	0.0003
Total Pitch error (rad)	0.0009
Heading offset angle (rad)	0.009
Heading meas. error (rad)	0.000
Total Heading error (rad)	0.001
Vessel speed (m/s)	6.2
Total heave error (m)	0.050
Measured depth (m)	93.9

Environmental parameters for the area of survey are defined

1. Define environment	
Latitude (deg)	14
Water depth (m)	40
Water temperature (deg C)	26
Salinity (ppt)	35
Sound speed (m/s)	1538
Peak-to-peak swell (m)	1.0
Roll angle (deg)	2.0
Pitch angle (deg)	3.0
Seafloor slope (deg)	0.0
2. Select Vessel and sounding parameters	
4	
Sounding speed (knots)	8
Swath overlap (percent)	25
Depth mode override	
Angular coverage override (deg)	
Swath limit override (m)	

All error estimates at 68% confidence	
Additional parameters, error sources etc.	
pH	7.9
Ambient Noise (dB)	0
F-A seafloor slope (deg)	1
Backscatter normal incidence (dB)	-15
Backscatter oblique incidence (dB)	-35
Water level error (m)	0.02
Spatial tide prediction error (m)	0.1
Spatio-temporal variation (m/s)	2
Thickness of S-T layer (m)	10
Sound speed error beyond profile depth (m/s)	0.5
Maximum sound speed profile depth (m)	500
Intermediate Calculations	
Pressure (kg/cm^2)	5.1
Sound speed (m/s)	1537.8
Latitude	0.244
Water level error (m)	0.102
Roll angle (rad)	0.035
Pitch angle (rad)	0.052
F-A seafloor slope (rad)	0.017
P-S seafloor slope (rad)	0.000

Producing a summary of the errors

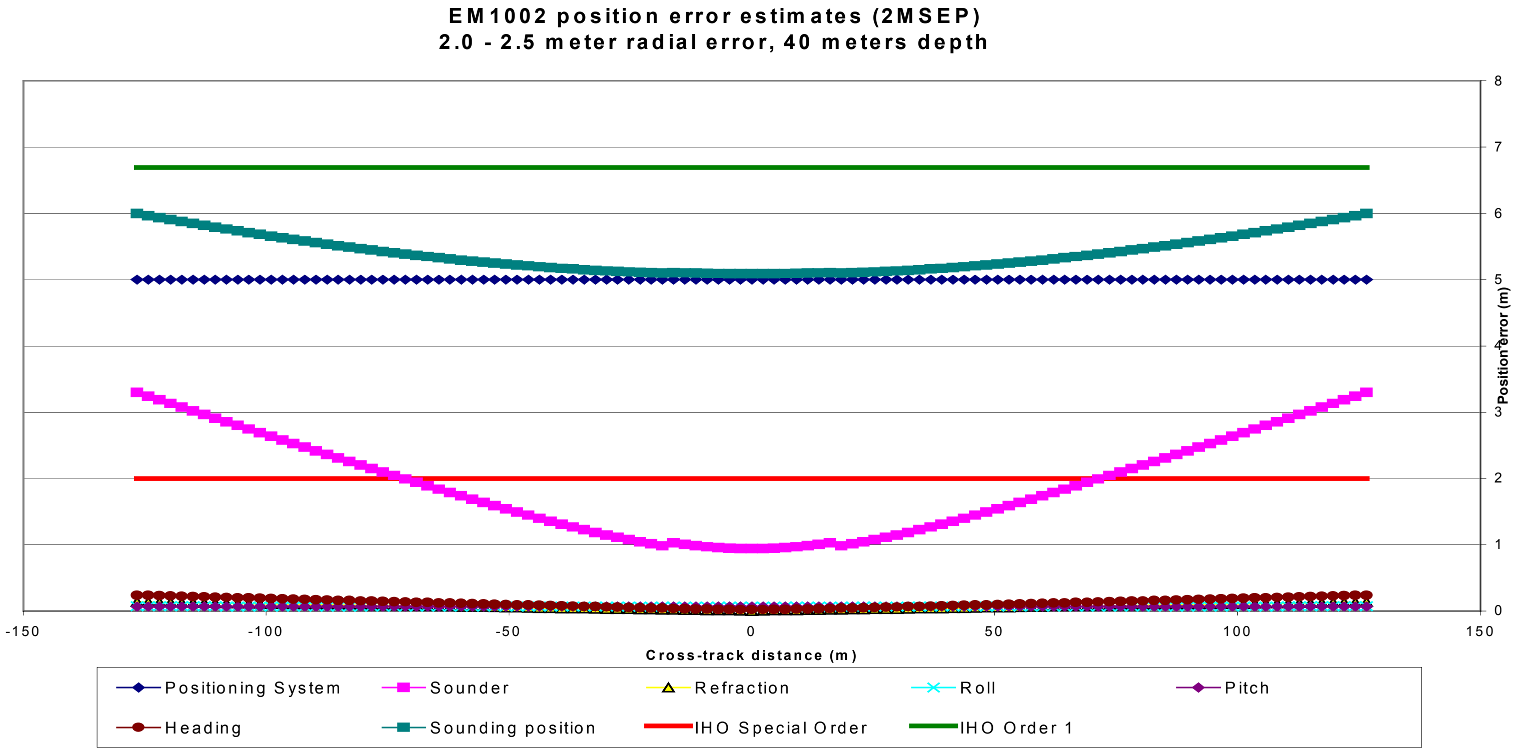
IHO summary	Special Order				Order 1			
Normal (ED) mode								
Depth accuracy	**79**	*of*	*111*	beams pass	**111**	*of*	*111*	beams pass
Position accuracy	**0**	*of*	*111*	Fails	**111**	*of*	*111*	beams pass
Target detect	**0**	*of*	*111*	Fails	**0**	*of*	*111*	Fails
Coverage	**52%**				Fails			
EA mode								
Depth accuracy	**97**	*of*	*111*	beams pass	**111**	*of*	*111*	beams pass
Position accuracy	**0**	*of*	*111*	Fails	**111**	*of*	*111*	beams pass
Target detect	**0**	*of*	*111*	Fails	**65**	*of*	*111*	beams pass
Coverage	**146 %**				Passes			

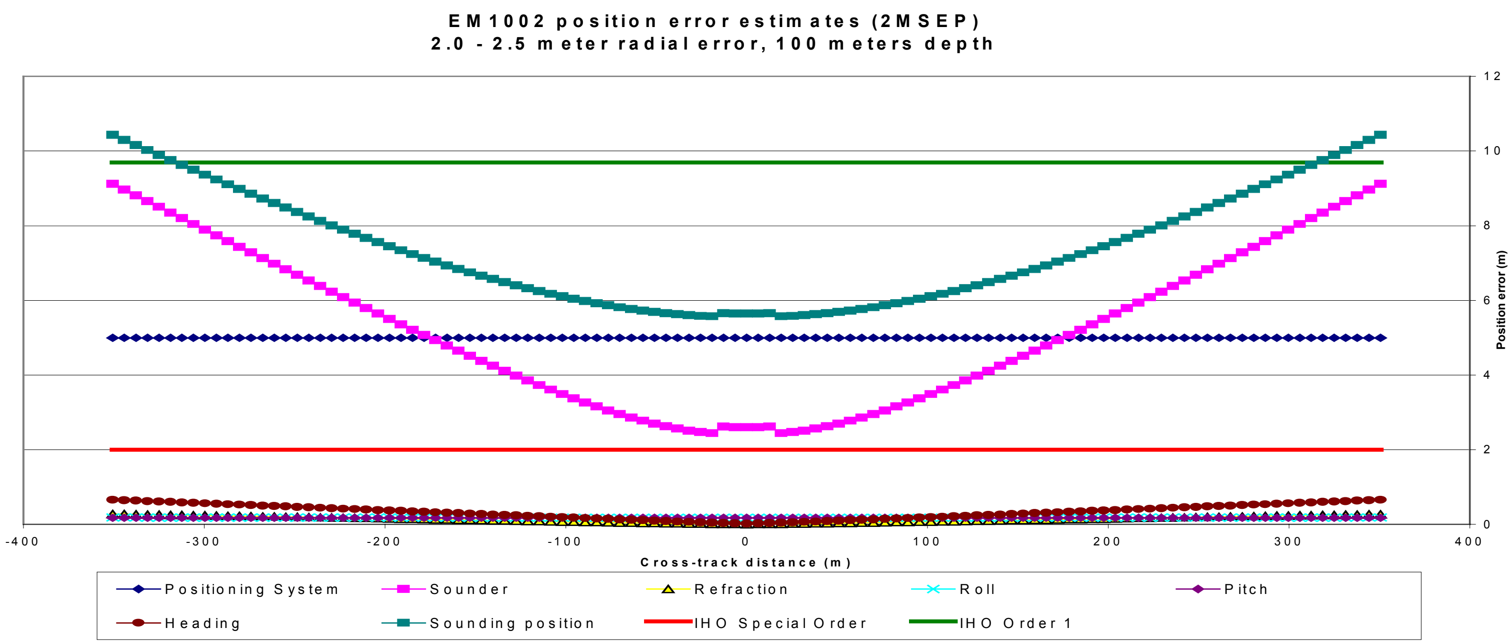
Positioning error summary			
Maximum positioning system error	4.0	*m*	
Maximum depth measurement error	3.3	*m*	
Maximum refraction error	0.1	*m*	
Maximum roll error	0.1	*m*	
Maximum pitch error	0.1	*m*	
Maximum heading error	0.2	*m*	
Maximum positioning error	5.2	*m*	
Number of beams meeting Special Order	0	*of*	*111*
Number of beams meeting Order 1	111	*of*	*111*
Number of beams meeting Special Order	0	*of*	*111*
Number of beams meeting Order 1	111	*of*	*111*

The results of the USNS SUMNER error analysis are shown in the following pages

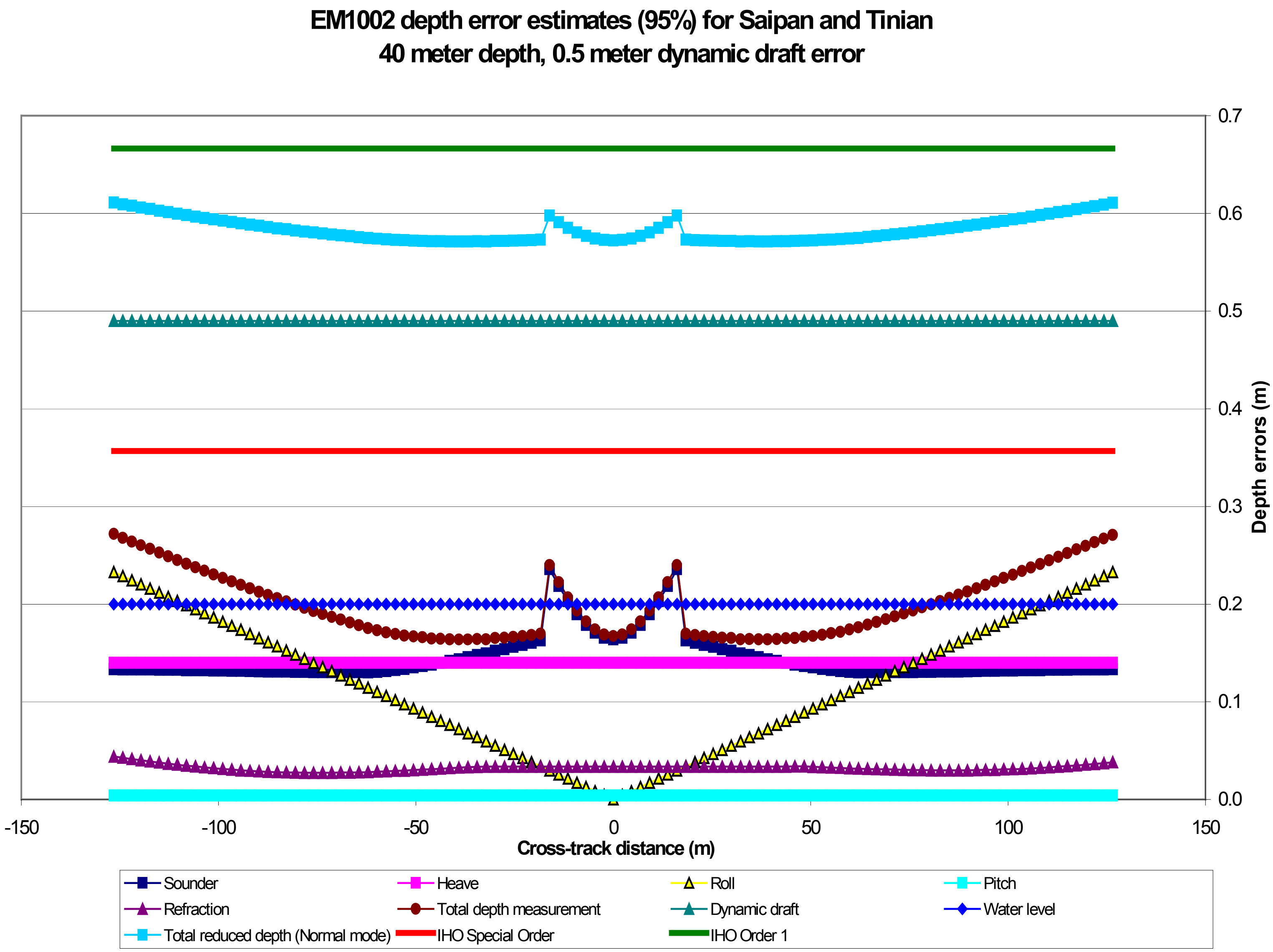
APPENDIX F

ANALYSIS OF USNS SUMNER ERRORS





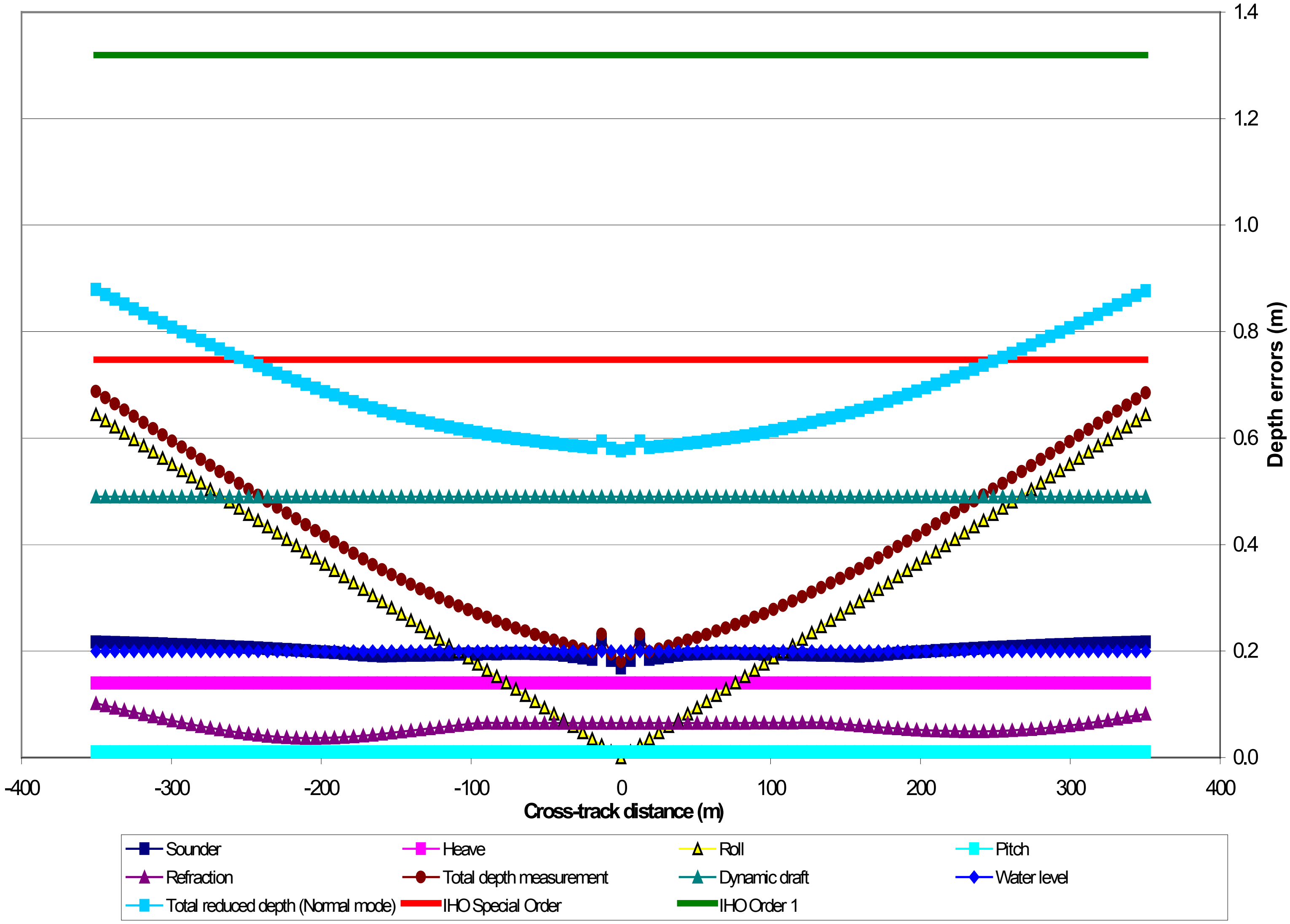
USNS SUMNER utilized the Fugro/Chance Omnistar Wide Area Differential GPS (WADGPS). Position accuracy modeling by Fugro/Chance for the CNMI area indicated positioning errors of up to 2 to 2.5 meters (1 sigma).



SAIPAN and TINIAN

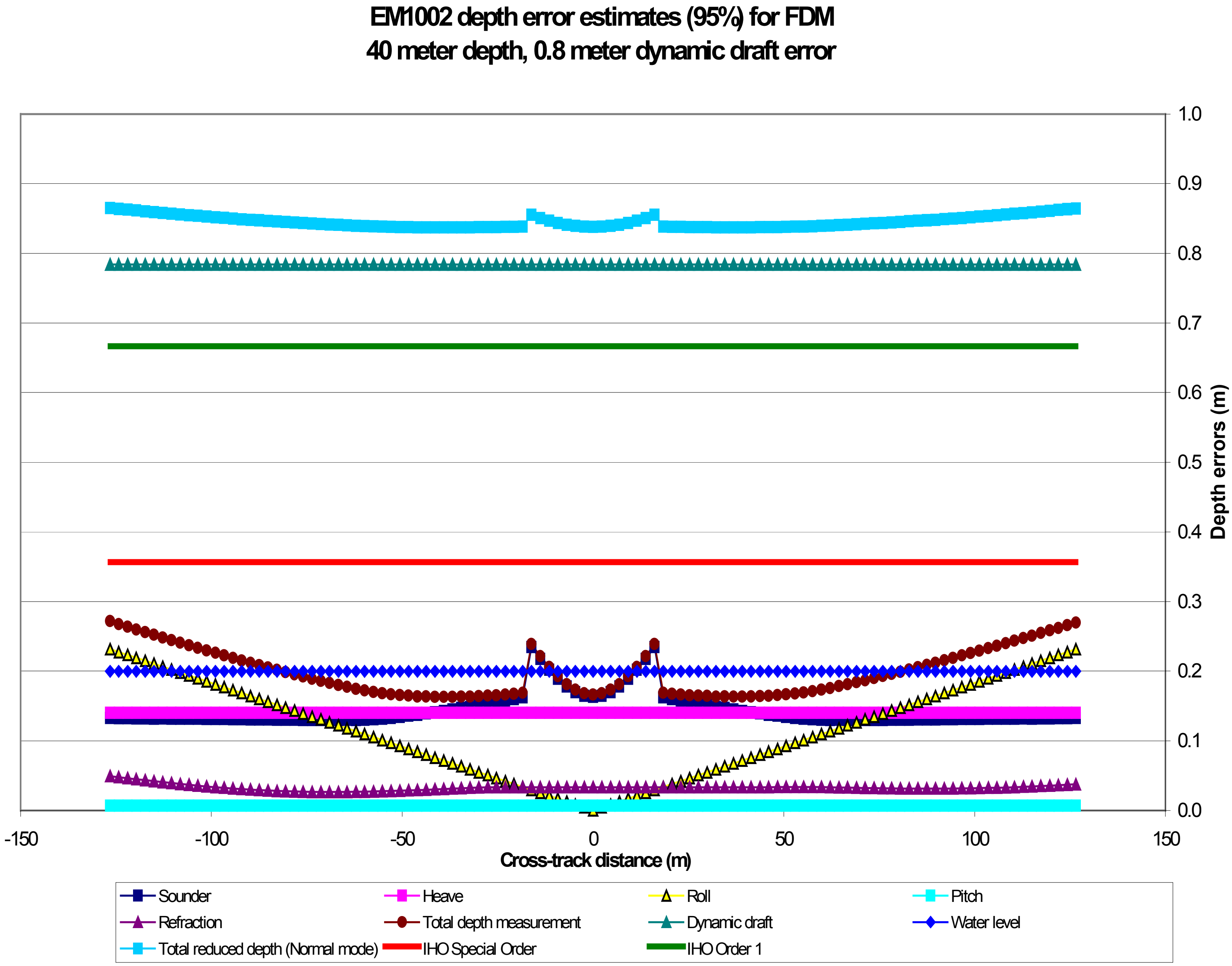
During surveys of Saipan and Tinian the vessel dynamic draft error was, initially, 0.1 meters and increased, with fuel burn and ballasting to approximately 0.5 meters. Modeling of this error indicates a total reduced depth error of no greater than 0.57 to 0.62 meters across the swath at the maximum 0.5 meter dynamic draft error.

EM1002 depth error estimates (95%) for Saipan and Tinian
100 meter depth, 0.5 meter dynamic draft error



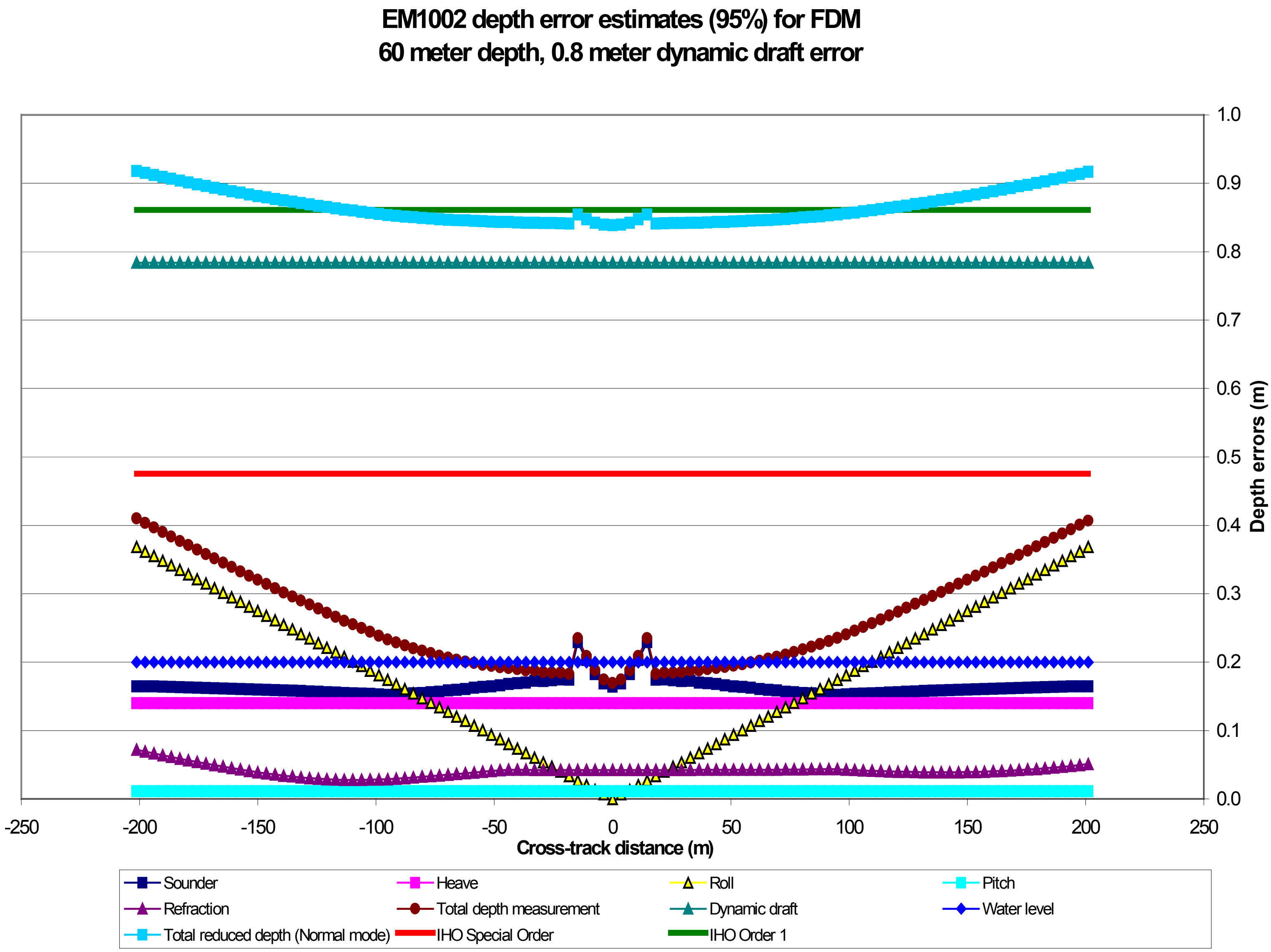
SAIPAN and TINIAN

During surveys of Saipan and Tinian the vessel dynamic draft error was, initially, 0.1 meters and increased, with fuel burn and ballesting to approximately 0.5 meters. Modeling of this error indicates a total reduced depth error of no greater than 0.57 to 0.62 meters across the swath at the maximum 0.5 meter dynamic draft error.



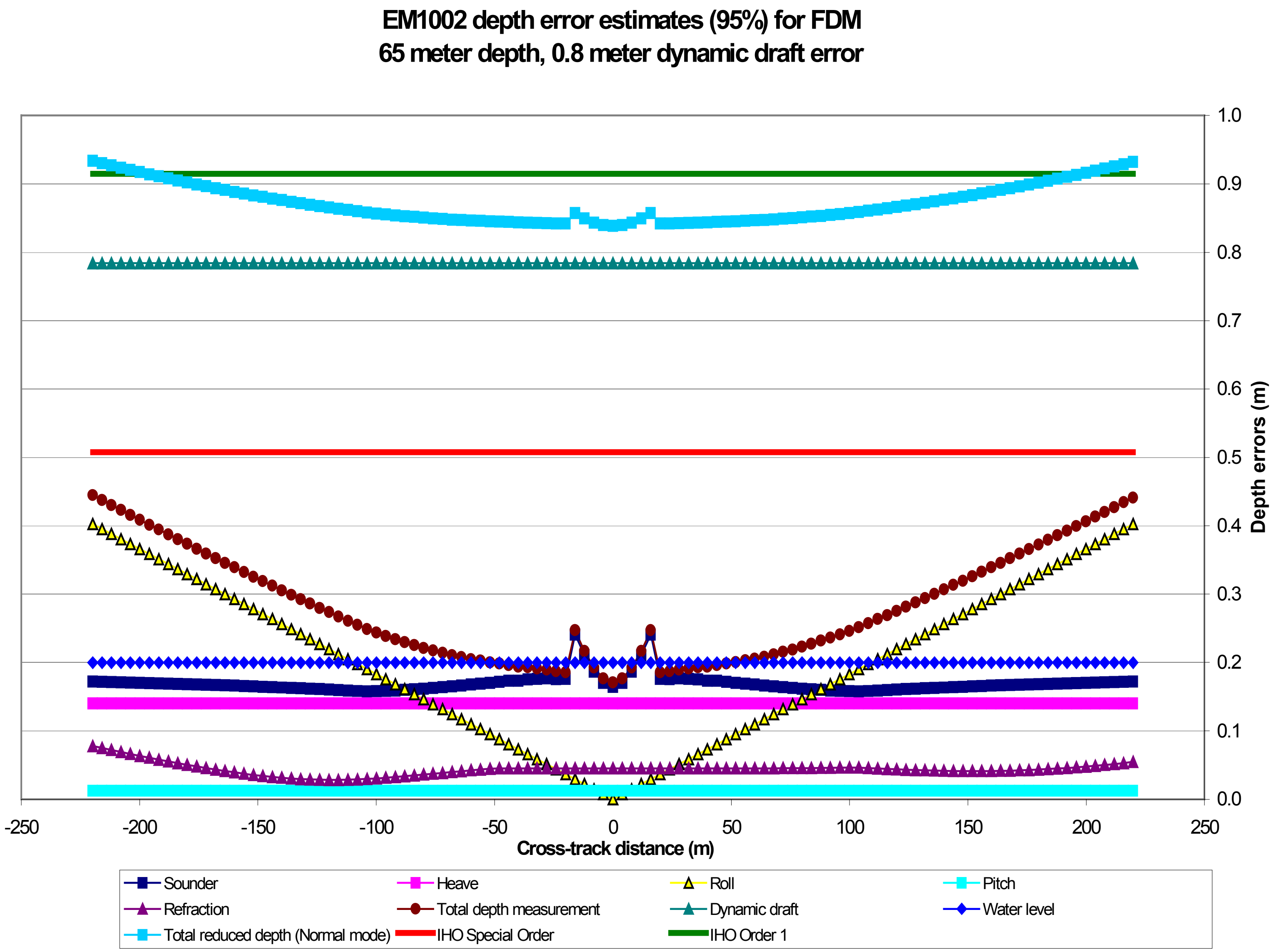
FDM Errors

During surveys around FDM the vessel dynamic draft error increased with fuel burn and ballesting to approximately 0.8 meters. Modeling of this error indicates a total reduced depth error of no greater than 0.83 to 0.88 meters across the swath at the maximum 0.8meter dynamic draft error.



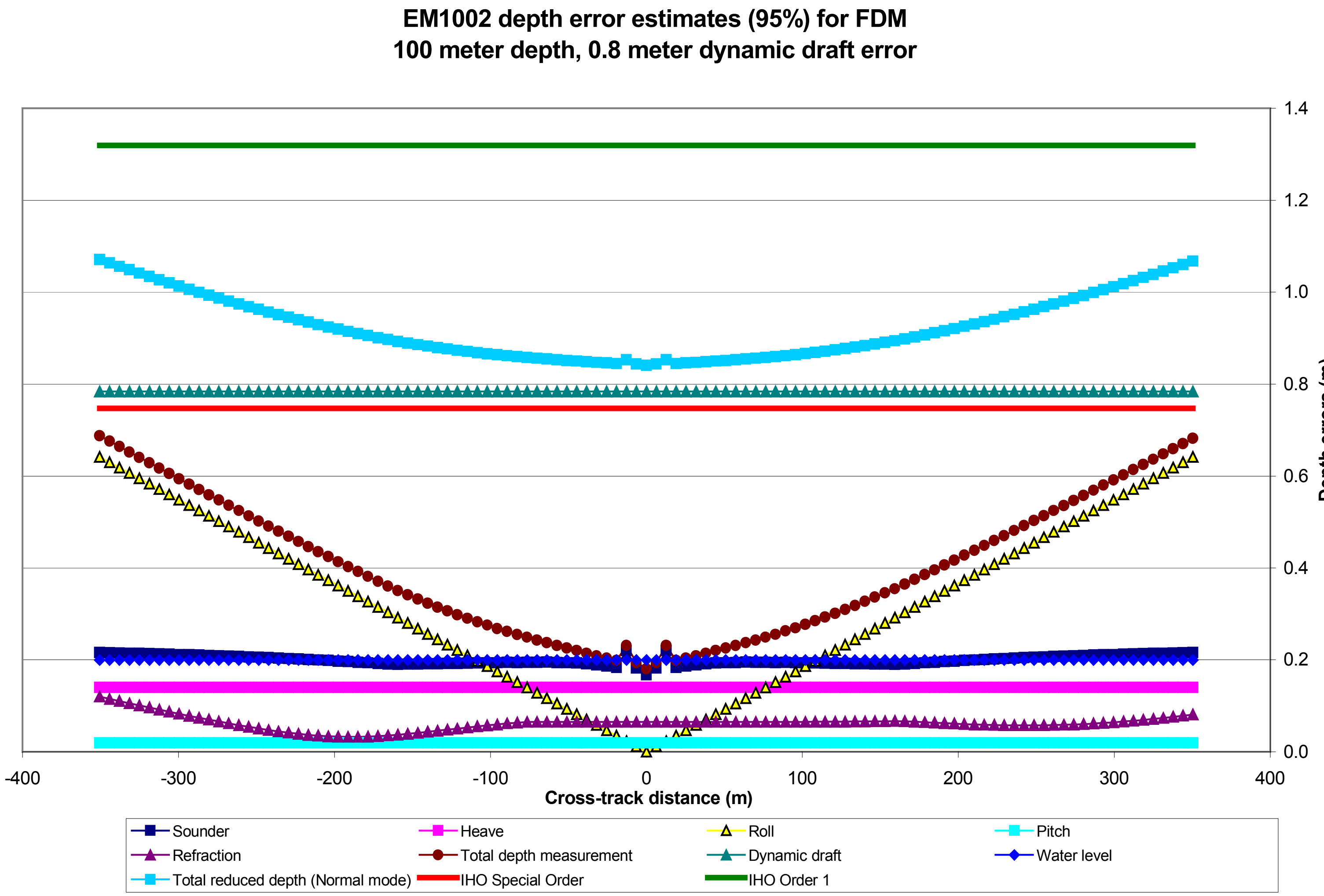
FDM errors

During surveys around FDM the vessel dynamic draft error increased with fuel burn and ballesting to approximately 0.8 meters. Modeling of this error indicates a total reduced depth error of no greater than 0.83 to 0.88 meters across the swath at the maximum 0.8meter dynamic draft error.



FDM errors

During surveys around FDM the vessel dynamic draft error increased with fuel burn and ballesting to approximately 0.8 meters. Modeling of this error indicates a total reduced depth error of no greater than 0.83 to 0.88 meters across the swath at the maximum 0.8meter dynamic draft error.



FDM Errors

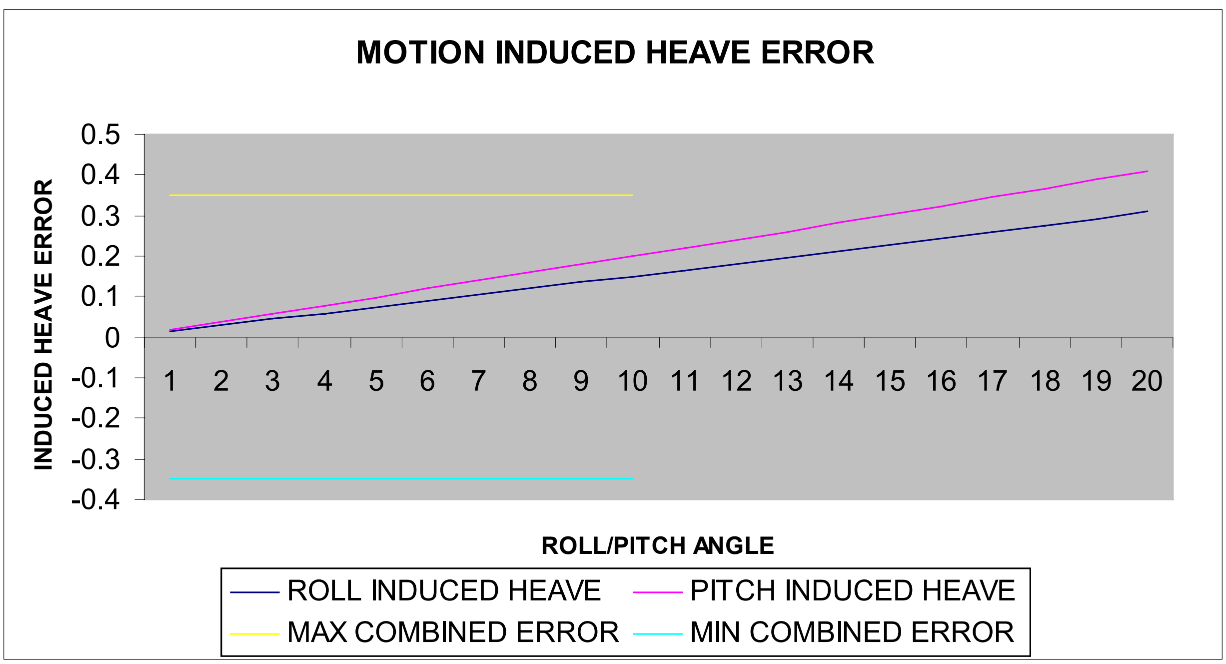
During surveys around FDM the vessel dynamic draft error increased with fuel burn and ballesting to approximately 0.8 meters. Modeling of this error indicates a total reduced depth error of no greater than 0.83 to 0.88 meters across the swath at the maximum 0.8meter dynamic draft error.

GUAM Errors. USNS Sumner sounding errors off Guam were essentially the same as those encountered durung the later stages of the FDM survey.

What has complicated the error analysis ti the fact that the motion corrections were applied twice, once in the POS/MV and again in the SIMRAD EM-1002 multibeam sonar.

The mulitbeam data from the Simrad em1002 system is roll, pitch and heave corrected in the Simrad em1002 multibeam system. Heave , roll and pitch data used in the Simrad em1002 multibeam system are from the POS/MV. Heading data used in the Simrad em1002 multibeam system is from a Sperry MK39 ring laser gyro. Position data the Simrad em1002 system uses comes from ISS-60. The position data was from a Tasman GPS receiver(satellite differential correctors). The position data was corrected for lever arm movement(roll, pitch) in ISS-60. The false heave created by the POS/MV system not being at the center of the ship was corrected for twice. It was corrected for in the POS/MV system and it was also corrected for in the Simrad em1002 multibeam system. The values should have been zeroed out in the em1002 multibeam system but they were not. So a negative heave value was induced into the data..

roll offset = -tan(roll)*(POS/MV across ship offset from center)
pitch offset = -tan(pitch)*(POS/MV along ship offset from center)



Based on the USNS SUMNER error analysis it appears most of the multibeam data meets or exceeds IHO order1 accuracy requirements.

However, as can be seen from the plot of the induced heave error, above, there will be occasions where and additional 0.2 to 0.3 meters of error from either or both pitch and roll may be added to the known errors.

The induced heave error will manifest itself randomly in concert with the random motions of the survey vessel. The maximum amount of additional error intro into the system could be +/- 0.2 to 0.3 meters (with extreme platform motion) for either pitch or roll. These errors could be additive (positive pitch and roll), subtractive (negative pitch and roll) or null each other out (positive pitch and negative roll) or an unlimited random combination. The induced heave error could not be modeled.

Therefore, a thorough examination of the data was conducted. One hundred locations where Lidar and USNS SUMNER data overlapped were randomly selected and compared. The results as follows:

	Max difference (m)	Min difference (m)	Average (m)
FDM	1.34	0.22	0.72
Guam	0.82	0.03	0.355
Tinian	0.63	0.13	0.49
Saipan	0.48	0.03	0.05

USNS SUMNER soundings were always shallower then Lidar soundings with the greatest differences found in USNS SUMNER turns at the end of lines.

For each location the best estimate of the USNS SUMNER sounding error would be to apply these observations to the modeled error predictions.

Only at Saipan and Tinian is USNS SUMNER sounding data expected to meet IHO order 1 accuracy and only in areas deeper than 65 to 70 meters.

In Guam, Saipan and Tinian the maximum sounding error is not expected to exceed 1.5 meters (shoal biased) and only approach this in few occurrences.

In FDM the maximum sounding error is not expected to exceed 1.8 meters (shoal biased) and only approach this in few occurrences.

The results above are based on a randomly chosen sample selection. A different random selection of points would likely produce different though similar results.

APPENDIX G

REPORT ON LEAD-LINE AND LIDAR DATA COMPARISON

As a sanity check between LIDAR standard processed data utilizing DGPS positioning and LIDAR data processed using OTF methods, a lead-line survey of portions of Apra Harbor and Dadi Beach was conducted.

The time frame for lead-line observations spanned 10 March through 14 March, 2001. A total of 225 lead-line observations were made. Thirty observations were discarded for various reasons and 195 observations were retained, compiled and compared, point-by-point with LIDAR data and, in one area, USNS SUMNER EM-1002 multibeam sonar data.

Several environmental conditions affect the accuracy of the lead-line readings. These were:

> Waves due to continuous 20 kt. winds with gusts to 25 kts. Winds resulted in waves of 0.4 – 0.6 meters with the survey vessel moving adound quite a bit at anchor. This made reading the tape somewhat subjective at times.
>
> Bottom roughness and variability affecting consistency of readings.
>
> Positioning inaccuracies. LIDAR data was positioned using DGPS while Lead-line data was positioned with a hand held GPS receiver, un-keyed Plugger.

The most precise and accurate observations were at the Dadi Beach location on the south coast of Orote Peninsula on Agat Bay. The bottom is relatively flat in some areas and water conditions were very calm, sheltered from wind. Wave height was on the order of 4 – 8 cm.

The least accurate and noisiest observations were those collected over Middle Ground shoal in Apra Harbor during the first day, 10 March.

Bottom roughness, particularly numerous scattered rocks and coral resulted in noise in the LIDAR depth values, shots hitting the rack rather than the surrounding flat sandy areas.

In some areas the LIDAR data was somewhat sparse. This required comparing data points that may not be optimally positioned close to each other.

DATA SUMMARY

Dadi Beach

DGPS
-.06
-.058
.2
-.06
-.04
.66
-.08
-.025
-.153
-.278
-.318
.368
-.048
.202
-.056
-.048
.166 MEAN

Middle Ground

	DGPS	OTF
	-.39	-.70
	-.17	-.62
	-.35	-.62
	-.10	-.47
	-.28	-.62
	-.41	-.83
	-.29	-.73
	-.14	-.45
	-.27	-.41
	-.26	-.45
MEAN	.266	.59

Apra North

	DGPS	OTF
	-.16	-.69
	-.10	-.56
	-.17	-.43
	.07	-.54
	.03	-.79
	-.10	-.81
	-.23	-.81
	-.29	-.74
	-.21	
MEAN	.151	.67

Inner Channel

	DGPS	OTF	EM-1002
	-.28	-1.04	.265
	-.52	-1.29	-.09
	-.49	-1.26	.125
	-.33	-1.15	.243
MEAN	.41	1.185	.181

All values are in meters and are relative to the mean lead-line observation.
The mean is the magnitude (absolute value) of the error.
Negative values are deeper than the lead-line observation

25 JANUARY 2001

From: Senior NAVOCEANO Representative, Gerald Oberlies,
NAVOCEANO DETACHMENT 128
To: Commanding Officer, Naval Oceanographic Office
Via: (1) Code 01O
(2) Code 01
(3) Code 0T

Subj: CRUISE REPORT, SURVOPS 6103-01, USNS SUMNER (T-AGS 61)

Ref: (a) NAVOCEANO MSG, 180541Z DEC 00, CONOPS FOR 6103-01.
(b) CINCPACFLT PEARL HARBOR HI, MSG 292212Z DEC 00, CONOPS APPROVAL.

Encl: (1) System Manager Report by Louis Cosse
(2) Equipment Summary Report by Steve Alexander
(3) Ancillary Reports
A. Current Meter Locations – by Jon Shepteis and Blaine Korreckt
B. Bottom Sample Location and Descriptions – Kevin Thaisen
C. Portasal Analysis – by Kevin Thaisen

NAVO Survey Personnel:

Louis Cosse'	DMGR
Steve Alexander	LET
Jeff Woody	DMGRT
Shirley Dorsey	Hydro
Marianne Hathaway	Bathy
Monika Hackauf	Bathy
Kevin Thiasen	Bathy
Dean Elko	ET

SUMMARY OF OPERATIONS

IAW ref (a) and (b), NAVOCEANO DET 128 was tasked to conduct SURVOPS 6103-01, a Military-Hydrographic Survey in Guam and Marianas Islands. This survey was to be conducted in concert with LIDAR Aircraft and FST Surveys. The USNS SUMNER's part was to collect swath bathymetry from the outer defined survey areas inward to the 30-meter contour or where ships' safety would permit. Data collection consisted of: Wide Area Differential GPS Navigation, SIMRAD EM1002 Multibeam Swath Sonar, EM121A Multibeam Sonar, Sea Surface Temperature (SST), Conductivity Temperature Depth (CTD), Water samples, Bottom samples, Current Meter Data, and XBT data. 31 CTD casts were collected during this survey.

Water samples were taken in each of the survey areas and analyses were performed using the Guildline Portasal. Comparisons of CTD values with results obtained from water sample analysis agreed very well. All water samples analyzed were within the tolerance limits of 0.02 Three current meters were deployed in the Siapan Survey Area. They will be recovered at some later date. Bottom Samples were collected in the Siapan Anchorage and in the Tinian Survey area and descriptions are included in the data shipment. Both FWD and AFT Hydro winches were used during this survey and both worked well. For more detailed descriptions of data collection and equipment, see Enclosure (1) System Manager's Report, and Enclosure (2) LET Report. Sea-state was very calm during most of the SURVOPS with the last two days in the FDM area being moderate seas.

HABITABILITY

All NAVO staterooms and spaces were maintained in excellent condition. The exercise room and its equipment are in good condition but were not used much this trip probably due to the heavy work load during this survops. Cooks Peter Francisco and Kenneth Kelly did an outstanding job in the galley as meals provided were of very high standards.

NAVOCEANO/CONTRACTOR RELATIONSHIP

Captain Troy J. Erwin and his crew provided excellent support throughout the SURVOPS. MDR, David Crockett was always readily available to meet our health and welfare needs. Q/Med David Jones kept the CTD winches operating smoothly.

STATISTICAL SUMMARY

PORT LOCATIONS:

SURVOPS 6103-01	**APRA HARBOR, GUAM TO APRA HARBOR, GUAM**
Port of Departure:	APRA HARBOR, GUAM
Start Date:	07 JANUARY 2001
Port of Arrival:	APRA HARBOR, GUAM
End Date:	25 JANUARY 2001

DATA COLLECTED:

SHIP AND GEOPHYSICAL DATA:

PRIMARY DATA COLLECTION	**MILEAGE**	**REMARKS**
SHIP MILES	2663	Good data
NAVIGATON: WADGPS	2663	
SIMRAD EM1002 SWATH SONAR	1346	
SIMRAD EM121A SWATH SONAR	122	

PHYSICAL OCEANOGRAPHY DATA:

XBT/CTD/WATER	GOOD	BAD	TOTAL	MILES	REMARKS
XBT'S			69		
CTD- FSI SENSOR	32				
WATER SAMPLES	Good			11	
WEATHER PAC				2663	
SEA SURFACE TEMP				2663	
BOTTOM SAMPLES	29			N/A	
ADCP	0			0	CASREP'D

SAFETY & SECURITY

Fire and Life Boat Drills were held weekly. A department wide safety meeting was held on 23 January. The Emergency Destruct training was conducted during the first pre-sail meeting. There were no accidents or injuries during this cruise.

SUMMARY

Survops 6103-01 consisted of four separate survey areas with varying priorities. They were approached in the following order: Siapan Anchorage, Tinian (Sunharron Roads), Farallon de Medinillia Island and finally Glass Breakwater off Apra Harbor, Guam. Our mission in each of these areas was to survey from the outer boundaries of these areas inward to a depth of 30 meters with LIDAR tasked to overlap SUMNER data from the 30-meter contour to shore. FST would do Apra Harbor and areas inaccessible to SUMNER. The Survey began from Apra Harbor, Guam at 16:00 Local on 07 January 2001. The SUMNER transited to the Siapan Anchorage and immediately began deployment of three current meters at pre-selected locations. Upon completion of the current meter deployment, a rendezvous was arranged to disembark the two current meter persons via small boat ops. After disembarking current meter personnel, a CTD Cast was made and Sound Velocity Data was entered into the SIMRAD EM1002 System. Next Calibrations were begun on the SIMRAD EM1002 Multibeam Sonar. This lasted approximately 10 hrs. Calibrations were performed in a less than desirable water depth. Due to the lack of availability of a better location to perform them. Calibrations were done in approximately 35 meters of water; a 100 to 140 meter depth would have been preferred, but nothing in this depth range could be found anywhere nearby with the flat featureless bottom needed for this type of calibration. Calibration procedures were discussed with NAVOCEANO Engineer Rebecca Martinolich via phone conversation. Upon completion of calibrations, survey tracks were begun in the Siapan Anchorage Area. Daily CTD's were preformed early each morning and late each evening. XBT's were preformed as needed to maintain environmental stability of sound velocity profile. These were also messaged back to NAVOCEANO as directed. Bottom Samples were randomly collected throughout the Anchorage area were safety permitted. We were obstructed in this area by the anchorage of ships in two locations, and some of the other anchorages were too close to the shoal areas to permit obtaining samples. At this point, it must be mentioned that during daily CTD operations and during bottom sample collection, station keeping was degraded due to the CASREP of our bowthruster. This added additional time to our conducting the casts and sampling and at the same time made predicting suitable locations difficult, due to drifting with strong currents. Another handicap was the oversized sample grabber we were forced to use, due to not having a smaller sampler onboard. Another cumbersome or awkward thing was having to use the Aft CTD Winch to do bottom samples. The SUMNER is not set up with the small winches as the T-AGS 50 Class Hydrographic ships (Littlehales and McDonnell) are. Therefore, using the larger winches also results in a larger work force to conduct these operations, whereas, on the T-AGS 50 ships CTD's and Bottom Sampling can be performed by one or two people. We could not position buoys, because our Zodiac would not run, it is so seldomly used that it is not trustworthy or I should say sea worthy. The Zodiac should be added to the weekly QMED inspection and also should at a minimum of quarterly, be lowered over the side during inport periods and run for awhile to assure operation. Also, for safety, diesel engines should be used rather than gasoline engines. There are no hand held GPS Devices on board, such as pluggers, this would be of assistance when using the Zodiac for positioning small notables, such as buoys.

Also of note, no tidal data was available to add as correctors. Lastly, we conducted no Side Scan Sonar operations aboard SUMNER.

Special thanks is in order to Master Troy Erwin for his handling of the USNS SUMNER in tight maneuvering areas; which allowed us to collect the data to meet our objectives of the 30 meter contour.

Special thanks is also in order to 2/O Kristin Mangold for her efforts in Radar Range and Bearing Observations to position the Island of Farallon de Medinillia. From her observations; the Island lies 1.1nm west of its present charted position.

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Code N34D
File

GERALD E. OBERLIES, Sr.
SNR, NAVOCEANO DET 128

TO: SNR, OCDET 128
FROM: SYSTEM MANAGER, OCDET 128

SUBJ : USNS SUMNER CRUISE 610301 REPORT

1.OBJECTIVE
OCDET 128 was tasked to conduct survey operations aboard the USNS Sumner in the Philippine Sea. Swath bathymetry data collected was SIMRAD EM1002 and EM121A. Other data collected were XBT, SST, SSSV, WeatherPak, bottom samples and CTD data.

2. ACCOMPLISHMENTS:
SURVOP 610301 started in Guam on Jan. 7, 2001 and arrived in Guam on Jan. 25, 2001.

A. UNDERWAY DATA COLLECTED:
1.SWATH BATHYMETRY
A. Simrad EM121A - DATA QUALITY: FAIR (122 NM)
B. Simrad EM1002 - DATA QUALITY: FAIR (1346 NM)
2. NAVIGATION - DATA QUALITY: FAIR (2663 NM)
3. ENVIRONMENTAL -DATA QUALITY: FAIR (2663 NM)
Environmental data included sea surface temperature, sea surface sound velocity, and WeatherPak data.
4. ADCP - DATA QUALITY: **CASREP** (0 NM)
5. XBTs: GOOD 53 BAD 13 TOTAL 66
6. ODEC 3.5 KHz - DATA QUALITY: **CASREP**(0 NM)
7. BIO-LUM DATA - DATA QUALITY:(0 NM)

B. ON STATION DATA COLLECTED
1. CTDs:- DATA QUALITY: FAIR (32 CTDs)
2. CORES - (0)
3. BOTTOM SAMPLES - (29 BS)

3. EQUIPMENT:
A. ISS-60
1. CC1(HP J210)
A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

2. CC2(HP 755 WORKSTATION)
A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

ENCLOSURE #1

3. INS(Pentium COMPUTER)

A. HARDWARE - NO PROBLEMS

B. SOFTWARE - NO PROBLEMS.

4. RTES(Pentium COMPUTER)

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

5. WS8(Pentium COMPUTER)

A. HARDWARE - NO PROBLEMS.

1. WS8 (HP 755) failed on a previous cruise and was replace with a Linux operating system PC until the new Linux PC's are installed to replace the HP workstations WS8 and WS12 during the coming upkeep period.

B. SOFTWARE - PROBLEMS.

1. The Area Based Editor worked well compared to the GSF Geoswath editor for the amount of data collected with the EM1002. But there seemed to be some bugs with the Area Based Editor.
   A. The editor would only load a few files at a time.
   B. There seemed to be some data that was being displayed for editing in geographic areas that were incorrect.
   C. It was frustrating to work on an area for a while and then try to unload it only to find out that the editor would not unload and all of your editing had to be done again.
2. The programs “xgsfdpg” and “chrtrx” would not run on the Linux PC.

6. WS12(HP APOLLO WORKSTATION)

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - BIG PROBLEMS.

1. WS8 and CC1 didn't have the memory resources to grid up the data collected from the EM1002. The grid cell size in “chrtrx” was a real problem and even when it was possible to get a decent grid cell size for the resolution, the memory needed to fill the grid seemed to be a real problem for the system resources. Even on CC1 we couldn't get all of the data collected in the Saipan area to plot. So there was no way to see what areas we didn't have data in after it was processed. Also there was no way to show any kind of finished product to anyone except by showing the data from the ABE software or the coverage grid data.

B. SIMRAD(Multibeam swath systems)

1. EM121A

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

1. EM1002

A. HARDWARE - PROBLEMS.

1. The controls for the monitor are in the back of the unit. So when the ship turns the monitor needs to be degaussed. You have to walk around the all of the the racks and to the back to press the degauss button. There were a lot of lines during this survey that were only a few minutes long and it was a real pain trying to watch the survey and degauss the EM1002 monitor. The SET came up with a quick fix for now.

2. The disk space for the EM1002 is a joke. If the data would have been logged on it and not on ISS-60, the data would have had to be backed up once a day or worse. Also when the system is not logging data is still being written into the process directory and the data has to be cleaned of once a day.

B. SOFTWARE - PROBLEMS.

1.The system was never calibrated with the new software and should have been before this survey. We were forced to calibrate the system in about 35 meters of water. It should have been done in about 130 meters.

2. During the survey the system switched from sensor input for the sound velocity to the sound velocity profile for the velocity at the transducer. This happened three times during the survey. It would have never been noticed when the sound velocity was updated, except that the velocity value used was not from the profile(Still don't know were it came from). The value used was noticed instantly from the swath data being collected.

C. XBT/CTD SYSTEM

1. WS1(Pentium computer) - NOT USED

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

2. WS5(Pentium computer)

A. HARDWARE - NO PROBLEMS

B. SOFTWARE - PROBLEMS

The CTD software ICTDAcq (version 1.2u 04Jan00) has bugs that are known to the office.

3. BOTTLE RELEASE SYSTEM- NO PROBLEMS

4. CTD- NO PROBLEMS

5. CTD DECK UNIT- NO PROBLEMS

6. ROSETTE - NO PROBLEMS

E. ADCP SYSTEM - CASREP

1. (Pentium computer)

A. HARDWARE -NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

2. ADCP deck unit

ADCP deck unit failed at the start of the cruise.

F. WEATHER PACK SYSTEM

1. HARDWARE -NO PROBLEMS.

2. SOFTWARE - NO PROBLEMS.

G. ODEC 3.5 kHz SYSTEM - CASREP

1. HARDWARE - CASREP.

2. SOFTWARE - NO PROBLEMS

H. ODEC 12/33 kHz SYSTEM

1. HARDWARE - NO PROBLEMS

2. SOFTWARE - NO PROBLEMS.

I. BIO-LUM SYSTEM - NOT USED

1. HARDWARE - NO PROBLEMS

2. SOFTWARE - NO PROBLEMS

J. GPS RECEIVERS - Wide Area DGPS system installed before cruise

1. TASMAN #1 - NO PROBLEMS

2. TASMAN#2 - NO PROBLEMS

L. SAIL Supervisor - No Problems

1. WS9(Pentium Computer)

A. HARDWARE - NO PROBLEMS

B. SOFTWARE - NO PROBLEMS

M. INMARSAT A Controller

1. WS10(Pentium Computer)

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

N. ADMINISTRATIVE COMPUTER

1. WS3(Pentium Computer)

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS

O. ADMINISTRATIVE COMPUTER

1. WS4(Pentium Computer)

A. HARDWARE - NO PROBLEMS.

B. SOFTWARE - NO PROBLEMS.

P. PLOTTERS

1. DesignJet 750C PLUS- NO PROBLEMS

Q. INMARSAT B Controller - CASREP

INMARSAT B antenna servo platform is not working.

R. MK39 RING LASER GYRO - PROBLEMS

1. On JD023 the ship had two power brown outs within an hours time. The gyro had to be reset . The system aligned itself, but still continued to output system failure messages. It took the gyro 1.5 hours.

S. POS/MV - NO PROBLEMS

T. PORTASAL - NO PROBLEMS

U. IMAGERY LAN CONCENTRATOR - NO PROBLEMS

V. BATHYMETRY LAN CONCENTRATOR - NO PROBLEMS

W. NETWORK ROUTER - NO PROBLEMS

3. POST PROCESSING:

A. Navigation: NOT PROCESSED

1. There is no procedure to process the navigation data.

B. Swath Data:

The swath data was processed with the AREA BASED EDITOR.

4. PROBLEMS:

The swath data was processed in two of the four areas (Saipan, Tinian)and 50% of the data in the 3rd (FDM) area was processed. Due to the problems of the ABE not unloading at times and having to redo that processing didn't help. Also two Linux PCs and another person would have made a difference.

5. REMARKS:

I've never seen a project as disorganized as this project was.

1. We were told to do one thing and the incomplete specs for the cruise stated different priorities.
2. It seems no one knew that the Sumner didn't have Wide Area DPGS installed at the time and it was crucial for the type of survey being done to my understanding.
3. There was no tide data and we were told that it didn't matter, the tide was not over two feet. So there was no way to tell if any errors in the swath data were due to having no tide data or some system error.
4. The EM1002 on the Sumner had new software installed on the ship by a Simrad rep. and was never calibrated. The system had never been used in a survey and we had to calibrate it in less than favorable conditions.

6. PERSONNEL:

Jerry Oberlies	Senior Navo Representative
Steve Alexander	Senior ET
Dean Elko	
Kevin Thaisen	
Monika Hackauf	
Marianne Hathaway	
Jeff Woody	
Shirley Dorsey	Hydro Rep.
Louis Cosse	System Manager

Enclosure (2)

From: Steve Alexander
To: Jimmie Glydewell, N63
cc: Gerald Oberlies, SNR
Tim Howell, N632

ET Cruise Report - 610301

Personnel: Gerald Oberlies, SNR
Louis Cosse, DMgr
Jeff Woody, DMgrT
Shirley Dorsey
Marianne Hathaway
Monika Hackauf
Kevin Thaisen
Dean Elko, ET
Steve Alexander, LET

Mission: 1. Plant three current meters, then off-load current meter techs.
2. Close-in (hydro-style) survey of several of the Marianas Islands.

Inport 2 - 7 January, 2001

1. The major emphasis prior to this survey was to get the Wide-Area DGPS installed and operational. Components were either already on-board or were FedEx'd as required. System installation was completed just hours before sailing time. Tasman receivers and POS/MV system running in DGPS mode.

2. WeatherPak sensor, which had been casrep't, was changed out and checked good. This cleared casrep 00-006.

3. ET Shop computer's drive "I", which is one of the four in the FedLog stack, was replaced clearing casrep 00-008.

4. A Linux-based computer was installed at WS-8, clearing casrep 00-005.

At sea, 7 - 24 January, 2001

1. Aft hydro winch CTD cable was determined to be shorted. Eliminated armored sea cable and sliprings as the problem. Replacing RG-214 cable between winch j-box and lab deck-box at Rack 20-A cured problem.

2. BBADCP deck unit would not power up. Traced to dead 60 volt DC power supply. Unit was casrep't for replacement power supply.

3. Inmarsat-B would not lock onto a satellite. Captain casrep't system.

4. Had a couple of electrical "brown-outs" which sent everyone scurrying. Glitch on 23 Jan knocked out ship's MK-39 gyro, but was restored by crew.

Equipment Status:

Navigation:

1. Tasmans - All receivers were re-keyed on 22 January 2001, 0000Z
2. Benthos DS 7000 - Not used.
3. EG&G 8011 Acoustic System - Not used.

Sonars:

1. Simrad EM-121 - operated well.
2. Simrad EM1002 - operated well.
3. ODEC 3.5 - Casrep't (00-002) for LPT-10/LPA-10KVA unit. Twelve new transducers are on board for replacement at a future date.
4. ODEC 12/33 - Used only as 12 khz pinger receiver during CTD casts.

Data Collection Suite:

1. ISS-60 Hardware - Still waiting on replacement motherboard for RTES computer. TADS and RTES computers are temporarily swapped to get system operational. Casrep 00-007 applies.

Data Processing System:

1. WS8 - Linux based computer installed and working OK.
2. WS12 - No problems.

Sensors:

1. BBADCP - Casrep't (01-001) for power supply.
2. Falmouth CTD System - Working well after winch to deck unit cable replaced. Spare sensor has been checked and is OK.
3. Portasals: Ship presently has only one unit aboard. It's been used and operates well. Second unit is casrep't (00-009) and has been shipped back for repairs.
4. MK12 XBT System - No problems.
5. SSSV - Working well. Was cleaned once while underway; requires bleeding air out of tank once per day.
6. Sea Surface Temp - Working well.
7. WeatherPak - Working well after sensor replacement.

Power Systems:

1. 3120LN Pacel - No problems
2. 390G UPS - No problems
3. Deltec UPS - No problems

Miscellaneous:

1. Network - No problems
2. PC workstations - Drive "I" of ET shop FedLog stack was replaced, clearing casrep (00-008). Others working OK.
3. POS/MV - No problems
4. Printers and plotters - One LaserJet 4 required rebuilding from on-board spare parts. No other problems.
5. MK-39 Gyro - Operating normally.
6. Speed Log - Operating normally.
7. Gravity - Operating normally.

Outstanding CASREPs:

1. 00-002 ODEC 3.5 khz Sub-bottom profiler
2. 00-007 RTES computer for motherboard
3. 00-009 PortaSal for repairs/replacement
4. 01-001 BBADCP for power supply/replacement

Respectfully submitted,

Steve Alexander, LET

DEPLOYMENT SHEET

PLATFORM: USNS SUMNER CRUISE #:6103-01 OP AREA: SAIPAN

DEPLOYMENT #:1

DEPLOY TIME/DATE LOCAL:13:00 8 Jan LAT:15 13.8N
GMT/JD:03:00 008 LONG:145 39.5E

DEPTH:35 PROJECTED INSTR DEPTH:46m *29

WH-ADCP 300Khz M36784 s/n: 0295

SENSORS: pressure (175m), temp WPN file:dpl3_

BIN SIZE: 1 M # OF BINS: 50 INTERVAL: 00:15:00
duration:60 days Wh usage:255 mem store:6.56 of 10mb
first bin :3m last bin:53m

RELEASE: 8242XS M49827 s/n:24596

RELEASE:645751
ENABLE A:674655
ENABLE B:674676
DISABLE A/B:674707

REMARKS: increased bins to 50.

Encl (3)

DEPLOYMENT SHEET

PLATFORM: USNS SUMNER CRUISE #:6103-01   OP AREA: SAIPAN

DEPLOYMENT #:2

DEPLOY TIME/DATE LOCAL:10:22 , 8 Jan LAT:15 08.0N
GMT/JD:00:22 008   LONG:145 40.8E

DEPTH:43.9   PROJECTED INSTR DEPTH:64, *58m!!

WH-ADCP 300Khz   M36785   s/n: 0297

SENSORS: pressure (175m), temp   WPN file:dpl2_

BIN SIZE: 1 M   # OF BINS: 70   INTERVAL: 00:15:00
duration:60 days Wh usage:290   mem store:8.6 of 10mb
first bin :3m   last bin:73m

RELEASE: 8242XS   M49824   s/n:24593

RELEASE:645666
ENABLE A:674321
ENABLE B:674344
DISABLE A/B:674367

REMARKS:** the adcp range was maxed out , the area has a considerable slope and the target area has small, so allowed for a miss. We hit the target area so will be a lot of editing to this one.

Encl (3)

DEPLOYMENT SHEET

PLATFORM: USNS SUMNER CRUISE #:6103-01 OP AREA: SAIPAN

DEPLOYMENT #:3

DEPLOY TIME/DATE LOCAL:07:33 8 Jan LAT:15 10.00N
GMT/JD:21:33 007 LONG:145 36.7E

DEPTH:39m PROJECTED INSTR DEPTH:30m

WH-ADCP 300Khz M45181 s/n: 660

SENSORS: pressure (175m), temp WPN file:dpl1_.wpn

BIN SIZE: 1 M # OF BINS: 33 INTERVAL: 00:15:00
duration:60 days Wh usage:219 mem store:4.6 of 10mb
first bin :3m last bin:36m

RELEASE: 8242XS M49828 s/n:24587

RELEASE:645772
ENABLE A:674741
ENABLE B:674762
DISABLE A/B:67017

REMARKS: approx 50m south of point.

Bottom Sample Field Summary

Encl (3)

Sample	JD	Depth (m)	Latitude	Longitude	Description
BS#1	1013	129	15 13.41 N	145 40.09 E	Calcareous sandy gravel, tan, fine to coarse subangular coral and shell fragments, sand is fine to coarse.
BS#2	1013	200	15 13.97 N	145 40.68 E	Calcareous gravelly sand, tan, fine to coarse subangular coral and shell fragments, gravel is fine to coarse.
BS#3	1013	68	15 14.28 N	145 39.62 E	Calcareous gravelly sand, tan, fine to coarse angular to subrounded coral and shell fragments, gravel is fine to coarse.
BS#4	1013	40	15 13.66 N	145 38.92 E	Calcareous sandy gravel, tan with green and pink, fine to coarse subangular coral and shell fragments and shells, gravel is fine to coarse.
BS#5	1013	33	15 12.41 N	145 39.41 E	Coral
BS#6	1013	32	15 12.50 N	145 38.43 E	Coral
BS#7	1013	151	15 11.98 N	145 37.24 E	Calcareous sand, tan, fine to coarse subangular to subrounded coral and shell fragments.
BS#8	1013	114	15 11.62 N	145 38.52 E	Calcareous sandy gravel, tan with trace of green, fine to coarse subangular to subrounded coral and shell fragments, gravel is fine to coarse.
BS#9	1013	30	15 11.75 N	145 40.20 E	Calcareous sandy gravel, tan with trace of pink, medium to coarse subangular to subrounded coral and shell fragments, gravel is fine to coarse and includes cobble size coral fragments.
BS#10	1013	55	15 10.46 N	145 40.54 E	Coral
BS#11	1014	269	14 56.03 N	145 36.04 E	Calcareous sand with trace of gravel, light yellowish-brown, fine to coarse subangular to

subrounded coral and shell fragments.

Sample	JD	Depth (m)	Latitude	Longitude	Description
BS#12	1014	210	14 55.31 N	145 37.16 E	Calcareous sand, tan, medium to coarse subangular to subrounded coral and shell fragments.
BS#13	1014	108	14 56.52 N	145 36.57 E	Calcareous gravelly sand, tan with trace of green and orange, fine to coarse angular to subrounded coral and shell fragments, gravel is fine to coarse
BS#14	1014	105	14 57.68 N	145 35.88 E	Coral
BS#15	1015	159	14 57.33 N	145 35.43 E	Calcareous sandy gravel, tan with green, fine to coarse angular to subrounded coral and shell fragments, sand is fine to coarse.
BS#16	1015	263	14 58.35 N	145 35.40 E	Calcareous sand, light yellowish-brown, fine to medium subangular to subrounded coral and shell fragments.
BS#17	1015	146	14 56.50 N	145 36.40 E	Calcareous sandy gravel, tan with trace of red and green, fine to coarse angular to subrounded coral and shell fragments, sand is fine to coarse.
BS#18	1015	189	14 55.80 N	145 36.83 E	Calcareous sand with trace of gravel, tan to light yellowish-brown, fine to coarse angular to subangular coral and shell fragments, gravel is fine to coarse.
BS#19	1015	109	14 59.20 N	145 35.21 E	Calcareous gravelly sand, tan with trace of green, fine to coarse subangular to subrounded coral and shell fragments.
BS#20	1015	66	14 58.66 N	145 36.09 E	Calcareous sand with trace of gravel, tan, fine to coarse subangular to subrounded coral and shell fragments with trace of terriginous clastics, gravel is coral and shell fragments.

Sample	JD	Depth (m)	Latitude	Longitude	Description
BS#21	1016	70	14 56.00 N	145 37.40 E	Calcareous sand, tan, medium to coarse subangular to subrounded coral and shell fragments with trace of terriginous clastics.
BS#22	1016	74	14 58.93 N	145 35.79 E	Coral
BS#23	1016	26	15 10.62 N	145 37.22 E	Coral
BS#24	1016	288	15 10.93 N	145 38.30 E	Coral
BS#25	1016	37	15 11.35 N	145 37.20 E	Calcareous sandy gravel, tan with trace of green, fine to coarse subangular to subrounded coral and shell fragments, sand is fine to coarse.
BS#26	1023	23	15 12.89 N	145 41.31 E	Calcareous gravelly sand, tan with trace of red, fine to coarse angular to subrounded coral and shell fragments, gravel is fine to coarse with trace of cobbles.
BS#27	1023	47	15 12.82 N	145 40.68 E	Calcareous gravelly sand, tan, fine to coarse subangular to subrounded coral and shell fragments, gravel is fine to coarse.
BS#28	1023	45	15 13.91 N	145 39.35 E	Calcareous sand with trace of gravel, tan, fine to coarse subangular to subrounded coral and shell fragments.
BS#29	1023	45	15 10.97 N	145 39.49 E	Coral

Enclosure (3)

OCEANOGRAPHIC LOG SHEET M BOTTOM SEDIMENT DATA	RETURN TO:	U.S. NAVAL OCEAN OFFICE 1002 BALCH BOULEVARD STENNIS SPACE CE 39522-5001

SHIP: USNS SUMNER	CRUISE: 610301	CHECKED BY: KEVIN THAISEN	DATE CHECK

BOTTOM SEDIMENT NUMBER (BS / CORE)	JD (2001)	SAMPLE POSITION LATITUDE N	LONGITUDE E	DEPTH (FMS)	DEPTH (METERS)	GEOMORPHOLOGY OF SAMPLE AREA	SAMPLER TYPE	SAMPLER WEIGHT	APPROX. PENE-TRATION	LENGTH OF CORE	C CO T
BS #1	013	15 13.41	145 40.09		129	HARBOR APPROACH	SHIP-EK	N/A			
BS #2	013	15 13.97	145 40.68		200	HARBOR APPROACH	SHIP-EK	N/A			
BS #3	013	15 14.28	145 39.62		68	HARBOR APPROACH	SHIP-EK	N/A			
BS #4	013	15 13.66	145 38.92		40	HARBOR APPROACH	SHIP-EK	N/A			
BS #5	013	15 12.41	145 39.41		33	HARBOR APPROACH	SHIP-EK	N/A			
BS #6	013	15 12.50	145 38.43		32	HARBOR APPROACH	SHIP-EK	N/A			
BS #7	013	15 11.98	145 37.24		151	HARBOR APPROACH	SHIP-EK	N/A			
BS #8	013	15 11.62	145 38.52		114	HARBOR APPROACH	SHIP-EK	N/A			
BS #9	013	15 11.75	145 40.20		30	HARBOR APPROACH	SHIP-EK	N/A			
BS #10	013	15 10.46	145 40.54		55	HARBOR APPROACH	SHIP-EK	N/A			
BS #11	014	14 56.03	145 36.04		269	HARBOR APPROACH	SHIP-EK	N/A			
BS #12	014	14 55.31	145 37.16		210	HARBOR APPROACH	SHIP-EK	N/A			
BS #13	014	14 56.52	145 36.57		108	HARBOR APPROACH	SHIP-EK	N/A			
BS #14	014	14 57.68	145 35.88		105	HARBOR APPROACH	SHIP-EK	N/A			

BS #15	015	14 57.33	145 35.43		159	HARBOR APPROACH	SHIP-EK	N/A			
BS #16	015	14 58.35	145 35.40		263	HARBOR APPROACH	SHIP-EK	N/A			

OCEANOGRAPHIC LOG SHEET M BOTTOM SEDIMENT DATA

RETURN TO: U.S. NAVAL OCEANO OFFICE
1002 BALCH BOULEVARD
STENNIS SPACE CEI 39522-5001

SHIP:	CRUISE:	CHECKED BY:	DATE CHECKE
USNS SUMNER	610301	KEVIN THAISEN	

BOTTOM SEDIMENT NUMBER (BS / CORE)	JD (2001)	SAMPLE POSITION LATITUDE N	LONGITUDE E	DEPTH (FMS)	DEPTH (METERS)	GEOMORPHOLOGY OF SAMPLE AREA	SAMPLER TYPE	WEIGHT OF SAMPLER	APPROX. PENE-TRATION	LENGTH OF CORE	CO CO TO
BS #17	015	14 56.50	145 36.40		146	HARBOR APPROACH	SHIP-EK	N/A			
BS#18	015	14 55.80	145 36.83		189	HARBOR APPROACH	SHIP-EK	N/A			
BS #19	015	14 59.20	145 35.21		109	HARBOR APPROACH	SHIP-EK	N/A			
BS#20	015	14 58.66	145 36.09		66	HARBOR APPROACH	SHIP-EK	N/A			
BS #21	016	14 56.00	145 37.40		70	HARBOR APPROACH	SHIP-EK	N/A			
BS#22	016	14 58.93	145 35.79		74	HARBOR APPROACH	SHIP-EK	N/A			
BS #23	016	15 10.62	145 37.22		26	HARBOR APPROACH	SHIP-EK	N/A			
BS#24	016	15 10.93	145 38.30		288	HARBOR APPROACH	SHIP-EK	N/A			
BS#25	016	15 11.35	145 37.20		37	HARBOR APPROACH	SHIP-EK	N/A			
BS#26	023	15 12.89	145 41.31		23	HARBOR APPROACH	SHIP-EK	N/A			
BS#27	023	15 12.82	145 40.68		47	HARBOR APPROACH	SHIP-EK	N/A			
BS#28	023	15 13.91	145 39.35		45	HARBOR APPROACH	SHIP-EK	N/A			
BS#29	023	15 10.97	145 39.49		45	HARBOR APPROACH	SHIP-EK	N/A			

Portasal Sample Results

The water samples collected during CTD cast 001 of Survop 610301 indicate very good correlation with the calculated salinity, as can be seen in Figure 1. The greatest variation, in bottle 3, was most likely due to sample bottle contamination.

cast 001	Bottle 1	Bottle 1a	Bottle 2	Bottle 3	Bottle 3a
Sample salinity	34.325	34.334	34.329	34.345	34.337
CTD salinity	34.3295	34.3295	34.3295	34.3295	34.3295
Difference	-0.0045	0.0045	-0.0005	0.0155	0.0075

Figure 1. CTD cast 001 calculated salinities vs. measured water sample salinity. All samples taken at a depth of 412m.

Figure 2 illustrates that the samples collected during CTD cast 010 continue to indicate very good correlation between CTD calculated salinities and measured sample salinities.

cast 010	Bottle 1a	Bottle 1b	Bottle 2a	Bottle 2b	Bottle 3a	Bottle 3b
Sample salinity	34.59	34.592	34.778	34.778	34.785	34.783
CTD salinity	34.59	34.59	34.773	34.773	34.778	34.778
Difference	0	0.002	0.005	0.005	0.007	0.005

Figure 2. CTD cast 010 calculated salinities vs. measured water sample salinity. Bottles 1a and 1b were taken at a depth of 295m, bottles 2a, 2b, 3a, and 3b were taken at a depth of 238m.

Figure 3 continues to illustrates very good correlation between CTD calculated salinities and measured sample salinities for CTD cast 019.

cast 019	Bottle 1a	Bottle 1b	Bottle 2a	Bottle 2b
Sample salinity	34.84	34.842	34.841	34.84
CTD salinity	34.839	34.839	34.839	34.839
Difference	0.001	0.003	0.002	0.001

Figure 3. CTD cast 019 calculated salinities vs. measured water sample salinity. All samples taken at a depth of 62m.

All water sample salinities and CTD calculated salinities have corresponded to within 0.02 Practical Salinity Units (PSU). The CTD appears to be functioning within normal parameters.

Lessons Learned in Multi-Platform Hydrographic Surveys

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***Abstract*-The United States Navy stands at the brink of transition from traditional navigation with paper charts to computer-based electronic charting. The Naval Oceanographic Office (NAVOCEANO), collector of worldwide hydrographic data for 172 years, is posturing to support this transition with state-of-the-art survey platforms, instrumentation, and processing and chart production software. Recently, NAVOCEANO, in cooperation with the National Ocean Service of the National Oceanic and Atmospheric Administration (NOS/NOAA), completed hydrographic surveys in the U.S. Pacific territories of Guam and Saipan in support of urgent Navy operational requirements. Data collection was conducted by the new multipurpose survey ship USNS SUMNER, a new independent rapidly deployable survey team called the Fleet Survey Team (FST), and the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS). Each survey system brought unique capabilities to the toolbox of surveying assets. Each survey system also brought unique perils to the data validator and chart compiler with system errors that first had to be recognized, then the causes determined, and then solutions found. It was indeed fortunate that these three different collection systems were able to work the same survey area, allowing comparison of three different data sets and the discovery of potential systemic errors. Following a very thorough investigation, data from all three systems were corrected and then used for the production of both a paper nautical chart and the Digital Nautical Chart (DNC) library. This new nautical chart information was provided to NOAA and the National Imagery and Mapping Agency (NIMA) for general distribution to both the public and the Fleet.**

I. INTRODUCTION

The Naval Oceanographic Office (NAVOCEANO), located at Stennis Space Center, Mississippi, has 172 years of hydrographic and oceanographic experience with a focused investment in state-of-the-art multi-purpose ships, services, and products. NAVOCEANO operates eight multipurpose survey ships, of which six are of the new T-AGS 60 class, arguably the world's finest oceanographic ships afloat. Furthermore, NAVOCEANO has maintained high standards in the hydrographic community by implementing the latest oceanographic sensor developments, GIS utilization, data visualization, and high-speed data processing facilities, and by building technical expertise with International Hydrographic Organization (IHO) certified Category A and Category B programs in hydrographic science. The Category A course is a one-year master's degree program jointly conducted with the University of Southern Mississippi. In addition, NAVOCEANO has maintained a commitment to the international hydrographic community through its International Surveys Program, which assists foreign nations in conducting hydrographic surveys and producing nautical charts. NAVOCEANO also participates in IHO working groups and other international activities to further advance hydrographic standards.

As navigation technology has changed from paper nautical charts to digital electronic charts, NAVOCEANO has implemented changes to support Naval operations in the digital age and has established the following capabilities as part of its mandate to support the Fleet:

- Highly mobile data collection assets capable of supporting immediate Fleet needs. These include the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system and the Fleet Survey Team (FST).

- Significant speedup in the processing, editing, and validation of multibeam sonar, lidar and side-scan sonar imagery data using the Bathy-Hydro Post-Processing (BHPP) suite of data processing and visualization software capable of achieving a 4:1 collection time to processing time ratio.

- Creation of a new Quality Assurance (QA)/Quality Control (QC) Branch to examine the QA/QC process and its role in the evolving production cycle.

- Construction of a Survey Operations Center capable of downloading survey data direct from survey ships anywhere in the world using low-bandwidth Inmarsat B to view NAVOCEANO survey vessels on a virtual world map, visualize how the survey is progressing, and track the status of data collection sensors in real time.

- A Digital Nautical Chart (DNC®) co-production program with the National Imagery and Mapping Agency (NIMA) for rapid turnaround of digital navigation information from survey to chart delivery for use by the Navy version of the Electronic Chart Display and Information System-Navy (ECDIS-N), other ECDIS, and Electronic Charting Systems (ECS).

- Implementing capabilities to rapidly produce and disseminate battlespace visualization of digital hydrographic and other tactically significant data layers to support ECDIS-N and shipboard Command and Control systems.

From January to March 2001, NAVOCEANO, in cooperation with the National Ocean Service of the National Oceanic and Atmospheric Administration (NOS/NOAA), U.S. Army Corps of Engineers (USACE), and the U.S. Geological Survey (USGS), completed a hydrographic survey campaign in the Western Pacific Ocean area to include Guam, Saipan, Tinian, and Farallon de Medinilla. Although each agency had its own reasons for participation in the cost leveraging primarily of the SHOALS system, NAVOCEANO survey operations were in support of urgent Navy operational requirements to meet Fleet navigational needs.

This paper will discuss the survey operations, data processing and validation, and product production for the Apra Harbor (Guam) and Saipan Harbor areas. These areas were surveyed by the airborne lidar SHOALS system, the rapidly deployable FST, and a new multipurpose ship, USNS SUMNER (T-AGS 61). Each survey system brought unique capabilities to the toolbox of surveying assets. Each survey system also brought unique challenges to the data validator and chart compiler with system errors that first had to be recognized, the causes determined, and then solutions found. It was indeed fortunate that these three different collection platforms were able to work the same survey area, allowing comparison of three different data sets and the discovery of potential systemic errors. This paper will also discuss the validation process which included a very thorough investigation of the error sources and the correction of data from all three systems, and the production of both a paper Field Chart and Digital Nautical Chart (DNC®) libraries.

II. REQUIREMENTS FOR SURVEY OPERATIONS

Between 8 January and 20 March 2001 NAVOCEANO coordinated the operation of three survey platforms: SHOALS, FST, and USNS SUMNER. During planning meetings prior to the Guam operation, SHOALS and the FST were specifically assigned tasks for which they were most capable. Partitioning of responsibilities prevented overlap, wasted time, and inefficiency. The Western Pacific Campaign was initiated because of numerous Navy shallow-water survey requirements around Guam and the Northern Mariana Islands. Multi-agency requirements dictated sharing the technical and financial resources of all participating agencies to ensure cost savings; therefore, Navy, USACE, USGS, and NOS requirements (Fig. 1) were consolidated into a single project:

- The NAVOCEANO initiative addressed numerous military charting, high-resolution data, and special product requirements. These included support of Special Warfare and Amphibious Warfare training, test and evaluation areas, exercise areas, anchorage and vessel basing in Guam and the Northern Mariana Islands, and general military charting requirements. Data collection requirements included, primarily, shallow-water bathymetry in the near shore, but also encompassed depths deeper than lidar capabilities.

- The USACE requirements focused on high-resolution coastal zone bathymetry to 35 meters and shoreline topography to meet coastal engineering requirements. USACE data are used for numerical modeling of storm surge, flood inundation, and evacuation route planning. USACE was also addressing coastal engineering and shoreline dynamics issues.

- USGS interest in the project was the collection of high-resolution data in support of coral reef mapping and environmental studies.

- NOAA/NOS survey interest was the collection of IHO Order 1 survey data and object/navigational hazard detection to be used in updating standard nautical charts. NOS provided complete tide gauge and tidal data support. The NOAA standard tide gauge, which had been recently serviced and checked, transmitted telemetry data available for downloading at 6-minute intervals.

III. PLATFORMS FOR SURVEY OPERATIONS

The survey areas of interest encompassed a depth range from the shoreline to approximately 1000 meters within environments ranging from mangroves and sheltered harbors and coastal waters to shallow offshore anchorages and deeps. No one sensor or platform was capable of acquiring data over the range of depths in these operational regimes and meet the IHO accuracy requirements. No vessel could safely survey

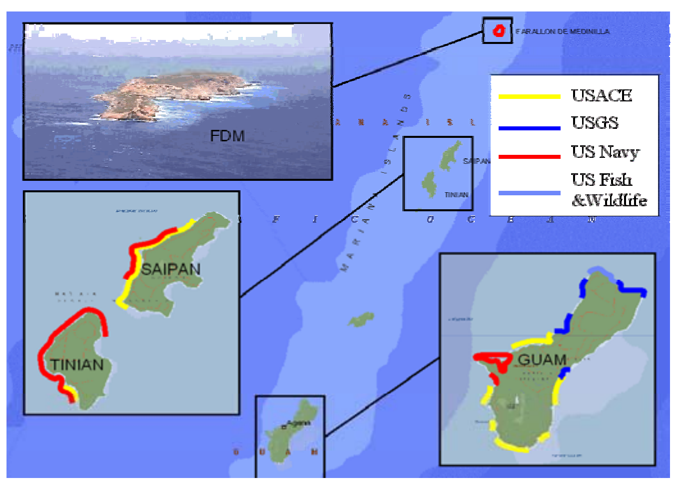

Fig. 1. Survey Areas and Requirements.

up to the shoreline, over the reefs, or into the surf zone. The requirements dictated a multi-sensor and multi-platform approach. The SHOALS system was tasked with the shoreline to 30-meter depth range, hazardous areas, and all areas unsuitable for surface vessels. This included all the USGS and USACE coastal areas, reef habitats, surf zones, and the shoal areas within Apra Harbor, Guam. The FST was tasked with all areas deeper than about 30 meters within Apra Harbor, where water conditions prevented lidar bottom detection and maneuvering constraints precluded SUMNER operations. The FST was also responsible for identifying bottom objects with their side-scan sonar. The USNS SUMNER with its significant multibeam sonar capability greatly expanded the scope and coverage of the project to the offshore areas of Guam and Saipan, unsuitable for the SHOALS and FST systems. SUMNER was also tasked with current meter deployments off Saipan.

A. SHOALS Survey Operations

The SHOALS system is operated by Fugro Chance Inc. for the NAVOCEANO-USACE Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX). Fugro Chance personnel were responsible for SHOALS system operation and maintenance and data collection and processing. Kenn Borek Air of Canada operated the Twin Otter aircraft and provided the aircraft, flight crew, and all aircraft maintenance. Additional information about SHOALS is available at the JALBTCX website (**www.SHOALS**.sam.usace.army.mil).

The project utilized substantial NAVOCEANO and USACE technical resources and worldwide operating experience. Two to three NAVOCEANO personnel were in the field at all times to provide on-scene technical support, survey expertise, field collection of environmental data, and liaison with local and regional officials and organizations for the duration of the project. They were responsible for performing complete data assessment and quality control, identifying problems and discrepancies in the data, ensuring compliance with survey specifications, and working closely with Fugro Chance operators to resolve all survey issues in the field.

The SHOALS survey was organized with respect to Navy/NOS and USACE/USGS requirements. The Navy/NOS areas required IHO Order 1 accuracy because of charting requirements, product requirements, and intended data usage, and as such, required high-accuracy soundings and very reliable object/hazard detection. USACE and USGS requirements were less stringent with no charting requirements. Coastal wave and storm surge modeling do not require the charting accuracy, data density, and fine structure detail dictated by Navy requirements. Coral reef mapping and environmental assessment requirements, however, required high data density, but not the charting accuracy.

The SHOALS effort was organized around these differing requirements to achieve the greatest survey efficiency. USACE areas were flown for single coverage with the system programmed for 8x8-meter spot density and a 220-meter swath. USGS areas were flown for single coverage with the system programmed for 4x4-meter spot density and a 110-meter swath. Navy areas were also flown with the system programmed for 4x4-meter spot density and a 110-meter swath. Where agency requirements overlapped, the area was flown to the higher standard.

To meet the target detection probabilities dictated by the IHO for Order 1 charting, the Navy areas were flown with ≥200% lidar coverage. A second set of lines was flown after a time delay of at least several hours to provide confirmation that laser returns on transient objects, such as fish or turbidity plumes, were easily resolved. The second flight coverage would theoretically, though randomly, interlace laser scan lines between first coverage scan lines and achieve thorough bottom illumination at all survey depths. This was particularly important in water shallower than 7 meters, where insufficient beam spreading had not fully illuminated the area between laser spots at 4x4-meter spot density.

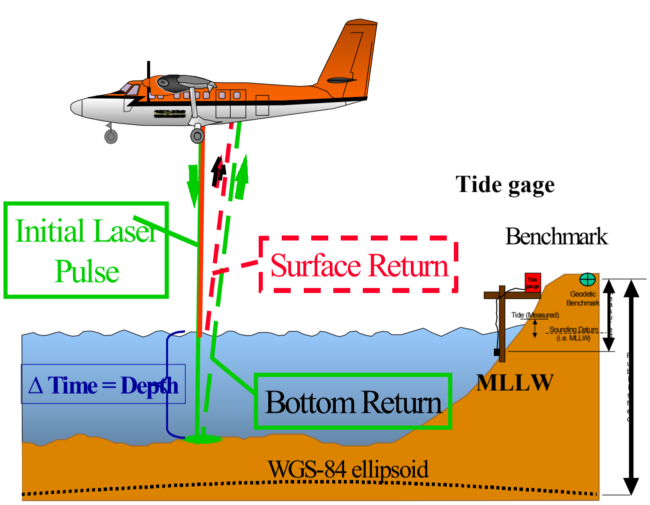

Fig. 2. Chart Depth determined by time between water surface and bottom return, minus the tide correction.

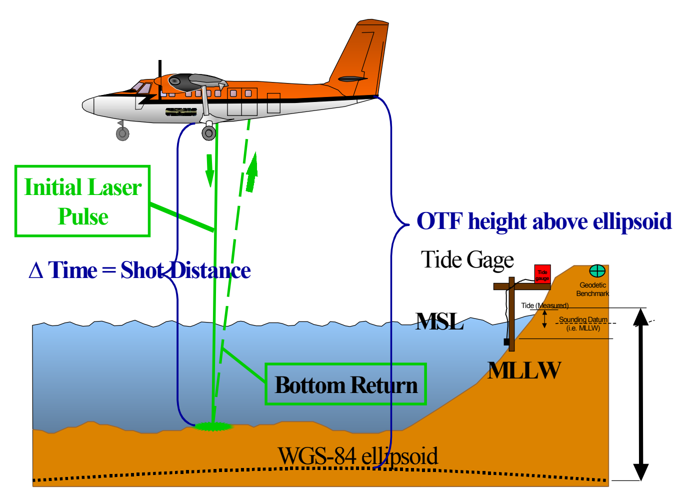

Fig. 3. Chart Depth = Laser Shot Distance - OTF aircraft height above ellipsoid + Offset ellipsoid to MSL – Offset MSL to MLLW.

Second flight coverage data were also used to validate first flight coverage data and to verify the tide correctors applied. Possible targets apparent in first flight coverage data were confirmed, or disproved, by their presence or absence in the second set of flight data. This technique proved quite useful in identifying data "fliers" due to fish, re-suspended sediments, white caps, foam, and aeration in surf zones, and for confirming/disproving doubtful data.

Prior to the arrival of the FST in mid-January, SHOALS was to map Apra Harbor, Guam and deliver a coverage plot to the FST. These coverage data were to be used by FST to plan their portion of the operation and to cover the areas that were too deep for lidar and/or where water clarity posed problems for laser penetration.

Technical problems with the DGPS UHF beacon systems delayed the start of SHOALS production flights by two weeks. In order to provide the FST preliminary coverage maps, the SHOALS survey commenced, utilizing VHF broadcast beacons; however, SHOALS could only use these beacons in the Kinematic-OTF mode of operations. This mode measured the bottom return with respect to aircraft height above the ellipsoid. (See Figs. 2 and 3 for diagrams on the two modes of operations.) Near the end of the survey, replacement DGPS-UHF beacons were delivered. In order to verify that the SHOALS system was operating correctly in the Kinematic-OTF mode, several test lines, using DGPS mode of operation, were run in Apra Harbor. Lidar data from test lines were then compared to the lidar data collected using the Kinematic-OTF mode.

The comparison revealed data offsets of approximately 0.4 meter. This 0.4-meter offset also by coincidence approximated the Mean Sea Level (MSL) to Mean Lower Low Water (MLLW) offset of 0.42 meter (see Fig. 3). In the Kinematic-OTF mode of operations, the SHOALS surveyed relative to the ellipsoid, which required the application of the ellipsoid-to-MSL and MSL-to-MLLW offsets to reduce soundings to MLLW datum. Thus, initially, the problem appeared related to the Kinematic-OTF mode of data reduction. However, the real cause was due to a misunderstanding of how the SHOALS software handled datasets which spanned more than one Julian Day. This misunderstanding resulted in incorrect tidal corrections being applied. These errors were all eventually discovered and corrected, and the tidal data reapplied at NAVOCEANO.

B. Fleet Survey Team Survey Operations

Due to the substantial depth of Apra Harbor, Guam, it was realized in the planning stages that lidar coverage alone in Apra Harbor would be insufficient to meet the survey requirements. The FST was tasked with the acoustic and side-scan sonar surveys of Apra Harbor, which were considered essential in fully mapping the harbor. The floor of Apra Harbor is littered with wrecks, wreckage, obstacles, and junk from World War II and earlier (Fig. 4). Some of the wrecks and obstructions discovered during the survey were previously unknown.

The FST utilized a modified LCM vessel of opportunity, operated by the Naval Station Guam Dive Locker Team. It was outfitted with a Trimble 4700 (G)GPS receiver operating in the DGPS mode, which received differential correctors from shore-based DGPS VHF beacons; Odom Hydrotrac Single Beam Echosounder; SeaBird CTD probe; Odom Digibar SV probe; EdgeTech 272T digital side-scan sonar combined with the Triton-Elics ISIS software suite; and the HYPACK MAX survey data collection suite. Some compromises in the installation resulted in the GPS antenna being offset from the echo sounder, resulting in a significant lever arm. The equipment was configured to support the generation of an IHO Category 1 standard survey with an intended output survey scale of 1:10 000.

The FST survey was split into four prioritized areas with line spacing set at 50 meters in all areas where the depth was 40 meters or greater; interlining was required in depths less than 40 meters to better delineate bottom features. Main lines were run with the Hydrotrac; in addition, alternate lines (100-meter spacing) were swept with the EdgeTech side-scan sonar operating on the 75-meter range scale in order to ensure 150% coverage across the area. All areas were totally ensonified due to the coral nature of the environment. Additional lines were run to complement the SHOALS coverage and to better delineate contours in the shallower areas of the survey as required.

The survey platform and its associated systems performed well, with no serious equipment malfunctions other than occasional short navigational timeouts. Since no gyro was available, azimuth was generated from historic (>3) DGPS position solutions. In order to reduce errors associated with using this method to calculate heading, platform motion, particularly yaw, was minimized by careful boat-handling and line keeping.

Fig. 4. One of many wrecks found by the FST side scan.

C. USNS SUMNER Survey Operations

The USNS SUMNER is one of six T-AGS 60 class ships used by NAVOCEANO. These ships are designed to provide multipurpose oceanographic survey capabilities in coastal and deep-ocean areas. This includes hydrographic surveying. SUMNER is 329 feet long with a displacement of 4700 L.T. and has diesel electric propulsion with twin props, retractable bow thruster, and Z-drive. A contract crew of about 25 personnel operates the ship, supplemented with a NAVOCEANO scientific party of about 10 personnel for conducting surveys. The SUMNER is equipped with the Science Applications International Corporation (SAIC) Integrated Survey System (ISS-60) for data collection, SIMRAD EM 121 and 1002 multibeam sonars, a sub-bottom profiler, high and low frequency single beam sonars, and a complete suite of oceanographic sensors.

The SUMNER was tasked with survey requirements in waters deeper than 35-40 meters, where their Simrad EM1002 multibeam sonar system would be most effective. SUMNER surveyed the approaches to Apra Harbor, Guam and the offshore anchorage and deep areas around Saipan, and collected about 95% of the data around Farallon de Medinilla. The multibeam systems provided highly detailed 100% bottom coverage. Three Acoustic Doppler Current Profilers were deployed for a 30-day observation period at selected locations within the Saipan anchorages. SUMNER also collected soundings, acoustic backscatter, bottom objects, water column properties (CTD, XBT, SST/SV), tidal currents, 3.5-kHz sub-bottom profiles, and bottom sediments data.

IV. DATA FUSION PROBLEMS AND CORRECTIONS

In the field, the data sets from the three different platforms were processed independently of each other. The SHOALS and SUMNER data sets were processed using the BHPP suite of software including the Area-Based Editor (ABE). The ABE is a software tool that enables visualization and statistical editing of bathymetry data and simultaneous display of imagery data. The ABE utilizes the Pure File Magic (PFM) data structure and I/O Library; thus, other data formats can be easily incorporated. The FST data set was processed using the CARIS HIPS and SIPS suite of software tools.

The only comparison between data sets that occurred in the field was between lidar data collected using the Kinematic-OTF mode and the test lidar data collected using the DGPS mode. Because the source of the errors between these two sets of lidar data could not be initially determined, the remaining on-scene personnel decided to conduct a leadline survey to determine a baseline data set that could not be questioned due to its technological simplicity. The leadline survey consisted of approximately 200 observations.

In the office, all three data sets were processed and validated using the BHPP suite of software tools. This allowed all three data sets and the 200 leadline observations to be statistically compared, individually and to each other, in areas of overlap. Figs. 5 and 6 indicate the data sets collected by each platform in Guam and Saipan, respectively.

The BHPP software allows the user the ability to statistically compare data sets collected with different resolution sensors (i.e., high-resolution EM1002 multibeam data collected by the USNS SUMNER, single-beam data collected by the FST team, and spot-beam data collected using SHOALS). This ability to view different resolution data sets together allowed for the detection of systematic errors that existed within each collection system.

A. Fleet Survey Team Data Set

When viewing and editing the FST data set using the BHPP, it was observed that features common between adjacent survey lines did not match, and soundings from cross-check lines did not consistently match the regular survey lines. Upon further examination of the FST data set, it was determined that contrary to indications, the post-processed HYPACK files were not imported by CARIS HIPS. The offset library (referral of all x,y,z lever-arm corrections to Reference Point) was not exported as indicated;

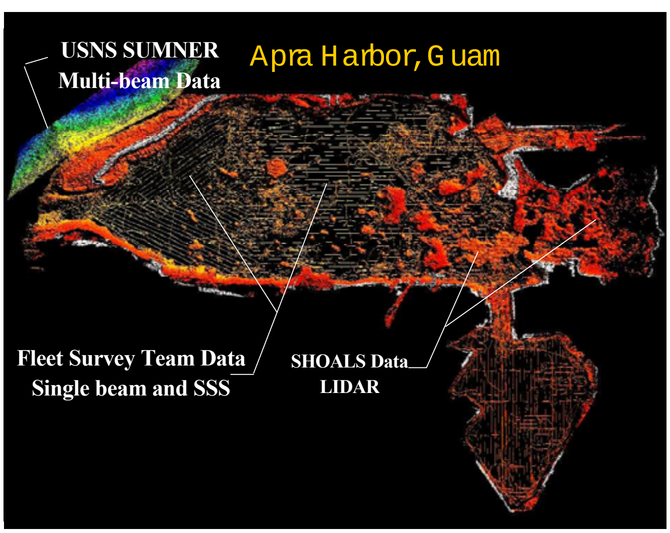

Fig. 5 SHOALS, FST, and SUMNER data fusion for Guam.

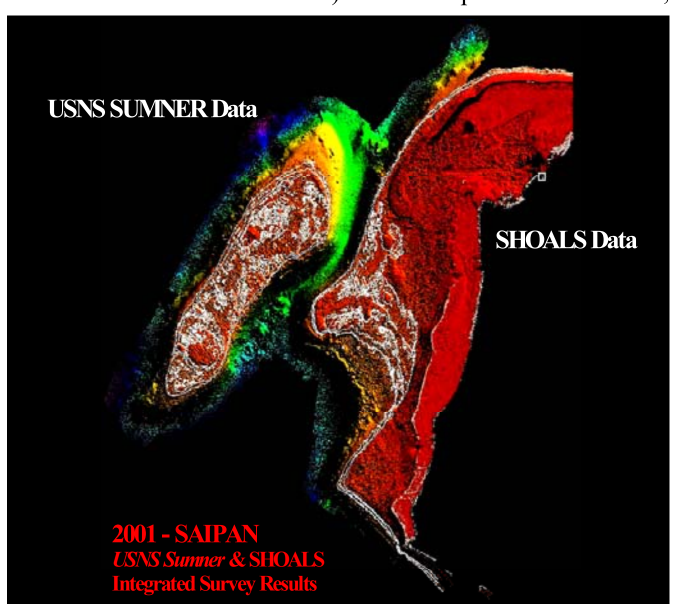

Fig. 6 SHOALS and SUMNER data fusion for Saipan

tides and draft settings also did not export. In short, only the "Raw" data was imported by CARIS HIPS, even though the HYPACK MAX system correctly exported processed data and indicated that it had done so. It was subsequently found that CARIS strips all corrections and accepts only raw navigation and depth solutions. In order to apply the lever-arm and tidal offsets, a software routine was written to directly import HYPACK MAX processed files into a PFM data structure used by the BHPP. Once the lever-arm and tidal offsets were accounted for, there was a good match between adjacent survey lines, as well as between the cross-check lines and the regular survey lines. This data set was then used as the reference area to compare against the other two data sets.

B. SHOALS Data Set

The BHPP was used to compare (both visually and statistically) the SHOALS data set to the FST data set in areas where overlap occurred. This comparison revealed areas where soundings from both data sets were statistically consistent; however, in other areas the soundings from the two data sets differed by as much as 0.8 meter. Upon further discussion between NAVOCEANO and the USACE, it was discovered that incorrect tidal offsets were being applied to SHOALS data sets that spanned more than one Julian day. Once the SHOALS software time-tagged data files spanning more than one Julian Day were corrected, the sounding measurements collected using SHOALS were statistically consistent with the sounding measurements from the FST data set in areas where the two data sets overlapped. Also, the lidar data collected using the Kinematic-OTF mode was statistically consistent with the test lidar data collected using the DGPS mode.

C. USNS SUMNER Data Set

The USNS SUMNER was a very late addition to the project and had not previously been used by NAVOCEANO to conduct shallow-water hydrographic surveys. We solved the following problems:

- The T-AGS 60 class ships use the very complex Integrated Survey System (ISS-60) to monitor and manage the large volume of survey data collected by all the sensors onboard the ship. One of the sensors, the POS/MV, used as the primary source of position to the ISS-60, provides attitude, heading, and heave to the Simrad EM1002 shallow-water multibeam system. The ISS-60 is configured to have the POS/MV apply the motion sensor offsets. On the SUMNER, however, the motion sensor offsets were being applied by the POS/MV and again by the EM1002 multibeam system. This error could not be corrected.

- Changes in draft due to fuel consumption during the course of the survey had not been taken into account. To determine valid draft corrections, several tests were conducted with the SUMNER following the two surveys. Results from these tests were then applied to the soundings collected in both of the survey areas. The recalculated soundings, based on the correction for draft of the USNS SUMNER, resulted in the corrected depths being shoaler by 0.3-0.5 meter.

- Using BHPP visualization software to view and edit the EM1002 data, it was discovered that the outer beams were being refracted upward, resulting in the depths from the outer beams being shoaler than the inner beams. This bending of the outer beams produced ridgelike artifacts in the data (Fig. 7), which were statistically different than the soundings from the inner beams as well as the soundings from the other two data sets (SHOALS and FST). In order to eliminate the errors associated with the outer beams, the edited data were restricted to the inner 120^{o} swath width. Testing is currently ongoing with SIMRAD personnel to correct the problem with the outer beam bending of the EM1002 data.

- SUMNER personnel elected to use the Fugro Starfix Wide Area GPS Service for positioning. Although this service adequately meets IHO Order 1 positioning requirements in many areas of the world, its capabilities do vary by distance from reference stations and ionosphere/sun spot activity, which is worse in the tropics. Our post-survey assessment of the Starfix service in the time and area of these surveys determined that it could meet only IHO Order 2 accuracy requirements. For this reason and because of the uncorrectable motion sensor data, all SUMNER data were downgraded to IHO Order 2.

V. NAVIGATIONAL PRODUCTS

Following a very thorough error assessment, data from all three systems were corrected and then used for the production of Smooth Sheets, a Field Chart of Apra Harbor, and DNC®

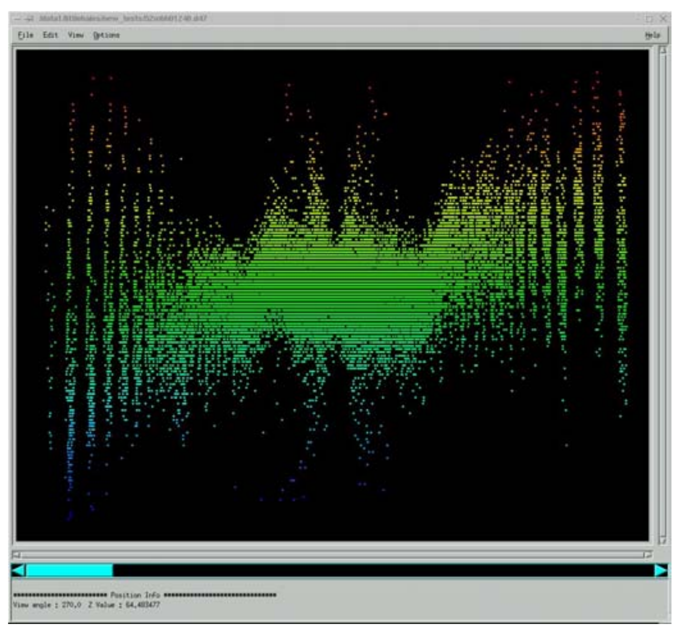

Fig. 7. EM1002 Swath Profile (gsf_geoswath) showing ridge-like effects.

libraries. These products were provided to NOAA and NIMA for general distribution to both the public and the Fleet.

The Smooth Sheets for the surveys and Apra Harbor Field Chart were produced using Intergraph MGE software, which is now being replaced by the CARIS production suite. A Smooth Sheet is the final, legible, accurate plot of a hydrographic survey plotted from verified corrected data and conforming to cartographic standards. Soundings are shoal-biased selected soundings extracted from high-resolution soundings data. This is a "Not for Navigation" product provided to host nations, in this case NOAA/NOS, as the primary hydrographic data source for chart compilations. A Field Chart (Fig. 8) is a navigation-quality limited-distribution chart produced as a temporary chart for use by Navy and other DoD organizations. It is produced only from NAVOCEANO surveys for specific operations as an interim product until the appropriate NIMA or NOAA chart has been produced. NOAA/NOS plans to publish revisions to Chart 81054 (Apra Harbor, Guam) in July 2002 and Chart 81076 (Saipan Harbor) in July 2003. Meanwhile, U.S. Navy ships and other platforms going into Apra Harbor were using the NAVOCEANO Field Chart for navigation.

The system being defined to display electronic charts for the U.S. Navy is called ECDIS-N. In addition to using electronic chart data, ECDIS-N will integrate a variety of other navigational sensors including GPS/DGPS, surface-search radar, gyrocompass, echosounder, and other pertinent navigational information on one display. The functional requirements and performance standards are closely modeled after the International Maritime Organization (IMO) standards for ECDIS. The primary data source ECDIS–N navigational displays will be the NIMA DNC®. The DNC® is an unclassified, vector-based, relational, digital database containing significant maritime features essential for safe marine navigation and is distributed on 29 CD-ROMs. It is a product specification, MIL-D-89023, and requires direct read for display without data manipulation. The DNC® portfolio was initially produced by digitizing approximately 5000 paper charts and consists of over 2400 digital chart libraries. The database is structured using the Digital Geographic Information Exchange Standard (DIGEST) Vector Product Format (VPF), which distributes the data into 12 thematic layers and uses the Feature Attribute Coding Catalog (FACC) to encode chart features and associated attributes. Currently, only DNC® 13 (U.S. West Coast) and DNC® 17 (U.S. East Coast) can be used for navigation because the contained libraries have been brought into routine updating. Chart libraries (Apra Harbor) and (Saipan Harbor) are contained on DNC® 12. Additional information is available at the NIMA website (**www.nima.mil/dncpublic**).

NAVOCEANO contracted the TASC Division of Northrop Grumman to update the Apra Harbor, Guam (DNC® harbor library h1256550) with the new survey data (Fig. 9). The Saipan Harbor (DNC® harbor library h1256520) was updated in-house. Both libraries were updated using the CARIS GIS and DIGEST Object Manager (DOM) software modules. These tools were mainly used in updating features in the various layers, compiling the soundings, creating and editing bathymetric contours, editing geometry and attributes, and rearranging the geometry of linear features to achieve proper topology. Presentation rules for the DNC® used the GEOSYM 4.0 symbol set.

Major changes were made to the Hydrography, Aids to Navigation, and Obstructions layers of the Apra Harbor DNC®. Changes included the addition of 46 bottom characteristics, the repositioning or addition of 53 aids to navigation, and the addition of 48 new obstructions

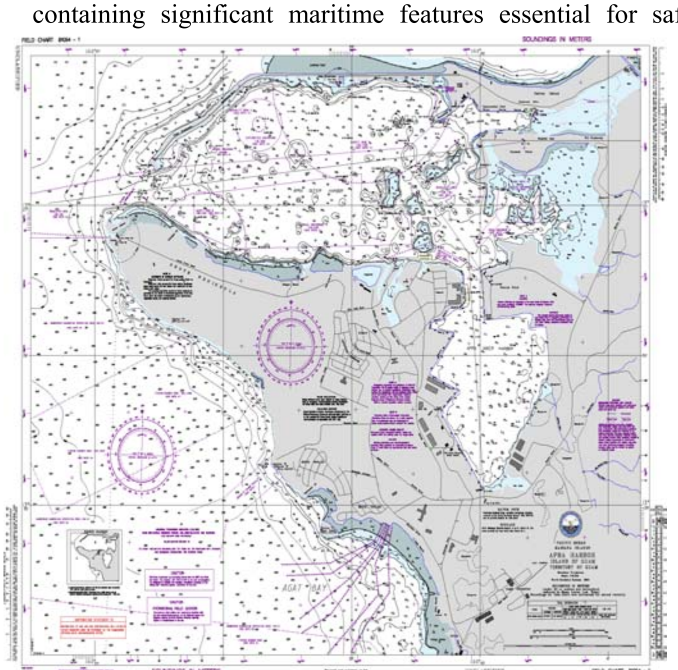

Fig. 8. Field Chart of Apra Harbor, Guam.

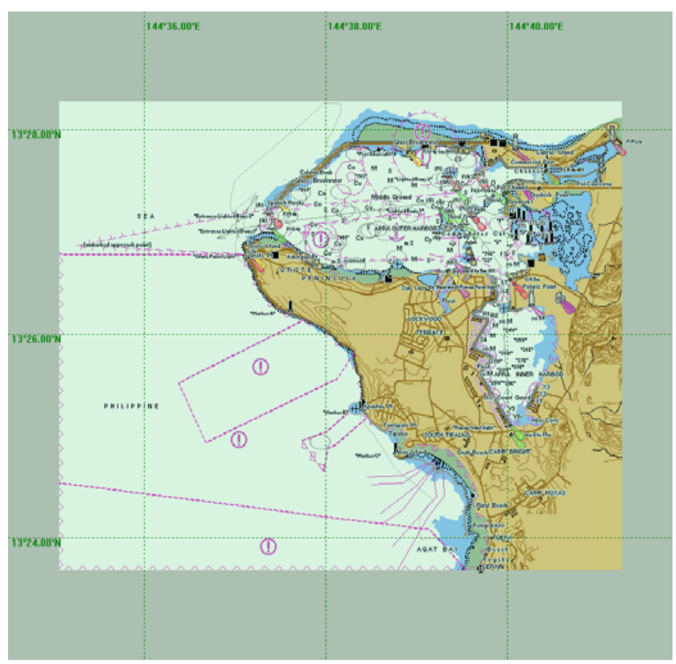

Fig. 9. Updated DNC library for Apra Harbor, Guam.

discovered during the course of the survey. Major changes were made to the Earth Cover, Environment, Hydrography, and Aids to Navigation layers of the Saipan Harbor DNC®. Changes included the addition of 30 foreshore areas, three current flow diagram objects, 17 bottom characteristics, and the repositioning or addition/deletion of 28 aids to navigation. Changes were also made to the Port Facilities and Data Quality layers of both libraries. A significant problem was that the surveys covered only some of the tiles in each library, which made contour matching at tile boundaries a cartographic art, which was especially difficult because original contours were nonstandard metric contours converted from feet. Other significant problems that were overcome were defining the limits of coral and foreshore drying height areas.

VI. SUMMARY COMMENTS

- Complex multi-platform operations require coherent plans.
- Multi-platform data collection is an excellent way to discover systemic errors.
- Take the time to thoroughly check out new systems or configurations and understand how they work.
- Understand your software completely, its handshakes with other systems, and the application of time tags and correctors.
- Rooting out sources of error will speed up data processing and product deliveries on subsequent projects.
- Do not presume that any one data set is superior in quality to another without scientific factual evidence.
- Use visualization software, such as BHPP, to compare different data sets and fully investigate all discrepancies.
- If nothing makes sense, the calibrated leadline still provides a definitive baseline measurement.

Questions and Issues for visit of NAVOCEANO personnel to NOAA Pacific Hydrographic Branch Week of September 29, 2003

Missing Data:

The following data was indicated as submitted to NOAA in accordance with NAVOCEANO Transmittal and Transfer Records but are not in possession by NOAA:

Oahu (00US16):

Three photo quality paper hydrographic sounding sheets: 00619, 00620 and 00621.

Thirteen digital smooth sheets: 09x.dgn, 10x.dgn, 11x.dgn, 12x.dgn, 13x.dgn, 14x.dgn, 15x.dgn, 16x.dgn, 17x.dgn, 18x.dgn, 19x.dgn, 20x.dgn, and 21x.dgn.

Thirteen paper hydrographic sounding sheets: 00609, 00610, 00611, 00612, 00613, 00614, 00615, 00616, 00617, 00618, 00619, 00620, and 00621.

Raster chart/lidar sounding quality control overlays:

Chart no. 19358- eight overlays
Chart no. 19364- seven overlays
Chart no. 19369- seven overlays
Chart no. 19362- one overlay
Chart no. 19367- two overlays
Chart no. 19366- five overlays

Talking paper- ?

Molokai (00US16):

Five smooth sheets- 03x.dgn, 04x.dgn, 05x.dgn, 06x.dgn, and 07x.dgn

Five ASCII.crs files containing position/depth/corrector data:
03x_10000.pfm.crs- 07x_10000.pfm.crs

Five ASCII.xyz files containing latitude, longitude and depth (meters)
03x_10000.xyz- 07x_10000.xyz

Five paper hydrographic sounding sheets:
00603, 00604, 00605, 00606, and 00607

Five raster overlays for chart 19351

Saipan (00US17)

Report of Survey for – unavailable at time of submission, to be forwarded later?

No data was provided for Kaulu Rock. This area is indicated in *Appendix A* of the *Hawaii LIDAR ROS* as being included in US Navy coverage. Is it NAVOCEANO's desire for NOAA to update charts using this data?

Additional Data:

While not submitted by NAVOCEANO, the following data, if available and unclassified, would be valuable in assisting NOAA in assessing survey coverage by system type. Degree of coverage by system (multibeam, LIDAR, side-scan sonar) greatly aids us in determining which areas of the charts have been sufficiently covered to disprove charted features and supersede charted depths with new survey depths. They also provide a measure of data quality to give NOAA confidence that the data meet specifications for charting:

- SWMB data:
  - Sun-shaded DTM's of multibeam coverage (typically at a 5-meter grid)
  - Processed, merged, cleaned data (e.g. CARIS HDCS format)
  - Raw sensor data (not as critical)
- Side-scan sonar data:
  - Side-scan image mosaics (ideally separated by 100%, 200%, etc coverage)
  - Raw or processed sensor data (not critical, but helpful)
- LIDAR:
  - Sun-shaded DTM's of coverage, separated by 100%, 200%, etc. Grid resolution no larger than spot spacing

It would increase data processing speed if NOAA were provided Smooth Sheet soundings and contours in chart units (e.g. feet for Guam).

Saipan, Tinian, and Farallon de Medinilla

1. We could use some clarification on the various positioning methods and associated used in the WESTPAC surveys. In particular:
   Tinian and FDM were not surveyd using DGPS due to range limitations according to the *WESTPAC LIDAR ROS* What was used, and what is the positional accuracy? If stand-alone GPS, would this not degrade positional accuracy to IHO Order 2? The Navy Smooth Sheet for Tinian notes LIDAR used DGPS, but does not note the source of the correctors. *Most Navy areas on Guam, Saipan, Tinian and FDM covered by LIDAR meet IHO Order 1 specifications for positional, depth measurement accuracy. The exceptions are:*

Guam – LIDAR and FST single beam data meets order 1. FST data is positioned with DGPS, LIDAR data is positioned kinematic GPS. The area immediately NW of the Apra harbor jetty, north of the harbor entrance was covered by USNS Sumner and is degraded to order 2 for positional and depth accuracy. All data within the inner and outer harbor meet order 1.

Saipan – the western third of the outer anchorage and areas deeper than approximately 40 meters were covered by USNS Sumner and are degraded to order 2 for positional and depth accuracy. All LIDAR data for Saipan was positioned with DGPS and meets order 1.

Tinian - due to insufficient DGPS beacon coverage LIDAR platform positioning utilized GPS and is degraded to order 2 for positional accuracy. SPS provides a global average predictable positioning accuracy of 13meters (95 percent) horizontally and 22 meters (95 percent) vertically. Ref. Federal Radionavigation Plan, Sec. 3.2.1, para B, pp 3-6. All areas covered by LIDAR meet IHO order 1 for depth accuracy and target detection. Those areas deeper than approximately 40 meters, were covered by USNS Sumner and are degraded to order 2 .

FDM - due to insufficient DGPS beacon coverage LIDAR platform positioning utilized GPS and is degraded to order 2. SPS provides a global average predictable positioning accuracy of 13meters (95 percent) horizontally and 22 meters (95 percent) vertically. Ref. Federal Radionavigation Plan, Sec. 3.2.1, para B, pp 3-6. All areas covered by LIDAR meet IHO order 1 for depth accuracy and target detection. Those areas deeper than 40 meters, were covered by USNS Sumner and are degraded to order 2 for positional and depth accuracy.

- The USNS SUMNER was noted as using WADGPS; what is the source of correctors and positional accuracy of the data? *USNS Sumner utilized the Fugro/Chance Wide Area DGPS system known as Omnistar. Accuracy analysis, conducted by Fugro/Chance, for the area, indicated significant error with respect to the pseudo-range correctors. This was due to the distance of the reference stations from the survey area (Okinawa and Manila, I believe). The error was of such an extent that DGPS positions exceeded those from standalone GPS. Therefore, ALL USNS Sumner data is degraded to order 2 for positional accuracy. Post survey, problems concerning the application of motion correctors and static draft were discovered. Subsequently, ALL USNS Sumner sounding data is degraded to order 2. Fortunately all USNS Sumner data utilized is deeper than 40 meters where loss of an order of IHO accuracy is not a significant concern.*

- The *WESTPAC LIDAR ROS* notes that position quality was monitored in real-time by checking HDOP, SNR, etc. Were any post-processing methods employed to check and remove bad positions or fliers in the data? *Yes, time series of the LOP's are graphically examined for spikes and discontinuities. These are normally seen when the constellation changes, RFI, etc. When* *these are identified, the LOP shift is checked for spec compliance. If it's excessive, the questionable section is deleted. If it doesn't exceed 1 cm at chart scale the software interpolates through the gap. If it's excessive we have a holiday that needs to be re-flown.*

2. Many of the existing questions we have about the survey data are due to NOAA's lack of familiarity with NAVOCENO survey procedures and standards. We do not currently have a copy of any Report of Survey for USNS SUMNER survey operations 6103-01, if one exists. While we do have Cruise Report, SURVEYOPS 6103-01, USNS SUMNER, this document contains minimal information about Saipan, Tinian, and Farallon de Medinilla operations.

- What was the sound velocity sampling regime for the USNS SUMNER? Were any sound velocity problems noted during the survey? *USNS Sumner was operating in, essentially, open ocean waters. As such, SVP's are quite stable. However, CTD's were done on a daily basis within the immediate operating area of the vessel. Synoptic XBT's are dropped on a 6 hour interval. All collected SVP's can be displayed and overlaid for comparison and evaluation real-time. USNS Sumner has a surface SV probe at the transducer depth. The surface SV is continuously compared to the corresponding SV in the MB sonar. If the SV discrepancy exceeds limits the surveyor is alerted. At this point an XBT will be dropped, merged with the local salinity profile and a SVP generated. This SV structure of the water column will be evaluated against other SVP's. If a new SVP is required a CTD cast will be done and a new SVP loaded into the system.*

- In a discussion of the survey in *Lessons Learned in Multi-Platform Hydrographic Surveys*, several data quality issues were noted. These included the POS/MV offsets being applied twice, once in the ISS-60 and again by the EM1002 multibeam system. It was determined that this error could not be corrected. What was the estimated effect of this error on the data quality? *Generally 0.8 – 1.5 meters. All USNS Sumner data accuracy was degraded to order 2 for this reason, as discussed in the ROS.*
- What quality control methods were used to assess the SWMB data from USNS SUMNER? *Cross checks, overlap with LIDAR data, comparison to charted soundings, 3D visualization of shaded data, area based editor.* Were cross check lines or other quality control methods used? *Yes, x-checks were done.* If so what were the results? *Compared to other Sumner data, within spec for order 2, in some cases within spec for order 1, compared to LIDAR about 0.8 – 1.5 meter discrepancy.* How were the data processed and cleaned? *The same way all our multi beam data is processed and cleaned. Using 3D visualization tools and our Area Based Editor. NAVO doesn't process and validate by line, we process by area. We also look at the statistical surface for problem areas, which get further attention. 3-D visualization tools are utilized to examine the data throughout the process.*
- What tide data were used to reduce USNS SUMNER multibeam data? *For ops at Saipan, Tinian and, FDM NAVO determined the Saipan gauge (163-3227) would be more appropriate for the immediate area. NAVO modified the zones and*

adjusted the correctors slightly to utilize the Saipan gauge (163-3227). NOAA verified NOAA tides from the NOAA tide gauge on Saipan (163-3227) were used as the reference.

- **3.** What was the source of the final tide data and zoning for each of these survey areas? *NOAA Pacific Hydrographic Branch, Seattle, WA. www.co-ops.nos.noaa.gov.* The *WESTPAC LIDAR ROS* seems to indicate that the NOAA-derived tidal zoning was used to correct all data; however, the NOAA zoning is based upon the Apra Harbor tide station as the reference station. The Navy smooth sheets for Saipan and Tinian, as well as the *ROS*, note that Tanapang Harbor Gauge, Saipan was used. Were the tides correctors observed (unverified), or verified? *For ops at Saipan, Tinian and, FDM NAVO determined the Saipan gauge (163-3227) would be more appropriate for the immediate area. NAVO modified the zones and adjusted the correctors slightly to utilize the Saipan gauge. NOAA verified NOAA tides from the NOAA tide gauge on Saipan were used as the reference. Zones were alters as follows:*

MAR300	*0 min*	*1.0*
MAR301	*6 min*	*1.0*
MAR302	*6 min*	*1.0*
MAR303	*0 min*	*0.97*
MAR400	*0 mim*	*0.93*

Zones MAR300 and MAR301 are split from Ushi Pt., Tinian to N 15 10' by E145 30'

With reference to Saipan 163-3227 Saipan is corrected with no phase or amplitude correctors applied. Tinian west, 6 minute phase delay with no amplitude correction. Tinian east, no phase delay with a 0.97 amplitude correction. FDM, no phase delay with a 0.93 amplitude correction

Were zoned tides applied to all data? *Yes.* Can we get a copy of the tide corrector file used to reduce the data? *We do not use corrector files. The corrections applicable to a zone are applied to the verified tides from the reference gauge. The corrected tides for a zone are loaded into the zone. The zone tides are numerically applied to the soundings that fall within the zone. Providing these files should not be a problem.*

4. The *WESTPAC LIDAR ROS* notes navigational buoyage being observed at variance from several charts of both Saipan and Tinian. Were any positions taken? *No NAVAID's were positioned on Tinian, NAVAIDS were only positioned at Saipan and Apra harbor. See Appendix E of the ROS.*

5. What are NAVOCENO's expectations of NOAA regarding the shoreline for the surveyed areas? *This is not really NAVO's call. We would expect NOAA to use the most*

accurate shoreline available, regardless of the source. If accurately geo-referenced satellite imagery can be used, that would be excellent. The *WESTPAC LIDAR ROS* notes that the source of the shoreline for the survey was vector shoreline from the DNC which should be revised to include the zero contour from LIDAR. The Navy smooth sheet notes the shoreline is "Survey Derived/ Landsat7 Image." Is it NAVOCENO's intent that NOAA should revise existing charted shoreline? *Yes, where appropriate and where LIDAR derived shoreline is more accurate. Obviously, this would not be the case along tidal flats at low tide. Tidal flats would have to be flown at the appropriate high tide, flown in kinematic mode and an ellipsoid-to-HW offset applied, or the soundings corrected to a HW datum with the zero contour derived. It must be remembered that the LIDAR zero contour in these data is referenced to MLLW and in some areas MLLW and HW may be quire far apart, horizontally. However, a significant amount of shoreline within the WESTPAC area is quite steep with HW and LW lines less than 1 meter apart, horizontally. Tinian, Saipan, FDM, parts of Guam, Na Pali coast of Kauai, North coast of Molokai, the Big island come to mind. In some areas shoreline reclamation has occurred and port facilities have been constructed rendering currently published shoreline inaccurate. These areas should be updated. Shoreline should be updated where needed from the best available source data.* If so additional documentation will have to be provided concerning the source and accuracy of the shoreline data. *What additional documentation?* Even then, it is unlikely that NOAA will be able to revise the shoreline, except in areas in which ground-based GPS positions were obtained (e.g. Guam). *If current shoreline is used in many areas, even in the face of documentation that it's wrong, then places like FDM will continue to be miss-positioned by about a mile on the charts. In areas such as FDM, LIDAR will, most likely, be the most accurate source data. Our experience is that satellite based shoreline is only as good as the geo-rectification, and without ground control points is less than satisfactory.*

6. The *WESTPAC LIDAR ROS* notes surf and rough sea as being significant but having little impact on the data. The Navy Smooth Sheet for Tinian notes data gaps due to poor water clarity and whitewater. In addition several smaller gaps appear on the Smooth Sheet, without any annotations. What are the exact extents of these, *No data, either due to water clarity issues, excessive depth or no coverage.* and which areas have less than 200% coverage? *All areas less the 40 meters deep have 200% coverage. Areas greater than 40m depth have 100% MB coverage.*

7. Did NAVOCENO submit any Notice to Mariners submitted to NIMA or USCG based on this survey data? *No.*

<u>Hawaiian Islands</u>

1. Many of the questions we have about the Hawaiian survey data are due to a need to determine the actual the actual coverage of each survey.

The *Hawaii LIDAR ROS* notes:

Oahu *"Portions of USACOE area sheets 29, 31, 32, 33, 34 and 35 will meet Order*

1 due to multiple coverage." (What areas meet Order 1? *All areas on Oahu meet order 1 accuracy requirement for positioning and depth. All were flown at 4x4 spot spacing.* Were these areas run at Navy standard 4x4-meter spot spacing and 200% coverage or at the USACE requirements of 8x8-meter spot spacing and 100% coverage?) *All areas on Oahu were flown at 4x4 spot density.* "*Sheets 04 and 05 do not meet Order 1 due to lack of multiple coverage."* (What do they meet? Were theses sheet run at Navy standards 4x4-meter spot spacing and 200% coverage or at the USACE requirements of 8x8-meter spot spacing and 100% coverage?) *Sheets 4 – 5 and 29 – 35 were flown at 4x4 spot spacing and meet order 1. These sheets may not have 200% coverage over the entire area because they were USACE areas, not Navy areas, 200% coverage was not a requirement. However, due to the difficult environmental conditions, most of these areas have 200% or better coverage due to multiple flights to attain data. Multiple coverage is not required to meet order 1. The reasoning behind 200% coverage is explained in the ROS.*

<u>Noted Exceptions to the above coverage in the *Hawaii LIDAR ROS* are:</u>

Oahu – *"Pearl Harbor, west and north to Kaena Pt. coverage is to 50m Depth."* (Which areas meet coverage requirements?) *All sheets from Pearl Harbor, west and north to Kaena Pt. coverage is to 50m Depth. Coverage is 200%.*

"*Kaneohe Bay, coverage limited to 11m - 13m in the channel and inner bay due to water clarity issues. Turbidity and to some extent chlorophyll increases at 8m - 10m depth with a rapid falloff of transmissivity…"* (How does this affect the submitted data quality? Which areas were coverage requirements met?) *It can affect data quality, but it doesn't affect data quality with respect the final submitted data. In the Kaneohe channel, essentially, all channel depths were deleted unless there was a very high confidence in their accuracy, confidence attained from examining the laser waveforms and agreement with existing soundings. The reason there is no data in the channel is there was, simply, no bottom return. Other holes in the data are due to poor clarity, either from turbidity, aeration, surf, whitewater or lack of bottom return.*

"Barbers Pt. harbor, coverage very limited due to water clarity." (We need specific extents of coverage, and a quality assessment of provided data.) *The extent of coverage is evident on the sounding sheet. There is no data in the harbor; bottom returns were lost in the vicinity of the harbor mouth.*

"Pearl Harbor, no coverage due to water clarity." (Was any additional survey action taken? If so is the data available to NOAA?) *NAVO's FST conducted a multi beam and SSS survey of Pearl Harbor in 2002. There were problems with DGPS. Essentially, they were not in DGPS mode for parts of the survey. Potentially, this will degrade the survey to order 2, which is*

inappropriate for the area. NAVO is still working on the data, rooting out that which in not DGPS based. Data is currently unavailable.

Kauai- **"***Port Allen, harbor coverage very limited due to water clarity."* (In which areas were coverage requirements met?) *The extent of coverage is evident on the sounding sheet. There is little data in the harbor, bottom returns were lost just inside the entrance to the harbor.*

In addition to the above mentioned gaps in the provided data, several small data gaps appear on the provided hydrographic sounding sheets. There is no mention of holidays in the *ROS* or on the Smooth Sheets. Are these holidays? *Open to discussion and what the definition of a holiday is. I would have to see the areas in question. I would not consider all to be holidays. Some of these holidays occur in surf zones or high hazard areas. These would not be called holidays if this were a vessel-based survey. Other holidays are outside the technical capability of the system, too deep or too turbid. The survey spec and plan was for a LIDAR survey form the shoreline out to extinction depth, where ever that may occur. Any data gaps for other reasons, such as a missed line, is normally considered a holiday. If an area was flown repeatedly and no data attainable, I don't consider that a holiday, it's a no data available area.* If so what are the actual extents of the holidays? *There is a missed line south of Barbers Pt, Oahu that is, technically, a holiday. However, based on the uniform and benign nature of the bottom it does not detract from the quality or completeness of the survey. If these data are considered with respect to a single beam survey with typically 2% bottom coverage, I would be hard pressed to call any data holes a holiday, in the classic sense. The extent of coverage is evident on the sounding sheet.*

The *Hawaii LIDAR ROS* section 1.1.2 notes *"CINCPACFLT recently removed Limited Distribution restrictions on hydrographic data in Pearl Harbor and the approach. This effectively transfers the responsibility of charts for Pearl Harbor from NIMA to NOAA NOS."* (Is there additional data available from the Navy to assist in updating NOAA chart 19366? *NAVO's FST conducted a multi beam and SSS survey of Pearl Harbor in 2002. There were problems with DGPS. Essentially, they were not in DGPS mode for parts of the survey. Potentially, this will degrade the survey to order 2, which is inappropriate for the area. NAVO is still working on the data, rooting out that which in not DGPS based. Data is currently unavailable.*

In addition there are areas south of LIDAR survey W00077 and W00078 (Navy surveys 00607-00608, 00US16) which were not covered by submitted data. Is there additional data available from the Navy to assist in updating NOAA chart 19359 and 19357)? *Good point. There was some ship work off Pearl Harbor, but I don't know its status at this time.*

The *Hawaii LIDAR ROS* section 1.5.1 notes *"The only area affected was within five miles of the VOR tower at Honolulu airport. This is an area of mixed Navy, USACoE and USGS requirements where Navy coverage requirements are not always met."* (Can more specific information be provided about where the coverage requirements were not met?) *200% coverage.*

2. The *Hawaii LIDAR ROS* section 6.4 notes "*Numerous wrecks indicated along Oahu's south coast were not detected in the LIDAR data. Status and/or existence of these wrecks is unknown.*" (What is the charting recommendation for these wrecks? *LIDAR did NOT disprove their existence.* How does this speak to object detection requirements being met? *LIDAR is not an imaging system. If the wreck does not stand proud of the bottom, is composed of small pieces scattered about or has essentially been dismembered it will not be seen by LIDAR, and probably not by a multi beam system. IHO object detection requirements are based on a 2m cube object. LIDAR can detect a 2m cube according to IHO spec, and sometimes a 1m cube object. Differentiating small objects from amongst bottom clutter and variability is a difficult problem for anything other than an imaging system. This same issue is applicable to MB data and is not unique to LIDAR.* NOAA's read on this statement is that the wrecks were not disproved.) *I would say that's correct for small wrecks that my be quite broke up, but with detecting capability of a 2m cube and multiple coverage, the detection of any wreck 2m cube or larger is extremely high. With the lack of any laser hits and corresponding shoal soundings after multiple coverage, pending further investigation, classifying the wreck, as "existence doubtful" should be appropriate.*

3. The *Hawaii LIDAR ROS* section 6.6 notes "*The only navaids positioned were a Navy-maintained buoy off PMRF Kauai and the observation tower at the Makua Training Area, Oahu."* (Were these positioned with the Rockwell handheld unkeyed plugger?) *Yes, unkeyed, stand alone GPS.*

4. We would like to discuss NAVOCENO's expectations of NOAA regarding the shoreline for the surveyed areas. *Where appropriate and where LIDAR derived shoreline is more accurate. Obviously, this would not be the case along tidal flats at low tide. Tidal flats would have to be flown at the appropriate high tide, flown in kinematic mode and an ellipsoid-to-HW offset applied, or the soundings corrected to a HW datum with the zero contour derived. It must be remembered that the LIDAR zero contour in these data is referenced to MLLW and in some areas MLLW and HW may be quire far apart, horizontally. However, a significant amount of shoreline within the WESTPAC area is quite steep with HW and LW lines less than 1 meter apart, horizontally. The Na Pali coast of Kauai, North coast of Molokai, the Big Island comes to mind. In some areas shoreline reclamation has occurred and port facilities have been constructed rendering currently published shoreline inaccurate. These areas should be updated. Shoreline should be updated where needed from the best available source data.* The *Hawaii LIDAR ROS* section 6.7 notes *"The shoreline source was initially generated from the vector shoreline used in the DNC of the area. This should be revised using high-resolution shoreline derived from the zero contour obtained from the LIDAR datasets."* Was the LIDAR derived shoreline (zero contour provided to NOAA? *Don't know. I believe it is on the smooth sheets.* It has also been NOAA's experience that LIDAR derived shoreline, without ground-truthing and field edit, is not completely reliable for charting tidal shoreline. *LIDAR shoreline should not be discounted just because it's from LIDAR. LIDAR systems are much more capable of defining a shoreline than any vessel. It's use should be selective and used where applicable, as discussed above. If current* *shoreline is used, even in the face of documentation that it's wrong, then places like FDM will continue to be miss-positioned by about a mile on the charts. In areas such as FDM, Molokai's north coast and parts of Maui, Kauai and the Big Island, LIDAR or Satellite imagery would be appropriate. LIDAR will, most likely, be the most accurate source data. Our experience is that satellite based shoreline is only as good as the geo-rectification, and without ground control points is less than satisfactory.*

5. The *Hawaii LIDAR ROS* section 8.3 notes "*Additionally, NAVOCEANO installed backup gauges on Oahu at the Barbers Pt. Harbor and the Waianae small craft harbor…* In addition section 8.4 notes *"Results of comparing zone HAW213 (Oahu west coast from Barbers Pt. harbor to Kepuhi Pt. and including Waianae) referenced to NOAA's Honolulu gauge and the installed Waianae gauge are as follows:*

Maximum difference: 0.35 meters
Mean difference: 0.15 meters
Standard Deviation: 0.179 meters"

The greatest discrepancy between the NAVO installed Waianae tide gauge and the NOAA tides was noted when high surf conditions were evident on the west side of Oahu. This is the maximum difference noted above. This was the case, occasionally, as the winter month's approached. The water buildup on the west side is not apparent in the NOAA Honolulu gauge data, as expected. During times of excessive tidal mis-match between Honolulu and Waianae, the west coast was not typically flown. In the few instances where data were collected during this time the data was discarded and the area re-flown.

- While the *Hawaii LIDAR ROS* describes the tide zones used and tide gauges installed, no definitive mention is made of the tide files used reduce data to MLLW. *The ROS states that NOAA tides and NOAA derived zones were used. It also states that the NAVO installed gauges were used to validate the NOAA zone and correction scheme. NAVO installed gauges at Barbers Pt, Waianae and Kauai were installed as a backup for a failed NOAA gauge and to verify the accuracy of the NOAA zones and corrections.* Were they in accordance with the provided tide zoning? Were they observed (i.e. unverified), or verified by NOAA? *NOAA verified NOAA tides from the NOAA tide gauge at Honolulu applied as per the NOAA zoning scheme with NOAA specified corrections.*

6. We would like to discuss in detail the chart comparisons and recommendation in APPENDIX C of the *Hawaii LIDAR ROS*.

<u>In General: all survey data:</u>

1. In areas with 200% or greater LIDAR coverage, were any statistical comparisons made between the first 100% and second 100% to ensure that no systematic errors were evident, and that the data compare within IHO Order 1 standards? *Yes. This is done as a standard procedure in the processing/validation. In processing, data can be color coded*

by depth, line or file. Line/file color-coding allows us to compare coverage. This was done in all areas. Another tool available is visualization of the statistical surface color coded by standard deviation. Areas of high standard deviation are thoroughly examined. 200% coverage was not required to meet any IHO requirement. The reasoning for doing 200% coverage is explained in the ROS.

2. How does the PFM sounding selection algorithm work? *Area based shoal biased sounding selection.* We assume it is a shoal-biased routine.

NOAA FORM 77-27(H) (9-83) U.S. DEPARTMENT OF COMMERCE

HYDROGRAPHIC SURVEY STATISTICS

REGISTRY NUMBER **W00099**

RECORDS ACCOMPANYING SURVEY: To be completed when survey is processed.

RECORD DESCRIPTION	AMOUNT	RECORD DESCRIPTION	AMOUNT
SMOOTH SHEET	1	SMOOTH OVERLAYS: POS., ARC, EXCESS	
DESCRIPTIVE REPORT	1	FIELD SHEETS AND OTHER OVERLAYS	

DESCRIPTION	DEPTH/POS RECORDS	HORIZ. CONT. RECORDS	SONAR-GRAMS	PRINTOUTS	ABSTRACTS/SOURCE DOCUMENTS	
ACCORDION FILES						
ENVELOPES						
VOLUMES						
CAHIERS						
BOXES						

SHORELINE DATA

SHORELINE MAPS (List):

PHOTOBATHYMETRIC MAPS (List):

NOTES TO THE HYDROGRAPHER (List):

SPECIAL REPORTS (List):

NAUTICAL CHARTS (List):

OFFICE PROCESSING ACTIVITIES

The following statistics will be submitted with the cartographer's report on the survey

PROCESSING ACTIVITY	AMOUNTS: VERIFICATION	EVALUATION	TOTALS
POSITIONS ON SHEET			
POSITIONS REVISED			
SOUNDINGS REVISED			
CONTROL STATIONS REVISED			

	TIME-HOURS: VERIFICATION	EVALUATION	TOTALS
PRE-PROCESSING EXAMINATION			
VERIFICATION OF CONTROL			
VERIFICATION OF POSITIONS			
VERIFICATION OF SOUNDINGS			
VERIFICATION OF JUNCTIONS			
APPLICATION OF PHOTOBATHYMETRY			
SHORELINE APPLICATION/VERIFICATION			
COMPILATION OF SMOOTH SHEET			
COMPARISON WITH PRIOR SURVEYS AND CHARTS			
EVALUATION OF SIDE SCAN SONAR RECORDS			
EVALUATION OF WIRE DRAGS AND SWEEPS			
EVALUATION REPORT			3
GEOGRAPHIC NAMES			
OTHER* (Chart Compilation)			59
*USE OTHER SIDE OF FORM FOR REMARKS — TOTALS			62

Pre-processing Examination by	*Beginning Date*	*Ending Date*
Verification of Field Data by R. Davies	*Time (Hours)* 0	*Ending Date*
Verification Check by	*Time (Hours)*	*Ending Date*
Evaluation and Analysis by R. Davies	*Time (Hours)* 3	*Ending Date* 09/22/2004
Inspection by B. Olmstead	*Time (Hours)* 10	*Ending Date* 09/23/2004

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NOAA FORM 75-96
(10-83)

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

MARINE CHART BRANCH

RECORD OF APPLICATION TO CHARTS

FILE WITH DESCRIPTIVE REPORT OF SURVEY NO. W00099

INSTRUCTIONS

A basic hydrographic or topographic survey supersedes all information of like nature on the uncorrected chart.

1. Letter all information.
2. In "Remarks" column cross out words that do not apply.
3. Give reasons for deviations, if any, from recommendations made under "Comparison with Charts" in the Review.

CHART	DATE	CARTOGRAPHER	REMARKS
81086	4/13/04	Russ Davis	Full ~~Part~~ ~~Before~~ After Marine Center Approval Signed Via
			Drawing No. Full application of soundings, curves and features from smooth sheet
81004	4/13/04	Russ Davis	Full ~~Part~~ ~~Before~~ After Marine Center Approval Signed Via
			Drawing No. Full application of soundings, curves and features from smooth sheet and chart 81086
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
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			Drawing No.

SUPERSEDES C&GS FORM 8352 WHICH MAY BE USED.