W00140-W00144

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. **Waiakane to Kawela**

LOCALITY

State **Hawaii**

General Locality **NW Coast of Maui**

Sublocality **Puuolai to Hanakaoo Point**

2000

CHIEF OF PARTY
Maxim F. Van Norden

LIBRARY & ARCHIVES

DATE

NOAA FORM 77-28
(11-72)

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

HYDROGRAPHIC TITLE SHEET

REGISTER NO. **W00140- W00144**

INSTRUCTIONS The hydrographic sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the office.

FIELD NO.

State **Hawaii**

General Locality **NW Coast of Maui**

Sublocality **Puuolai to Hanakaoo Point**

Scale **1:10,000** Date of Survey **8/01/2000 - 12/20/2000**

Instructions Dated Project No.

Vessel **LIDAR**

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

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

Soundings taken by echo sounder, hand lead, pole **SHOALS 400 Lidar**

Graphic record scaled by **Fleet Survey Team**

Graphic record checked by **Fleet Survey Team**

Evaluation by **A. Clos** Automated plot by **N/A**

Verification by **Physical Scientist: A. Clos, Cartographer: R. Shipley**

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

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

As a result, page numbers may be out of order or non-sequential.

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

UTM Zone 04

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
OFFICE OF COAST SURVEY
Pacific Hydrographic Branch
Seattle, Washington 98115-6349

November 25, 2008

MEMORANDUM TO: Captain John E. Lowell, NOAA
Chief, Marine Chart Division

THROUGH: Jeffrey Ferguson
Chief, Hydrographic Surveys Division

FROM: Captain David O. Neander, NOAA
Chief, Pacific Hydrographic Branch

Digitally signed by David Neander
DN: cn=David Neander, o=Pacific Hydrographic Branch, ou=NOAA/NOS/OCS/HSD, email=dave.neander@noaa.gov, c=US
Date: 2008.11.26 12:31:45 -08'00'

SUBJECT: Approval Memorandum for W00140-W00144
Northwest Coast of Maui, Hawaii
Puuolai to Hanakaoo Point

The Pacific Hydrographic Branch has completed an evaluation and chart application of Outside Source LIDAR Data from the Naval Oceanographic Office (W00140 – W00144). I have reviewed the data, reports and compilation to the chart. It should be noted that water level correctors were not applied to the data. However, due to the small tide range affecting the survey areas it is recommended that the uncorrected survey data be selectively charted except where specifically recommended in the Evaluation and Quality Assurance Memorandum and Chart Application Memorandum.

Within the 2008 NOAA Hydrographic Survey Priorities (NHSP), the northwest coast of Maui is listed as “Priority 3”. Except as noted in the Evaluation and Quality Assurance Memorandum and Chart Application Memorandum, LIDAR provided adequate depth information in the near shore areas where it was utilized. However, due to the object detection limitations of LIDAR and the fact that water level correctors were not applied, it cannot be stated definitely that least depths on all new and charted features were obtained. Additional fieldwork including side-scan and/or multibeam surveys of AWOIS items, approaches to harbors and anchorage areas is recommended as resources allow in order to complete bottom search and object detection requirements. It is recommended that the area encompassing LIDAR surveys W00140-W00144 remain classified as “Priority 3”.

Survey data acquired by LIDAR should be classified as Category of Zones of Confidence (CATZOC) “B” if used to update ENC’s (Seafloor Coverage: Full seafloor coverage not achieved; uncharted features, hazardous to surface navigation are not expected but may exist. Typical Survey Characteristics: Controlled, systematic survey to standard accuracy.).

cc: Chief, HSD Operations Branch N/CS31

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE OFFICE OF COAST SURVEY
Pacific Hydrographic Branch Seattle, Washington
98115-6349

July 24, 2008

MEMORANDUM TO: Captain David Neander, NOAA
Chief, Pacific Hydrographic Branch

FROM: Andrew Clos
Hydrographer Intern

Digitally signed by Andrew Clos
DN: cn=Andrew Clos, o=NOAA, ou=NOS-PHB, email=andrew.clos@noaa.gov, c=US
Date: 2008.11.26 11:28:15 -08'00'

SUBJECT: Review of Outside Source Data Surveys W00140 to W00144
U.S. Naval Oceanographic Office (NAVOCEANO)
Maui Island

I have reviewed outside source hydrographic surveys W00140 to W00144 with regard to data integrity and completeness of the data submission package, survey field procedures, data processing and quality assurance methods, and overall data accuracy and data quality. Surveys W00140 to W00144 comply with specifications and requirements set forth in the NOS Hydrographic Surveys Specifications and Deliverables Manual, with the following exceptions:

- SHOALS 400 LIDAR data acquired in this survey does not meet NOAA HSSDM requirements (equivalent to IHO Order 1) for object detection. The capability of LIDAR to meet NOAA object detection requirement is still unproven and questionable, and item investigations to either disprove charted features or acquire definitive least depths were not conducted. These data do meet NOAA HSSDM requirements for depth and position accuracy.
- Water level data was not applied to these surveys.

Refer to the Outside Source Data Quality Assurance Checklist for specific charting recommendations.

Final Recommendations:

- The data should be used to chart soundings and depth curves representing general bathymetric trends, and new shoals and features that are not currently depicted on NOAA charts 19347, 19348 and 19350.
- The data should not be used to supersede near shore features such as wrecks, rocks, obstructions, foul areas or coral reefs.
- The charted shoreline should be retained as charted.
- Bottom samples were not acquired and should be retained as charted.

Digitally signed by Kurt Brown
Date: 2008.11.26 11:33:22
-08'00'

Reviewed and approved: ________________________________

PS Kurt Brown, NOAA
Acting Hydrographic Team Leader, PHB

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE OFFICE OF COAST SURVEY
Pacific Hydrographic Branch Seattle, Washington
98115-6349

November 14, 2008

MEMORANDUM TO: Captain Dave O. Neander
Chief, Pacific Hydrographic Branch

FROM: Rick Shipley
Cartographer, Pacific Hydrographic Branch

Date:
2008.11.26
11:20:35 -08'00'

SUBJECT: Application of Outside Source Data Surveys
W00140-W00144
U.S. Naval Oceanographic Office
SHOALS 400 LIDAR

I concur with all recommendations by the reviewer Andrew Clos except where noted in their reports.

Summary of compilation:

-soundings, curves and features applied
-no rocks, shoals were superseded
-shoreline was retained as charted
-bottom characteristics were retained
-recommend aids to navigation be updated with the latest information
-no additional Dangers to Navigation were found during compilation

It is recommended that OSD surveys W00140-W00144 supersede charted information within the common area and applied to charts 19347, 19348, and 19350.

Record of Application to Charts is attached.

Review and Approved________________________ Gary C. Nelson 2008.11.26 12:27:06 -08'00'

Gary Nelson, Cartographer Team Leader
Pacific Hydrographic Branch

Registry No: W00140, W00141, W00142, W00143, W00144

State: Hawaii

General Locality: Maui

Sub Locality:

Dates of Survey: 01 AUGUST - 20 DECEMBER 2000

OSD Supplier: US Naval Oceanographic Office (NAVOCEANO)

OSD Project No: 00US16 - Surveys 00607, 00608, 00609, 00610, 00611

Reviewer: Andrew Clos **Review Date:** July 10, 2008

I. DATA INVENTORY

A. Reports

Report Type	Format	Document Title	Date
Descriptive Report or equivalent	Microsoft Word	Hawaii_final.doc, HAWAIII LIDAR ROS.doc	9/14/2004 1/31/2002
Data Acquisition and Processing Report or equivalent	Microsoft Word	Hawaii_final.doc, HAWAIII LIDAR ROS.doc	9/14/2004 1/31/2002
Horizontal and Vertical Control Report or equivalent	N/A	N/A	
System Certification Report or Equivalent	N/A	N/A	
Other			

B. Data

Data Type	Format	Description (Raw, Processed)
Smooth Sheet Sounding Plots	PDF	SHEET07.pdf, SHEET08.pdf, SHEET09.pdf, SHEET10.pdf, SHEET11.pdf
XYZ ASCII Files	Text file	sheet07.txt, sheet08.txt, sheet09.txt, sheet10.txt, sheet11.txt.
Multibeam	N/A	N/A
Side Scan Sonar	N/A	N/A
LIDAR	N/A	N/A
Single Beam	N/A	N/A

Data Type	Format	Description (Raw, Processed)
Detached Position Point Feature	N/A	No positions were taken
Kinematic / Static GPS	N/A	Data not provided.
Sound Velocity	N/A	Data not provided.
Water Levels	N/A	Data not provided.
AWOIS	None	None identified by the hydrographer.
DtoN	None	None identified by the hydrographer.
Shoreline	N/A	Data not provided.
Bottom Sample	N/A	No bottom samples taken.

Yes ___ All data open correctly and without error (MBES lines, SSS lines, VBES, Crosslines, Fieldsheets, Smooth Sheets, Sessions, DTM's, BASE grids, Mosaics, and DP's).

C. Sensors

List all sensor(s) that were used to acquire data.

Sensor	Manufacturer	System	Model	Vessel / Platform
Lidar	Optech	SHOALS	400	SHOALS AIRCRAFT
Position	Ashtech	Z-12		SHOALS AIRCRAFT
Motion	APASS			SHOALS AIRCRAFT

Comment 1 ___ Are all sensors listed above capable of meeting NOAA HSSDM accuracy and object detection requirements? Provide information in the comments section.

II. DATA ACQUISITION AND PROCESSING

A. System Calibrations and/or Certifications

Comment 2 A sensor offset and alignment survey was conducted to NOAA HSSDM requirements

No Offset values provided

N/A Patch tests were conducted for shallow-water multibeam systems

N/A Alignment bias and latency values provided

N/A Draft measurements were conducted

____ Static Draft ____ Dynamic Draft ____ Loading

N/A Draft values were provided

Comment 3 Sensors were calibrated in accordance with manufacturer requirements and NOAA specifications

No Calibration reports were provided.

B. Sound Velocity Corrections

N/A Sound velocity sampling regimen is in accordance with NOAA HSSDM requirements

N/A Sound velocity profiles were supplied

N/A All profiles appear valid

C. Water Levels

Comment 4 Water level measuring equipment and methods are consistent with NOAA equipment and methods and are capable of meeting specifications

Equipment / method used: ____

No Tide corrector files were supplied

N/A All tide correctors appear valid

N/A Water level correctors applied to sounding data

___ Verified ___ Observed ___ Predicted ___ NOAA Zoning ___ Other zoning

N/A Water level error estimate provided by CO-OPS

Water level / zoning error estimate: __________________

E. Survey Methodology

__Yes__ The surveyor has conducted adequate quality control of horizontal positioning data

__N/A__ DTM, BASE surface, and/or mosaics indicate that seafloor coverage requirements (per NOAA HSSDM) were met and no significant coverage holidays exist.

__N/A__ All least depths over shoals, wrecks, rocks, obstructions, and other features have been determined

__Yes__ The Hydrographer has conducted the required quantity of cross lines, or acquired sufficient redundant data, in accordance with the HSSDM, to assess internal data consistency.

F. Data Processing and Quality Control

__No__ An adequate description of data processing and quality control methods is provided in documentation.

Processing software used: __N/A__

__N/A__ Data processing methodology is robust enough and adequate to provide a dataset suitable for charting.

__Unknown__ Data have been reviewed and are cleaned appropriately with no noise, fliers, or systematic errors noted.

__Unknown__ Crossline agreement or redundant data overlap has been visually inspected by the hydrographer

__N/A__ Disagreements have been noted

__Yes__ A Chart comparison was conducted by the hydrographer

__Yes__ Disagreements have been noted.

III. DATA QUALITY AND RESULTS

A. Internal Data Consistency

Yes — Full resolution data was provided in order to gauge the adequacy of cleaning and/or processing of the data.

N/A — A review of the data reveals no positioning errors exceeding NOAA specifications

Yes — Crossline agreement or redundant data overlap shows no disagreements exceeding NOAA HSSDM tolerances.

N/A — **A**nomalous data (fliers, noise, etc) were apparent in the BASE surface, DTM, and/or selected sounding set.

N/A — Are there any tide errors exceeding NOAA HSSDM requirements observable in the data

No — Are there any observable SV errors exceeding NOAA HSSDM accuracy standards.

Unknown — All shoals are valid (no fliers) and the proper least depth has been retained.

N/A — Where multiple systems, platforms, and/or sensors were used, junctioning or overlapping data agree within NOAA HSSDM tolerance between platforms.

Unknown — Any statistical assessment of the data (e.g. BASE standard deviation, QC reports, etc) indicate that data agree within NOAA HSSDM tolerances.

B. Error Budget Analysis

Unknown — An error budget analysis was provided by the surveyor

- N/A — The error budget analysis indicates that data are capable of meeting NOAA HSSDM standards
- N/A — The evaluator concurs with the provided error budget analysis

No — The evaluator has conducted an error budget analysis

- N/A — The error budget analysis indicates that data are capable of meeting NOAA HSSDM standards

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

None — AWOIS Items are located within the limits of the survey.

- N/A — AWOIS Items can be sufficiently confirmed or disproved using data from this survey (Attach AWOIS pages to the certification memorandum.).

E. Dangers to Navigation

__None__ Dangers to Navigation (DTONs) were selected and submitted by the surveyor / data provider

- __N/A__ DTONs have been verified by the office evaluator.

__None__ Additional DTONs were noted during office evaluation and submitted

F. Aids to Navigation

__None__ Aids to Navigation (ATONs) were positioned during this survey

- __NO__ New ATONS were positioned during this survey
- __Yes__ Survey positions match charted positions
- __N/A__ The surveyor / data provider issued DTONs or notified the USCG for any ATON discrepancies
- __N/A__ ATON discrepancies were noted during office evaluation and submitted as DTONs.

G. Shoreline and Bottom Samples

__N/A__ The shoreline (MHW and/or MLLW lines) were included as part of this survey

- __N/A__ Surveyed shoreline matches charted shoreline
- __N/A__ Surveyed shoreline compares with NGS/RSD source data
- __N/A__ Surveyed shoreline should be used to revise nautical charts

__N/A__ Shoreline features were positioned during this survey

- __N/A__ Surveyed features match charted shoreline
- __N/A__ Surveyed features compares with NGS/RSD source data
- __N/A__ Surveyed features should be used to revise nautical charts

__N/A__ Bottom samples were acquired during this survey

- __N/A__ Bottom sample spacing was in accordance with NOAA HSSDM requirements
- __N/A__ Bottom samples should be used to update NOAA charts

Comments:

1. Data for surveys W00140-W00144 were acquired solely with the SHOALS 400 Lidar System. According to the Report of Survey (ROS), the system is theoretically capable of meeting IHO Order 1 object detection requirements in depths of 5 to 30 meters at a 4 x 4 meter spot density. At this time NOAA does not have sufficient empirical test results confirming that the SHOALS 400 system meets NOAA HSSDM object detection requirements in survey conditions. These data should not be considered to meet object detection requirements.[1]

2. Hawaii_final.doc states that "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 were entered into a "STATIC" file and are applied to the data during post processing. The STATIC file was not submitted with the bathymetric data. It is not known if the system alignment survey method meets HSSDM standards.[2]

3. HAWAII LIDAR ROS, states the SHOALS system "was calibrated prior to survey operations and whenever major system components affecting data accuracy were changed or adjusted." No calibration reports were submitted.[3]

4. No tide correction was applied to the Maui surveys.[4]

Chart Comparison

Charts used:
Chart 19347 - Channels Between Molokai, Maui, Lanai and Kahoolawe, 1:80,000. 17th Ed. December 1997.
Chart 19350 - Maalaea Bay, 1:10:000, 11th Ed. March 2001
Chart 19348 - Approaches to Lahaina, 1:15:000,7th Ed., March 2001

W00140
Comparison with Chart 19347: Generally soundings agreed within 1 fathom. In the area shown below (20.644°N, 156.451154° W) the charted value of 6.5 fathoms does not agree with the smooth sheet sounding values that range between 8 and 8.7 fathoms when converted from meters. However, according to Hawaii LIDAR ROS.doc, the smooth sheet soundings are not corrected for tides.[5]

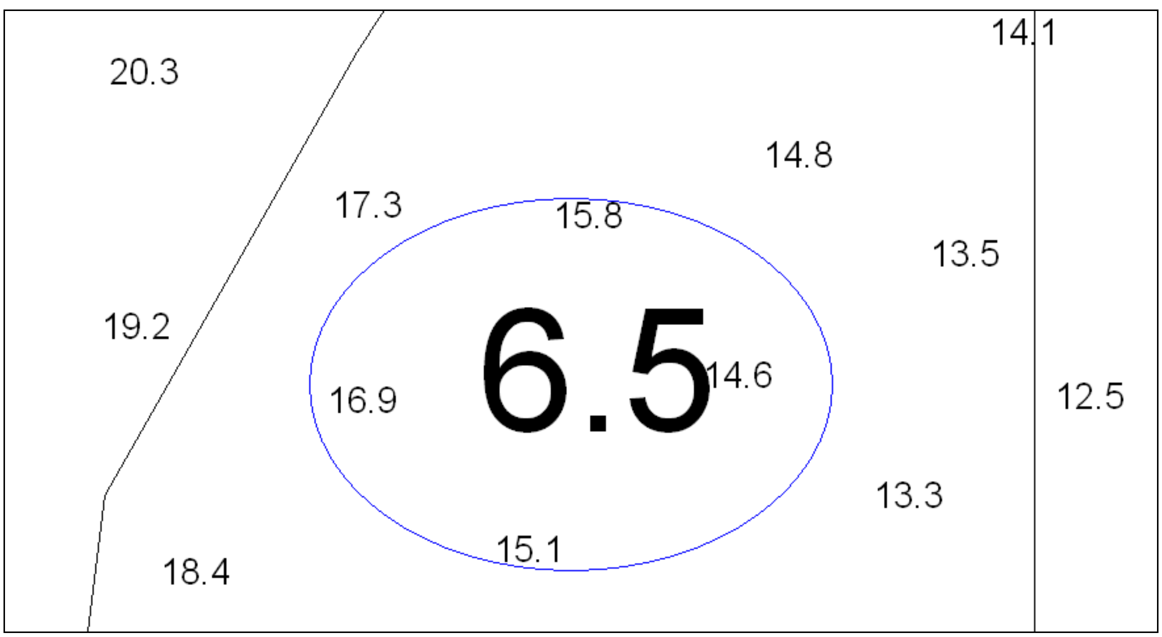

Figure 1 – Surveyed 8 fathom sounding over a charted 6.5 fathoms. Small numbers are in meters, large number (charted) in fathoms.

W00141

Comparison with Chart 19347: Generally soundings agreed within 1 fathom. In the area immediately within the charted value of 12 fathoms (20.69°N, 156.453°W), a wide range of smooth sheet soundings values were found. Converted to fathoms, depths of 14.5, 13.8, 11.8, and 15.9 are found within the '12.'[6]

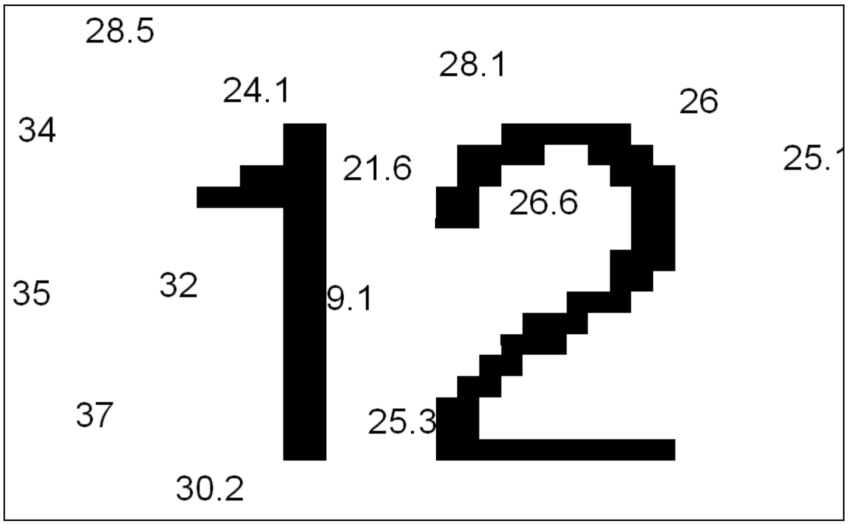

Figure 2 - High variability of smooth sheet soundings found within the charted fathom value. Small numbers are in meters, large number (charted) in fathoms.

At 20.708°N, 156.4476° W, the 3/4 fathom charted reading lies along a smooth sheet soundings values that are between 2.13 to 2.297 fathoms when converted from meters. However, according to Hawaii LIDAR ROS.doc, the smooth sheet soundings are not corrected for tides.[7]

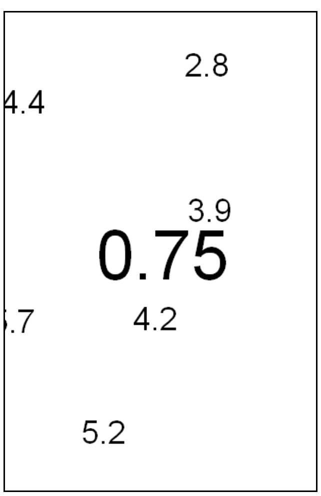

Figure 3 - Surveyed 2.2 (3.9 meters) fathoms near a charted ¾ fathom.

At 20.715°N, 156.4526°W, all of the smooth sheet soundings agree with the charted value, except one, 15 (8.2 fathom) sounding that occurs in the center of the charted number of 5 ¼.[8]

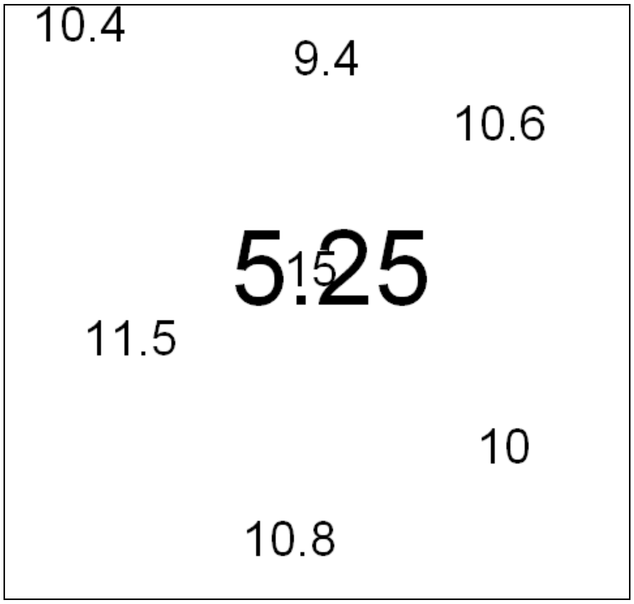

Figure 4 - All numbers agreeing except a 15 meter sounding (8.2 fathoms) that occurs right in the center of the charted value of 5.25 fathoms.

<u>W00142</u>
Comparison with Chart 19350: Generally soundings agreed within 1 fathom.

The figure below shows an area (20.7816°N, 156.482°W) where the smooth sheet sounding shows a depth of 5.58 fathoms, while the charted value in the same location is 7.333 fathoms. This disagreement is more pronounced than any of the others.[9]

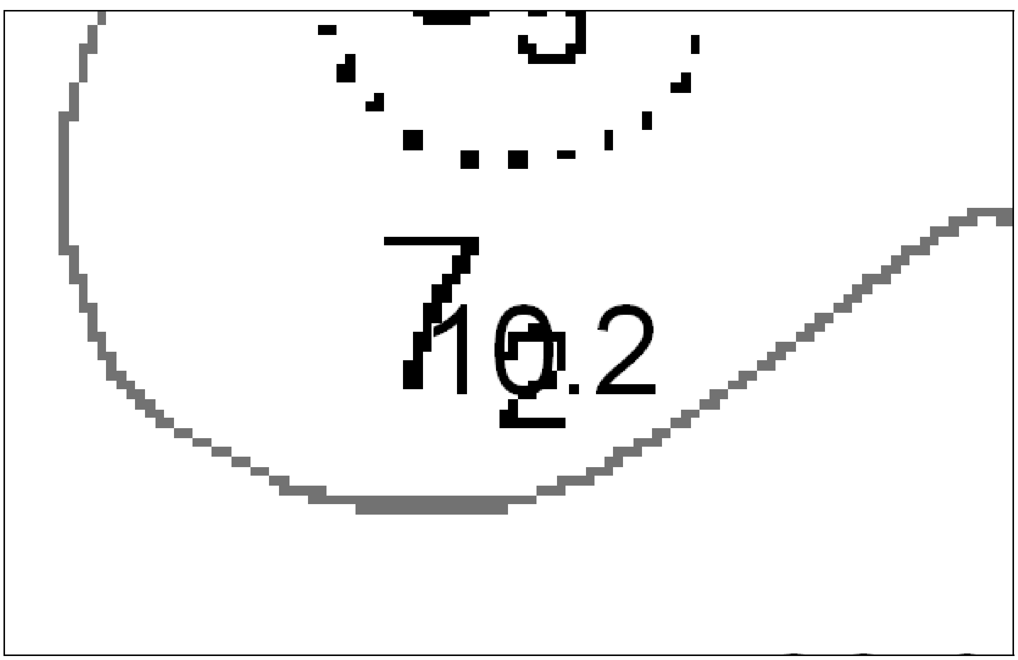

Figure 5 - 10.2 meters (5.58 fathoms) lies directly over the charted value of 7.333 fathoms. Other values on this chart had much smaller differences.

W00143
Comparison with Chart 19350: Generally soundings agreed within 1 fathom.[10]

W00144
Comparison with Chart 19350: Generally soundings agreed within 1 fathom.[11]

At 20.910°N, 156.708°W, a charted 18 fathom lies directly over a smooth sheet sounding that measures 28.7 meters (15.7 fathoms).[12]

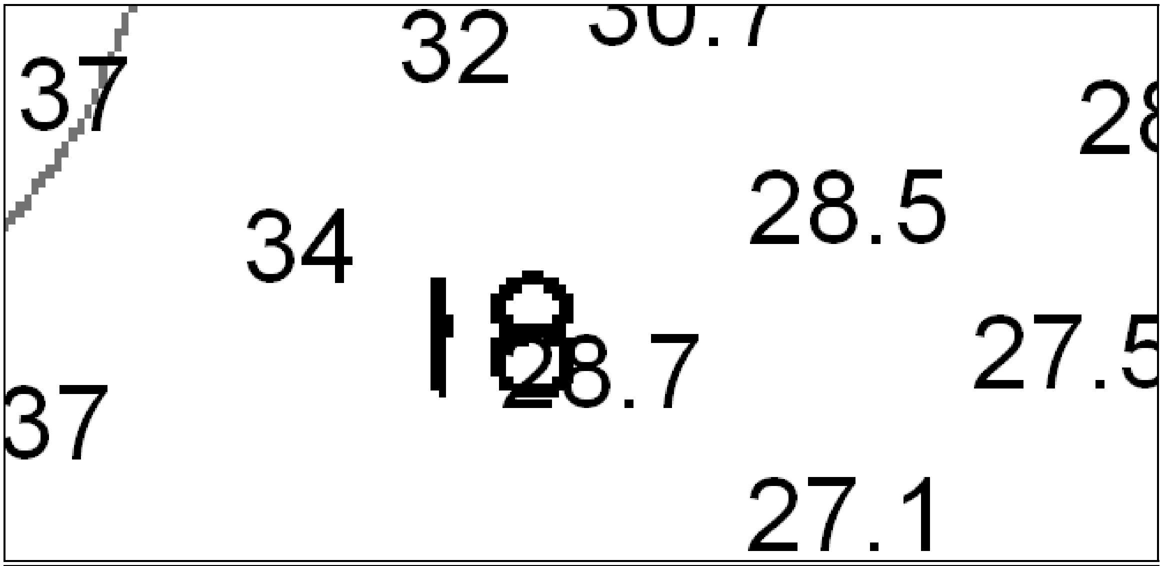

Figure 6 - 28.7 meters (15.7 fathoms) over a charted 18 fathoms.

Revisions compiled during office processing by the cartographer

[1] Concur.
[2] Concur.
[3] Concur.
[4] Concur. See approval memo dated 07/24/08, attached to this report.
[5] Concur with clarification. Chart as shown on the Hdrawing.
[6] Concur with clarification. Chart as shown on the Hdrawing.
[7] Concur with clarification. Retain shoaler charted sounding shown outside of acceptable LIDAR data. See approval memo dated 07/24/08, attached to this report.
[8] Concur with clarification. Chart as shown on the Hdrawing.
[9] Concur with clarification. Chart as shown on the Hdrawing.
[10] Concur.
[11] Concur.
[12] Concur with clarification. Chart as shown on the Hdrawing.

FILE: **HAWAII LIDAR ROS.DOC**
UPDATED: **26 MAR 2004**
BY: **Scott Ebrite SNR**

NAVAL OCEANOGRAPHIC OFFICE

Stennis Space Center, Mississippi

REPORT OF SURVEY

LIDAR

HAWAII

Vessel: SHOALS AIRCRAFT

Detachment: SHOALS PROJECT

Country: U. S.

Dates of Survey: 01 AUGUST - 20 DECEMBER 2000

Archive Number: 00US16

Areas: Hawaiian Islands
Oahu
- **Makua Training Area, Pokai Bay, leeward coast; Kaena Pt. to Barbers Pt.**
- **Kaneohe Bay**
- **MCBH Kaneohe**
- **Bellows AFS - Waimanalo Bay and Bellows Beach**
- **Kahuku**
- **Pearl Harbor/Approach**
- **Waialua Bay**

Kauai
- **PMRF - Barking Sands, Majors Bay, Waimea Bay**
- **Port Allen**

Molokai
- **Kaunakakai area and south coast, other areas**

Hawaii
- **Kawaihae Harbor and approach, other areas**

Maui
Lanai

UNCLASSIFIED

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REPORT OF SURVEY CONTENTS

1.0 General

1.1 Introduction.

The Hydrographic Survey Specification for the aforementioned areas was generated at the request of the primary Functional Customer (CINCPACFLT) in response to a DoD/US Navy initiative. This initiative is to support present and future increased naval activity and usage in WESTPAC as follows.

1.1.1 Seal Delivery Team One (SDVT-1) has requested SHOALS surveys of several training areas within Hawaii and the WESTPAC areas of Guam, Saipan, Tinian and Farallon de Medinilla (FDM). The requirement is not simply to update existing nautical charts, but to create unique high-density digital bathymetric datasets that can be used by SDVT-1 to improve the safety of their SDV training operations. SDVT-1 uses commercial GIS packages (ESRI ArcView with Spatial Analyst) to produce tailored products for their operations, including 3D perspectives of their target and training areas. Additionally, SDVT-1 has, or will be, requesting STOIC's (Special Tactical Operational Information Charts) for their training areas.

1.1.2 Pearl Harbor and Approaches
Pearl Harbor and its approaches are a safe haven for major surface and sub-surface Fleet units. The survey is required for updating charts 19AHA19366, 19AHA19362, 19AHA19369 and 19AHA19364. 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. CINCPACFLT also intends to cancel chart 19AHA19369 following NOS publication of new editions of 19AHA19362 and 19AHA19369 with necessary approach data for Pearl Harbor. CINCPACFLT would like to create a complete baseline dataset of unclassified hydrographic and topographic data for use by NOAA NOS in updating Pearl Harbor charts. These data will provide a complete bathymetric model of Pearl Harbor that will be suitable for a variety of uses, including SDVT-1 training, geospatial product prototyping, high-resolution DNC, environmental impact modeling, and harbor defenses. USACOE has recently completed a standard survey of Pearl Harbor in support of normal dredging operations and these data have been forwarded to NIMA and NOAA NOS.

1.1.3 Pacific Missile Range Facility (PMRF) Kauai
PMRF desires detailed bathymetric data inshore of the Silas Bent survey of 1995. Their test and evaluation clientele are increasingly interested in very shallow water operations. Barking Sands, the PMRF beach north of the airfield, is also used for various amphibious training operations, including major exercises (RIMPAC). Majors Bay, south of the airfield, is a major amphibious and SOF training area. SDVT-1 also requires data in Waimea Bay, between PMRF and Port Allen, and Port Allen to support training operations. Data will be used for updating NOAA NOS charts 19ACO19381, 19BHA19382 and 19XHA19386 and NIMA charts COMBT808528 and COMBT801253.

1.1.4 Bellows Air Force Station - Waimanalo Bay
Bellows Beach is one of the three primary beaches in the Hawaiian Islands used for amphibious exercises including RIMPAC. Lack of high-density data for the approach to the beach presents problems for both safety and environmental protection. High-density data will improve the margin of safety in using this beach for future exercises. Data will be used to update NIMA chart COMBT800744 and NOAA NOS chart 19AHA19358. Data will also be used for future STOIC production.

1.1.5 Makua Training Area including Pokai Bay and leeward coast from Kaena Pt. to Barbers Pt.
Makua Military Reservation is a live fire facility. Data are required to support SDVT-1 and ASDS and amphibious landing exercises at Makua Beach. Data will be used to update NIMA chart COMBT805647 and NOAA NOS chart 19ACO19357.

1.1.6 Kahuku
Data are required to support SDVT-1 training operations. Data will be used to update NOAA NOS chart 19ACO19357.

1.1.7 Kawaihae Harbor, Hawaii
This area on the leeward coast of the Big Island is used for SDVT-1 training. Kawaihae Harbor is the Sea Port of Debarkation (SPOD) for USMC units deploying to Hawaii for training at the US Army training facility on Hawaii.

1.1.8 Kaunakakai, Molokai
The area is to be used for SDVT-1 training operations. Data will be used to update NOAA NOS chart 19XHA19353.

1.1.9 Honolulu/SE Oahu
This area is to be used for SDVT-1 training operations. Data will be used to update NIMA chart COMBT800744 and NOAA NOS chart19AHA19364.

1.1.10 Kaneohe Bay, MCBH Kaneohe
This area is to be used for SDVT-1 training operations. Data will be used to update NIMA chart COMBT800744 and NOAA NOS chart 19BHA19359.

1.1.11 The Hawaiian Islands datasets consist of LIDAR data collected in support of the above requirements, and data collected in support of USACOE and USGS requirements. The delineating factor separating these data and requirements are:

1.2 IHO Standards and Coverage.

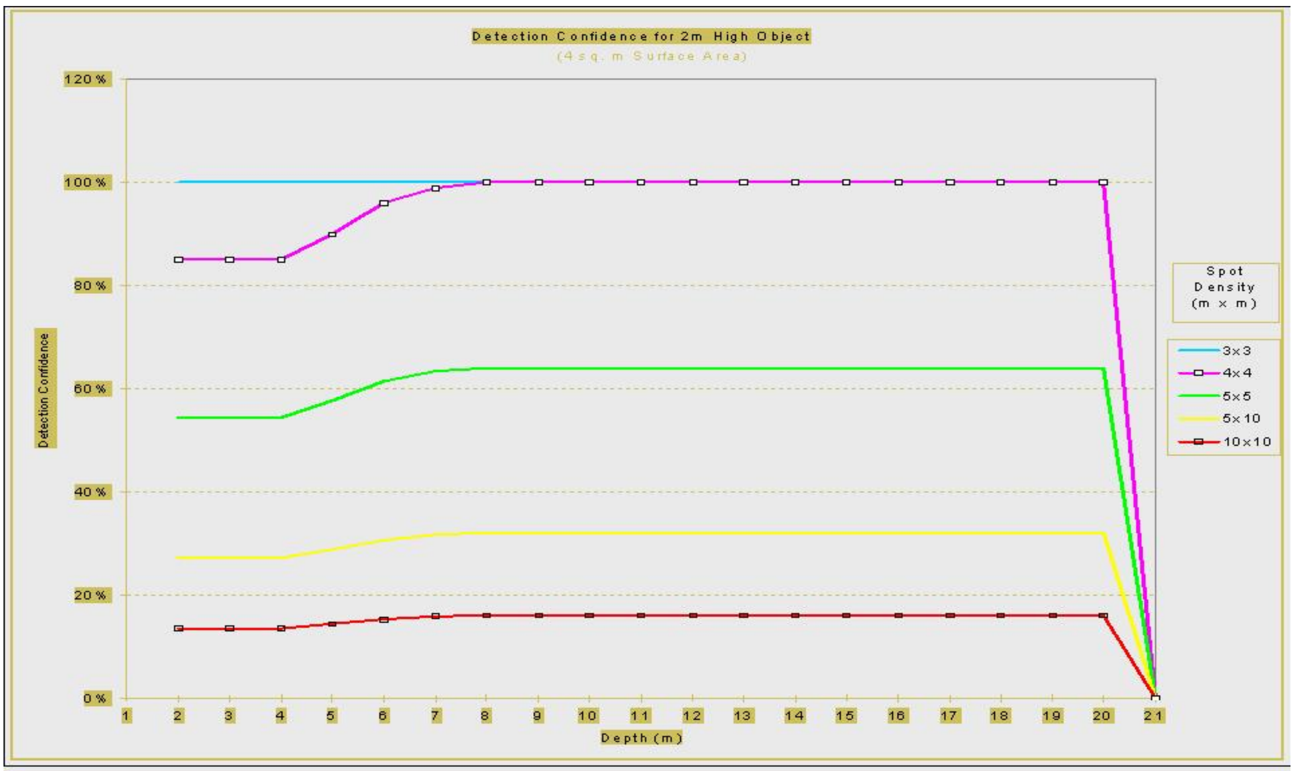
1.2.1 All Navy areas meet IHO Order 1 specifications for positional and depth measurement accuracy. Theoretically, all Navy areas meet IHO Order 1 target/object detection requirements at the 95% confidence level for depths from 7m to 20m with single flight coverage. At depths deeper than 20m signal-to-noise ratio limitations greatly reduce target detection capability, particularly for small objects (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 and a lower power laser, at 4x4 spot spacing, targets of 2 meters were detected 100% of the time in depths 5 –

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.

1.2.2 The Navy areas were surveyed at 4x4-meter spot density and with greater than 200% coverage to ensure a very high confidence of target detection. USGS areas were also flown at 4x4-meter spot density and 100% coverage. USACE areas were flown at 8x8-meter spot density and 100% coverage. USACE and USGS areas were not typically surveyed to meet charting standards, and therefore do not require IHO accuracy and do not meet Order 1 standards for target/object detection. These areas were surveyed to support coastal modeling, storm surge, coral reef and environmental studies. There are, however, exceptions to this procedure, described below.

1.2.3 Where the USACE and USGS areas were small and adjacent to and interleaved with Navy areas, the USGS and USACE areas were typically flown as part of the Navy area for operational efficiency. In such cases, these USGS and USACOE areas will have multiple coverage and also will meet Navy requirements. Regardless of spot density and coverage, all areas meet IHO Order 1 positional and depth accuracy. These specific areas are described in the graphics of Appendix A.



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

Figure 1. Target detection confidence

1.3 Sheet/Area Details.

1.3.1 Oahu

IHO Order 1 sheets consist of sheets 01 - 03, 06 - 28, and sheet 30. Portions of USACOE area sheets 29, 31, 32, 33, 34 and 35 will meet Order 1 due to multiple coverage. Sheets 04 and 05 do not meet Order 1 due to lack of multiple coverage.

1.3.2 Kauai

All west coast sheets, 01 - 13, from Port Allen north to Barking Sands and the Na Pali coast meet IHO Order 1 requirements. Sheet 14 at Nawiliwili meets Order 2 requirements due to lack of hazard/object detection.

1.3.3 Molokai

Sheets 01 - 10 along the south coast meet IHO Order 1 requirements. Sheets 11 - 18 meet Order 2 requirements due to lack of hazard/object detection.

1.3.4 Maui

All Maui sheets meet IHO Order 2 requirements. Maui sheets do not meet Order 1 requirements. NO TIDE CORRECTIONS APPLIED. Lack of double coverage to ensure target detection.

1.3.5 Lanai

All Lanai sheets meet IHO Order 2 requirements. Lanai sheets do not meet Order 1 requirements. NO TIDE CORRECTIONS APPLIED. Lack of double coverage to ensure target detection.

1.3.6 Hawaii (Big Island)

Kawaihae Harbor meets IHO Order 1 requirements. All other Hawaii areas meet Order 2 requirements due to lack of hazard/object detection. NO TIDE CORRECTIONS APPLIED other than Kawaihae Harbor and Bay.

1.3.7 Coverage. LIDAR coverage is 100% or better from above the shoreline to approximately 35m depth in all areas. Exceptions are:

1.3.7.1 Oahu - Pearl Harbor, west and north to Kaena Pt. coverage is to 50m depth.

Oahu - 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 in the 532 nm optical band. See Appendix F for Kaneohe optics data demonstrating optical properties in the bay.

Oahu - Barbers Pt. harbor, coverage very limited due to water clarity.

Oahu - Pearl Harbor, no coverage due to water clarity.

Kauai - Port Allen, harbor coverage very limited due to water clarity.

1.3.8 Hydrographic Survey Specifications:

Hydrographic Survey Specifications for Hawaii, Archive No. 00US16

1.3.9 Positioning systems (see paragraph 2.2 for further details).

ASHTECH Z-12 GPS receiver in the aircraft operated in differential mode utilizing the established US Coast Guard differential beacon network in the Hawaiian Islands.

1.4 Weather.

The survey was conducted from late summer into winter. The only weather that affected operations were the winds, occasional rain showers and seas on the windward coasts. The Hawaiian Islands fall within the North east trade winds. The winds were a continuous 15 - 25 kts. Winds flowing over the mountain ranges and funneling down through the valleys made for difficult flying in many areas, with line keeping and altitude holding nearly impossible. Many holidays resulted that required numerous re-fly's. Surf on Oahu's north and east coasts, and the Big Islands windward north and east coasts made getting complete coverage in one or two flights difficult, if not impossible.

1.5 Extraneous activities affecting the survey.

1.5.1 Honolulu International Airport operations.

This is reported to be the 15th busiest airport in the US. Initial discussions with the FAA indicated no flights would be possible within five miles of the airport, the area within the Terminal Control Area (TCA). After NAVO suggestions to the FAA to fly the survey flights during off-peak hours, we worked the survey flights into the midnight to 0500L time slot. Even at this time of day there were an average of 60 arrival/departures that required the SHOALS aircraft to vacate the area for short, though numerous, periods of time. Additionally, transitioning the flight crew from daytime to nighttime operations required a 24-hour rest period prior to and after night ops. As holidays became apparent in processing, usually after swapping back to daytime operations, we had to break flight operations for 24 hours to switch to night ops. This affected productivity and efficiency. Toward the end of the survey as time became a serious constraint, it became apparent there would be areas that did not get the required double flight coverage. This is because we couldn't continue to suffer the loss of 24 hours of survey time to swap the flight crews from days back to nights, and still meet other survey requirements within the allotted time frame. This was deemed not a serious issue in the area affected due to the relatively uniform bottom and no "surprises". 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.

1.5.2 Political concerns.

Prior to survey operations we were informed of numerous possible political concerns and sensitivities of the island residents. These were primarily noise abatement, environmental and governmental intrusion issues. We were informed by the FAA that residents are particularly sensitive to noise with respect to aircraft over-flight, and to expect many complaints concerning our low flying aircraft. During the course of five months of surveying only one noise complaint was received. Local officials informed us of native Hawaiian sensitivities and suspicions with regard to anything government or militarily related, mostly in reference to politically charged land use issues. No problems were encountered.

1.5.3 Surfers and Boogie boarders.

Due to the popularity of Hawaii's beaches and surf, some lines had to be rescheduled to avoid "lighting up" the beach goers and wave riders.

2.0 Geodetic Control

2.1

Horizontal Datum:	WGS-84
Projection:	Transverse Mercator
Vertical Datum:	MHW (MLLW for LIDAR-derived topography)
Sounding Datum:	MLLW
Spheroid:	World Geodetic System of 1984

A vertical datum of MLLW for LIDAR-derived topography is contrary to the standard MSL datum for vertical elevations. All LIDAR data is referenced to the sea surface, thus LIDAR topography is referenced to the sea surface which is referenced to MLLW. The only exception to this is with kinematic GPS surveys utilizing On-The-Fly (OTF) processing techniques where the data are referenced to the ellipsoid. The Hawaii survey DID NOT USE OTF techniques.

2.2 Existing and New Control Used

N/A

2.3 Datum shifts

Datum shifts were not required for the survey.

2.4 Horizontal Control Reports

N/A

2.5 Station Descriptions/Recovery forms

N/A

2.6 **Sounding Datum**: Mean Lower Low Water (MLLW).

3.0 Digital Surveying System

3.1 Data acquisition system

SHOALS airborne system.

LIDAR Characteristics:

Laser type	Nd:YAG flashlamp-pumped
Wavelength	1064 nm and 532 nm
Pulse Energy	15 mJoules @ 1064 nm
	5 Mjoules @ 532 nm
Pulse Duration	9 ns @ 1064 nm
	6 ns @ 532 nm
Beam Divergence	12 mrad
Initial Beam Diameter	0.3-0.5 cm
Pulse Repetition Rate	200 Hz
Scan Rate	2.7 kHz

3.2 Data processing systems SHOALS Data Processing System

3.2.1 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. Time-tagged position and depth, the *.out file and laser waveform files were then transferred to the NAVOCEANO system. Data quality control and validation were carried out using the NAVOCEANO Area Based Editor running under LINUX.

4.0 Coverage See Appendix A-1

5.0 Calibrations

5.1 Positioning Systems

5.1.1 No formal calibrations of the Ashtech AZ-12 receivers operating in the DGPS mode were conducted in the field. However, the internal accuracy (precision) of the system was monitored by the SHOALS system utilizing standard positional QC (HDOP, PDOP, and SNR) techniques.

5.2 LIDAR System

5.2.1 The LIDAR system was calibrated prior to survey operations and whenever major system components affecting data accuracy were changed or adjusted. Re-calibration is required and was done when the laser head, etc. was changed. Bench calibration of the laser is conducted prior to installation. Calibration over a measured distance is done after the system is installed in the aircraft. This is a procedure comparable to a SONAR bar check, with the laser pulsed at a target over a known distance. Airborne roll calibration is done prior to survey. This is essentially a Roll bias type of calibration against the water surface.

5.3 Hydrographic Survey Platform Characteristics

DeHaviland Twin Otter Aircraft, operated by Kenn Borak Air of Calgary, Alberta, Canada.

6.0 Hydrography

6.1 Sounding Development

120-meter swath at 4x4 meter spot density. Greater than 200% coverage in Navy areas separated by a time span of several hours. USGS areas were covered at 4x4-meter spot density at 100% coverage. USGS areas along Oahu's south coast were covered at 200% because of their small size and proximity to Navy areas. USACOE areas were covered at 8x8-meter spot density and 100% coverage. This is also discussed in 1.1.13.1 and 1.1.13.2.

6.2 Sounding Selection

NAVOCEANO PFM sounding select and PFM sounding extract software.

6.3 Cross check agreements

Standard crosscheck lines were not run. All Navy areas required two-flight coverage, with the second flights flown some time after the first flights (4 hours to several days). This survey development technique and adjacent line overlap proved more than sufficient to identify any positional or tide correction problems.

Tide correction problems were identified early in the survey. The problem was not with the tides themselves, but with application of the tide correctors. There were three primary problems. (1) Extraneous and unprintable (viewable) ASCII characters contaminated some tide corrector files such that the tide would not apply when APPLY_TIDES was run, and no error message issued. These were identified early and resolved. (2) A data file time stamp problem was identified in the OPTEK airborne software. When the day changed over at midnight GMT a bit is supposed to be set in the *.fl file. This didn't always happen. However, the time stamp was not reset to zero, just continued. As ping time is derived from the ping counter, the tide correctors were being applied from the wrong day. (3) Four data file format changes occurred of which NAVO was never informed. Three of these affected data time. Addition to these main three problems, a couple of errors were discovered in the tide zone polygon definition files. One polygon was not closed and another had an extraneous point that caused the polygon to cross several others. These errors were all corrected and tides re-applied at NAVOCEANO. Currently, there are no discrepancies in the tide corrections and all soundings are properly corrected.

6.4 Agreement with Existing Charts

See Appendix C for a synopsis of chart and data comparison. The highly detailed LIDAR data show more features. Numerous wrecks indicated along Oahu's south coast were not detected in the LIDAR data. Status and/or existence of these wrecks is unknown.

6.5 Agreement with Prior Surveys

Due to the short-notice nature of the tasking and rapid generation of the definitive report, previous survey data were not made available and therefore neither a critical nor favorable comparison can be made.

6.6 Navigational Aids

Navaids were not positioned during the course of this survey. No tasking for this was designated and no suitable equipment was available. Discussions, however, with the Honolulu Harbor Master, Hawaii Ports and Harbors Commission, Harbor pilots and the USCG district revealed no discrepancies with charted navaids and the Notice to Mariners.

The only navaids positioned were a Navy-maintained buoy off PMRF Kauai and the observation tower at the Makua Training Area, Oahu.

Buoy designated "TANGO"	Position:	N 22 00.330'	W 159 47.557'
Tower, Makua	Position:	N 21 31' 43.56"	W 158 13' 37.81"

6.7 Shoreline

The shoreline source was initially generated from the vector shoreline used in the DNC of the area. This should be revised where possible using high-resolution shoreline derived from the zero contour obtained from the LIDAR datasets.

7.0 Sailing Directions

No discrepencies were noted from discussions with harbor masters, harbor pilots or the USCG.

7.1 General

N/A

7.2 Landmarks

N/A

7.3 Cautions

N/A

7.3.1 Coastal Pollution

None noted although water quality in the harbors is somewhat degraded in comparison to that of the open ocean, primarily as a result of increased turbidity due to vessel activity and reduced circulation. Local environmental awareness, however, results in minimal pollution.

7.4 Anchorage and Moorings

N/A

7.5 Photography

Photographs of selected areas of shoreline were taken in support of future STOIC production in Navy exercise areas. Areas that were photographed are the Makua Training Area, Pokai Bay, Waimanalo Bay (Bellows AFS), Kahuku, MCBH Hawaii at Kaneohe (east of Pyramid Rock), PMRF and Majors Bay, Kauai.

8.0 Tides and Tide Gauges

8.1 NOAA-maintained automatic tide gauges are at the following locations:

Honolulu Harbor, Oahu
Mokuoloe, Oahu (northern Kaneohe Bay)
Nawilili, Kauai
Kawaihae, Hawaii

See Appendix B-1 for NOAA tide station descriptions.

8.2 Tide zones were developed by NOAA from historical data from these gauges.

The tidal zoning scheme is detailed graphically in Appendix B-2.

8.3 Additionally, NAVOCEANO installed backup gauges on Oahu at the Barbers Pt. Harbor and the Waianae small craft harbor. On Kauai NAVOCEANO installed a tide gauge at a small craft harbor just south of PMRF between Kekaha and Waimea. NOAA gauges supporting the zoning were located on the windward side of the islands, well away from much of the survey area. The NAVOCEANO installed gauges were installed as a backup to the NOAA gauges. Furthermore, the data from the NAVOCEANO installed gauges were used to confirm the NOAA tide-zoning scheme.

8.4 Tide Zone Accuracy

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

9.0 Currents and Tidal Streams

See Appendix E for a summary of Hawaiian currents from published literature. *Informational for tactical products*.

9.1 Large-scale Currents

Source: www.atftp.soest.hawaii.edu.
The average currents around the Hawaiian Islands form a large Gyre centered at about 32N. The geostrophic basin scale clockwise circulation sweeps the islands roughly east to west and intensifies southward. At and near the surface, currents driven by the wind combined with the geostrophic currents result in more complicated flow patterns.

South of Hawaii, the surface North Equatorial Current (NEC) reaches an average westward speed 0.35 knot at 13 N, and gradually decreases towards the islands. Between 18 N and 22 N, the currents are strongly influenced by the islands. The NEC forks at Hawaii; the northern branch becomes the North Hawaiian Ridge Current (NHRC), and intensifies near the islands with a typical speed of 0.5 knots. West of the islands, two elongated circulations appear. A clockwise circulation is centered at 19 N, merging to the south with the southern branch of the NEC. A counter-clockwise circulation is centered at 20-30 N. Between them is the narrow Hawaiian Lee Counter Current (HLCC). Surface currents over the western islands and north east of the NHRC are variable. Current variability shown below indicates numerous eddies or swirls in the lee of the islands.

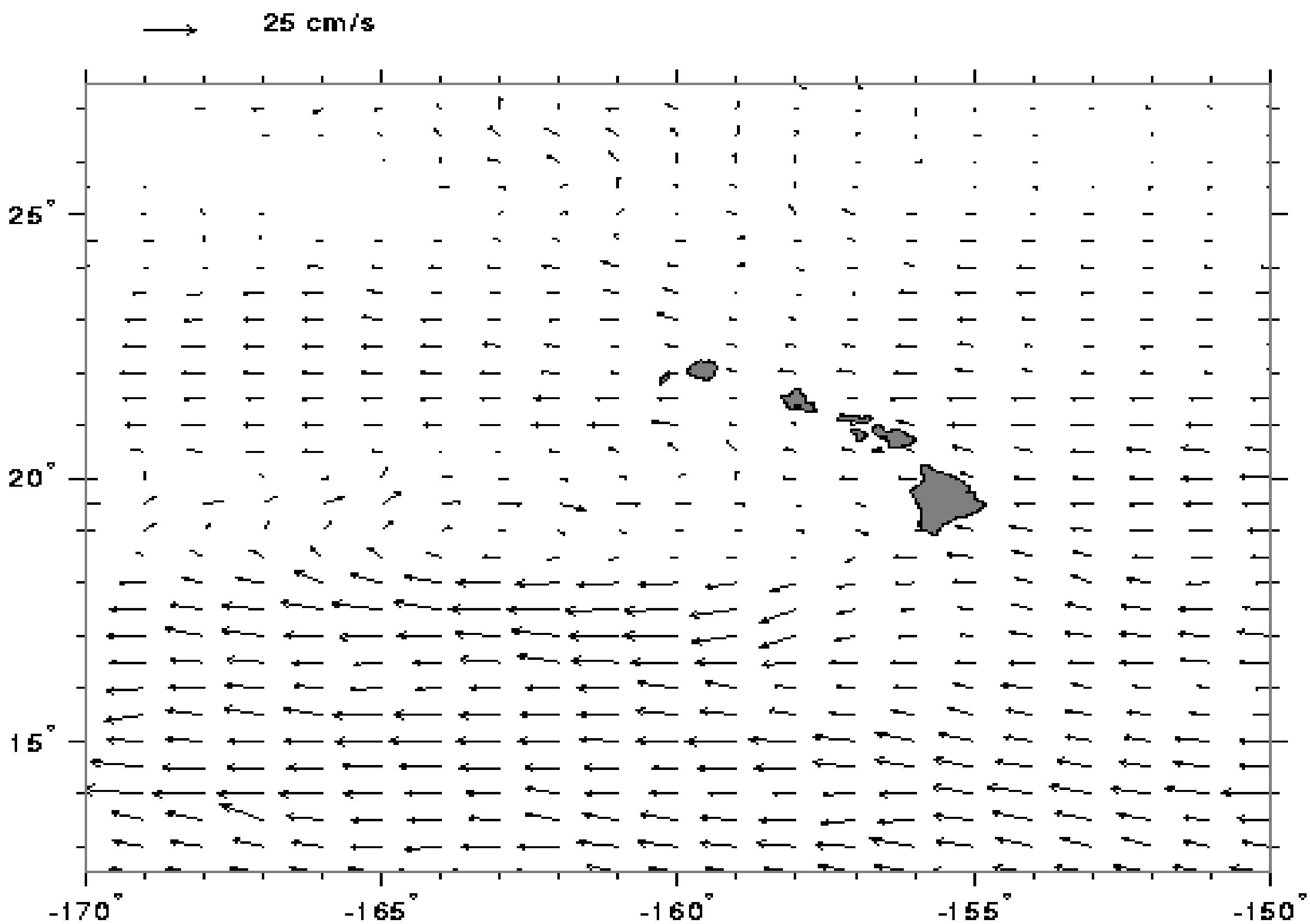


Figure 2. Large-scale ocean circulation around the Hawaiian Islands.

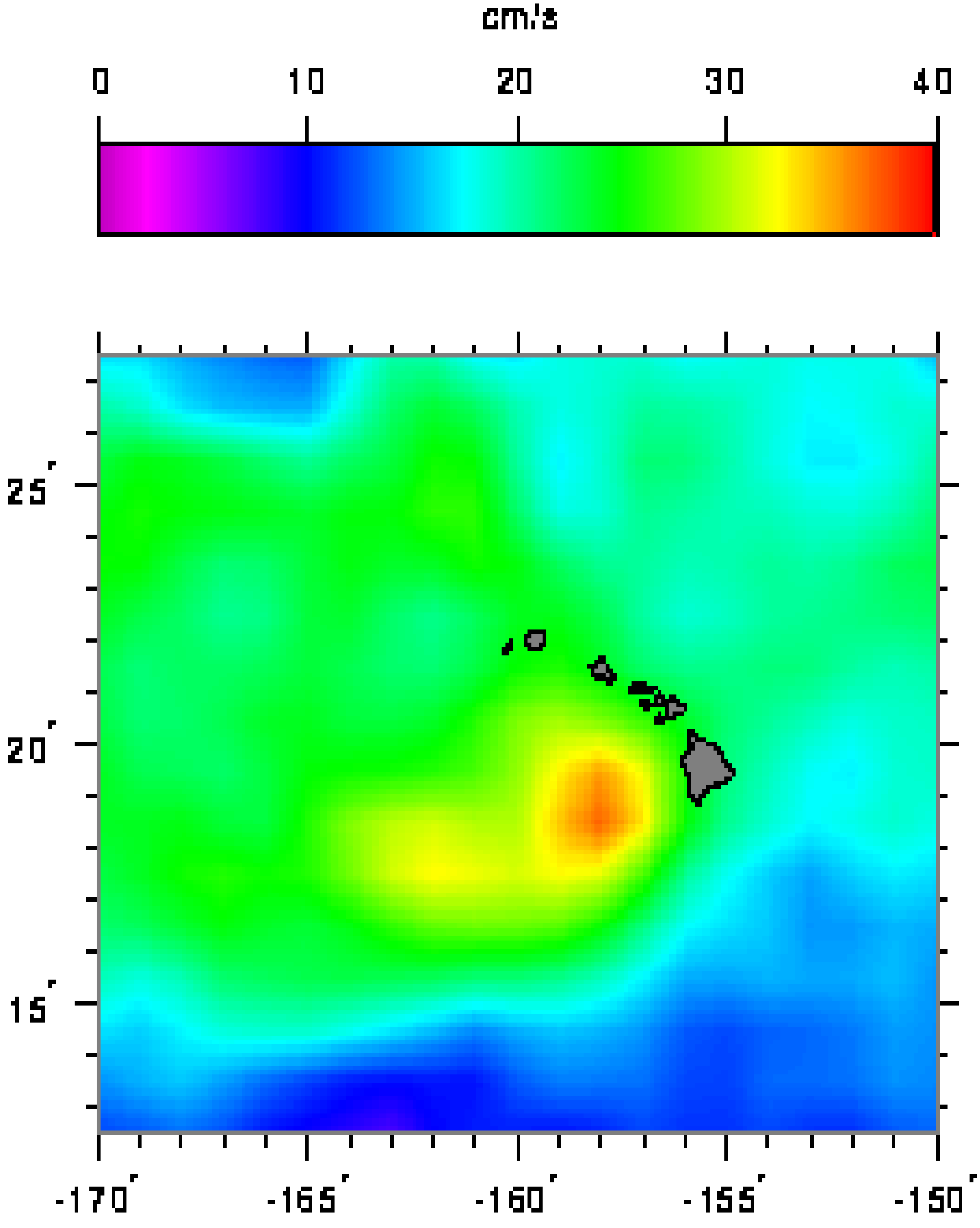


Figure 3. Large-scale ocean circulation variability around Hawaii indicates numerous eddies and swirls which obliterate slower average circulation.

9.2 Regional currents

The island chain affects the ocean by two important mechanisms: interactions of the islands with the large scale ocean currents, and wind speed variations in the lee of the islands.

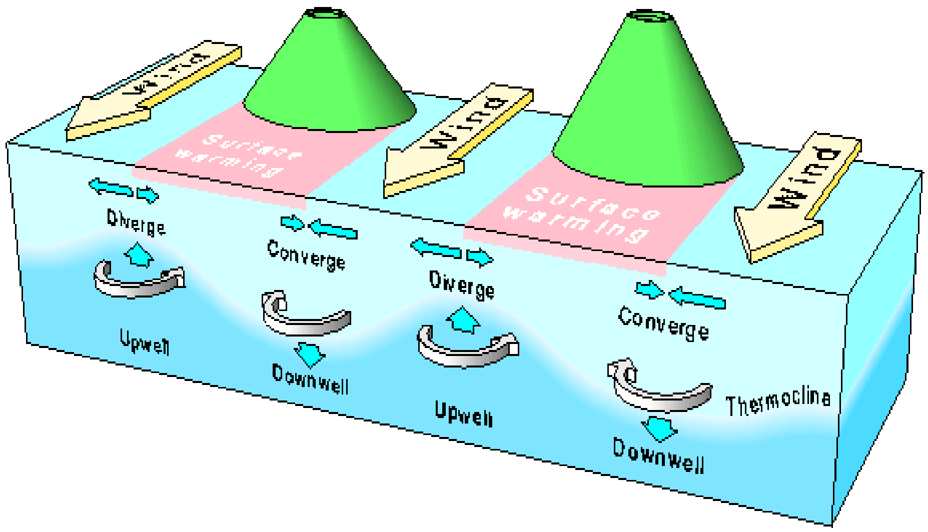


Figure 4. Regional current formation due to the modifying effect of land masses on large-scale circulation.

At the northern and southern boundaries of each island, the trade winds with speeds of 22-44 mph are separated from the calmer lee by narrow wind shear lines. Locally, the depth of the surface mixed layer depends on wind speed: in the channels, deep mixed layers are observed; in the lee, stirring by the wind is not sufficient to mix down solar heating and intense daytime warming of the ocean surface results. Sharp surface temperature fronts, sometimes reaching a difference of 4 C, are often associated with these wind shear lines.

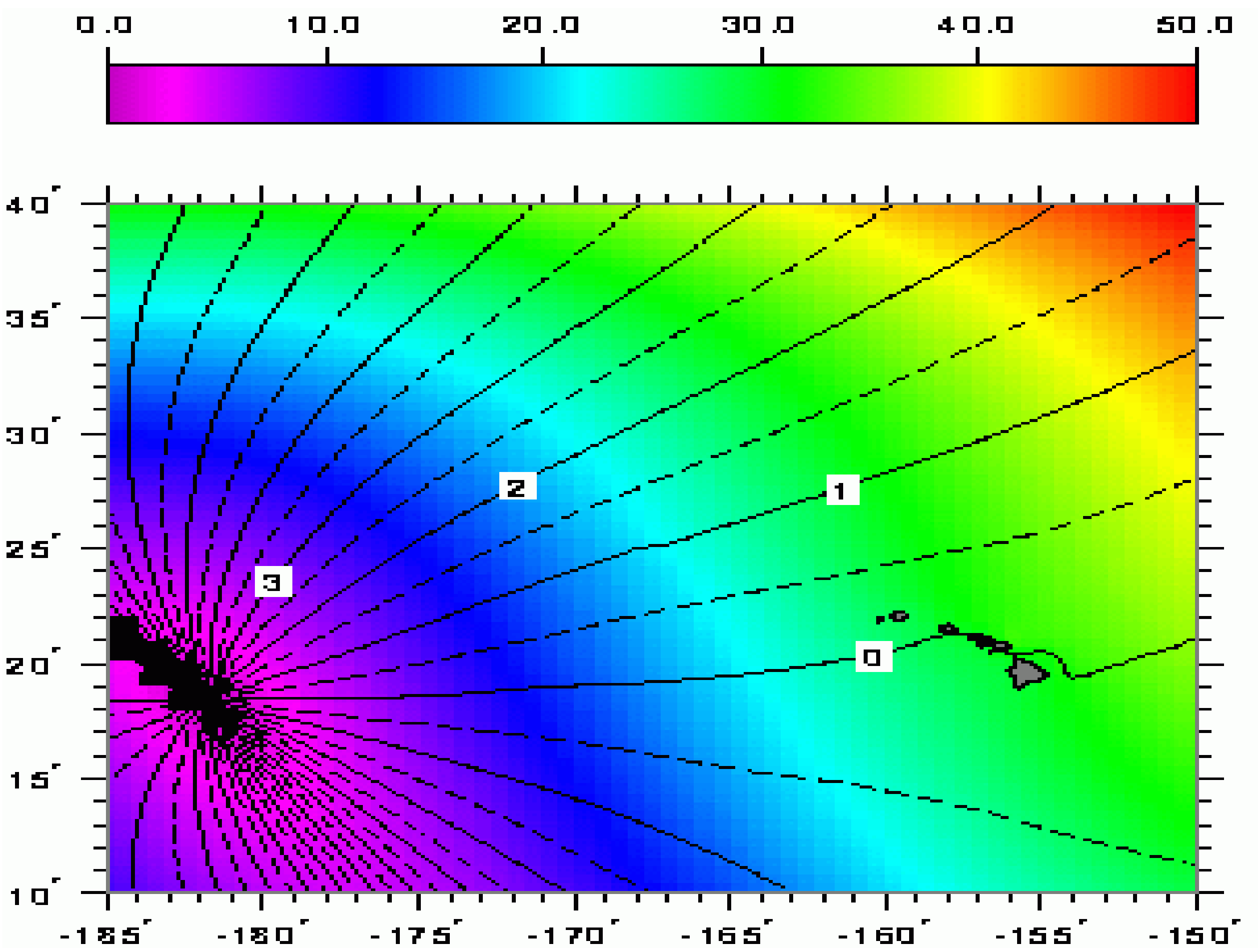
Variations of wind have subtle effects on current patterns. When wind blows for many days over a surface mixed layer, the water moves to the right of the wind in the Northern Hemisphere due to the earth's rotation. Water therefore moves away from the northern shear line. To compensate for this divergent surface motion, water upwells from greater depths, appearing as a cold spot at the surface. Similarly, water moves towards the southern shear line, resulting in a deepening of the thermocline there.

Geostrophic currents result from these variations of thermocline depth, in the form of intense counter-clockwise eddies under northern shear lines, and somewhat less intense clockwise eddies under southern shear lines. This process is quite dramatic -- the depth of the mixed layer in the lee of the island of Hawaii can vary from less than 20 m in the counter-clockwise eddy, to more than 120 m in the clockwise eddy. The large counter-clockwise average circulation is believed to result from the repeated occurrence of eddies spun up by the shear lines of the islands of Maui and Hawaii.

Eddies can also be generated when intense currents such as the NEC impinges on the islands. The large clockwise circulation south west of the island of Hawaii appears to be caused by many such clockwise eddies repeatedly formed near South Point.

9.3 Tidal Currents and other Oscillations

On scales of oceanic basins, tides exist as very long waves propagating in patterns determined by their period and the geometry of the basin. The figure below shows the response of the North Pacific to the tidal period of 23 h 56 min, the largest diurnal component. Phase lines along which high tide occurs at the same time converge to an amphidrome point west of Hawaii where the tidal range is zero. Phase lines rotate counter-clockwise around this amphidrome, so that the offshore diurnal tide reaches the Hawaii island first, then sweeps across Maui, Oahu and



finally Kauai.

Figure 5. Response of the North Pacific to the longest duration tidal component (23h 56m) and the effect of the Hawaiian land mass.

Local bathymetry affects the ranges and phases of the tides along the shore, as the tidal waves wrap around the islands. For example, high tide at Haleiwa on the north shore of Oahu occurs over an hour before high tide at Honolulu Harbor.

Tidal currents result from tidal variations of sea level, and near shore are often stronger than the large scale circulation. Current meter records collected off Oahu, Maui and Hawaii (below) show that semi-diurnal and diurnal tidal currents tend to be aligned with the shoreline. Due to high variability of tidal currents around the islands, however, this statistical representation may not correspond to the flow at a particular time -- tidal currents cannot be predicted as precisely as sea level. Strong swirls often result from tidal currents flowing around points and headlands, and present hazards to divers.

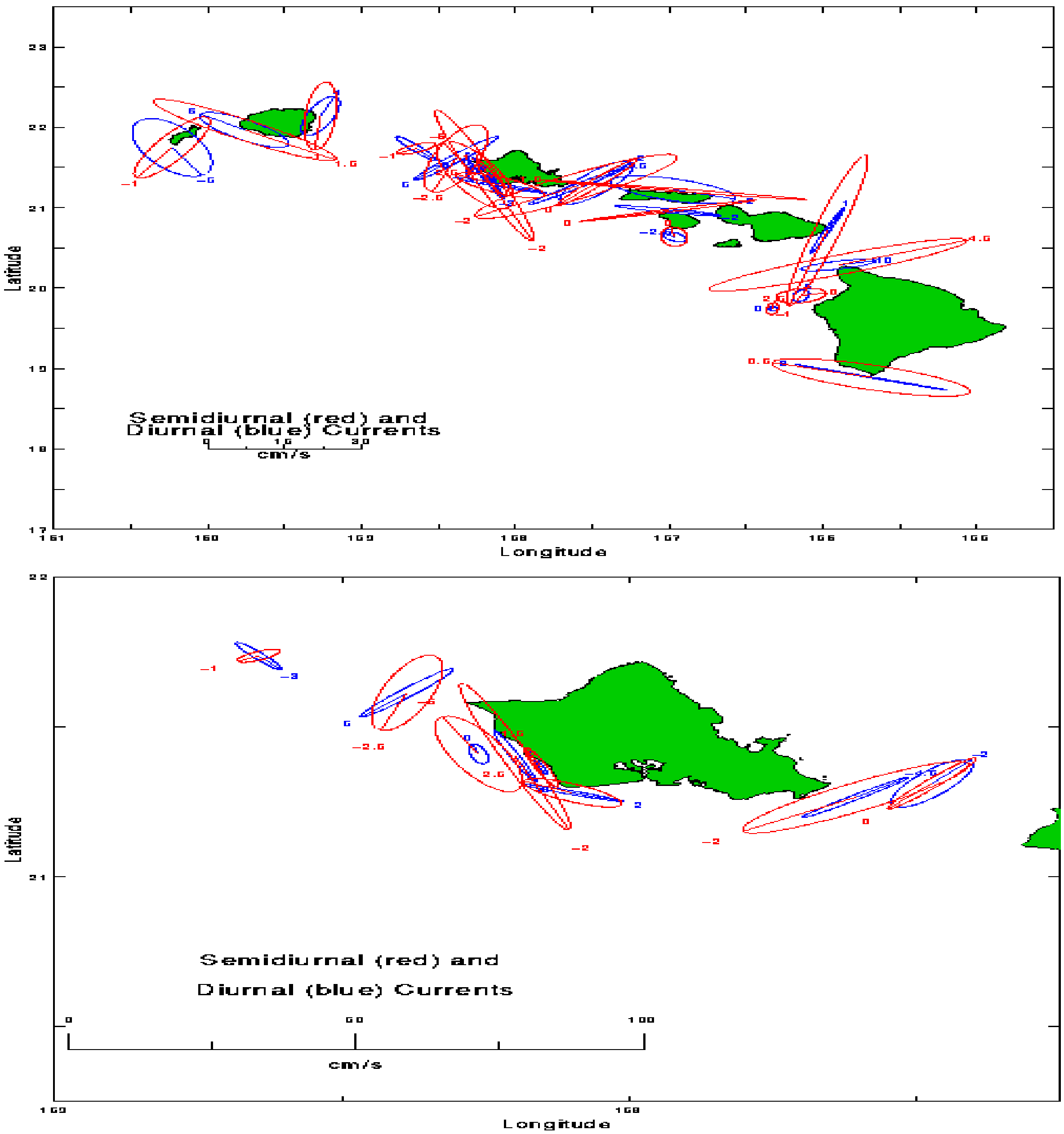


Figure 6. Representative tidal current flow around the Hawaiian Islands. Diurnal and semi-diurnal tidal flows tend to be aligned with the shoreline. Strong eddies are often found around points and headlands.

Variations of sea level and currents at periods of 1.5 to 3 days are also observed around the Hawaiian islands. Although they manifest themselves as oscillations just like tides, they are not forced by gravitation, but by time-varying winds and possibly swells. They displace the sea surface by only a few centimeters, but the depth of isotherms by tens of meters. Such oscillations, usually occurring during the winter, may be associated with currents up to 1 knot, and horizontal water displacements of 8 km (5 miles).

10.0 Seabed Topography and Texture

Seabed topography is derived from the LIDAR data. No bottom samples were collected.

10.1 Near Shore Seabed Topography

Numerous coastal areas in the Hawaiian Islands are exposed to a Predominately northerly swell for most of the year. During the winter months the swell becomes quite significant. As a result the beaches and near shore areas are quite dynamic. Oahu north shore beaches undergo re-sculpting during the winter months. The same occurs along the leeward west coast where the beaches and near shore of Makua and Makaha are significantly altered. Along Kauai's northwest Na Pali coast the beaches completely erode in winter, then reappear in the spring. Along Barking Sands, and Majors Bay (Waiokapua Bay) Kauai, north and south of PMRF, beaches and near shore are quite dynamic during any time of high swell and rough surf.

Figure 7. Barking Sands, Kauai. Near shore seabed topography.

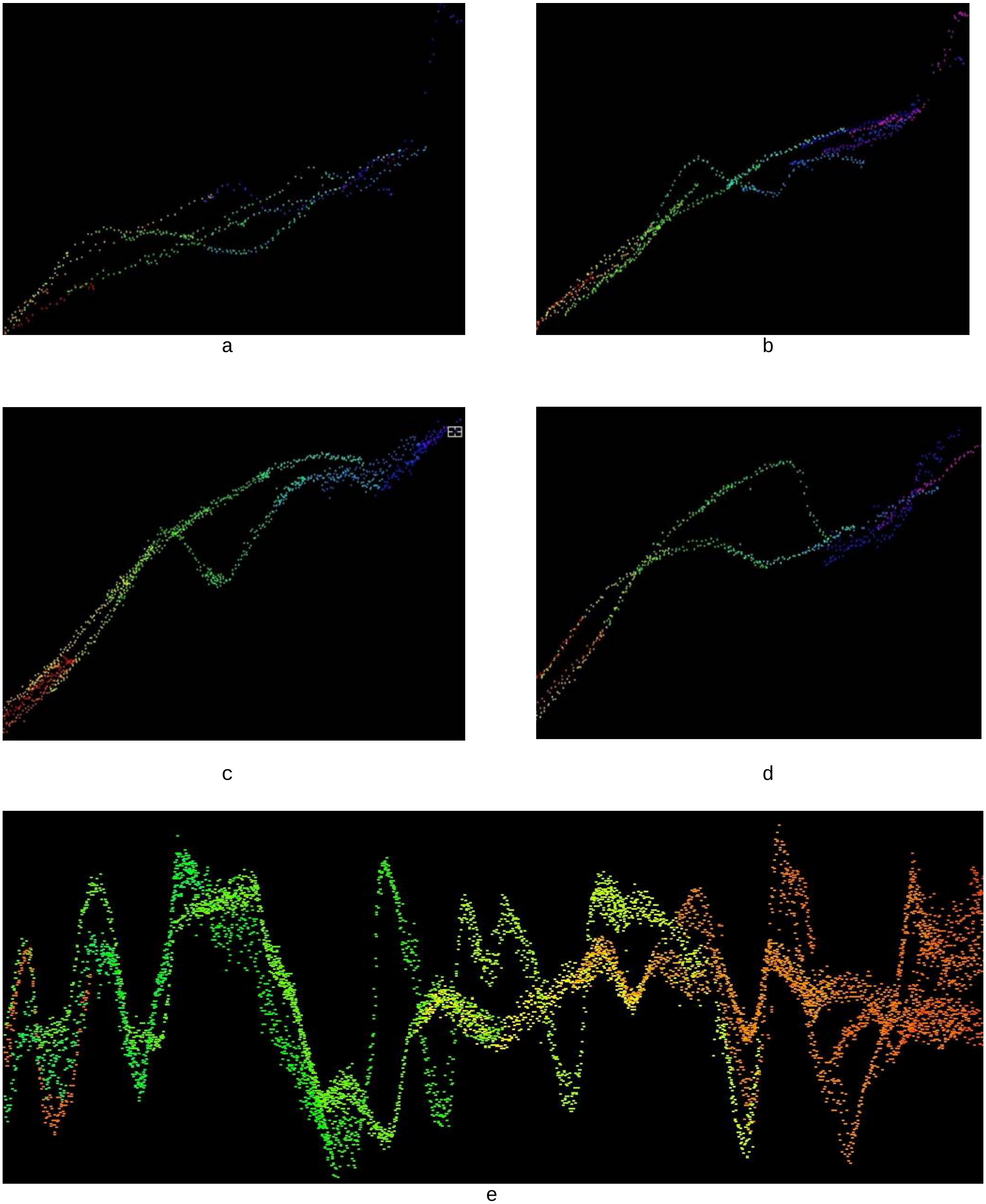


Figure 8. Series of near shore seabed to beach profiles from the area of Barking Sands, Kauai depicted in Figure 7. Insets a-d are west to east cross sections. Inset e is from the north east to southwest along the full length of the near shore.

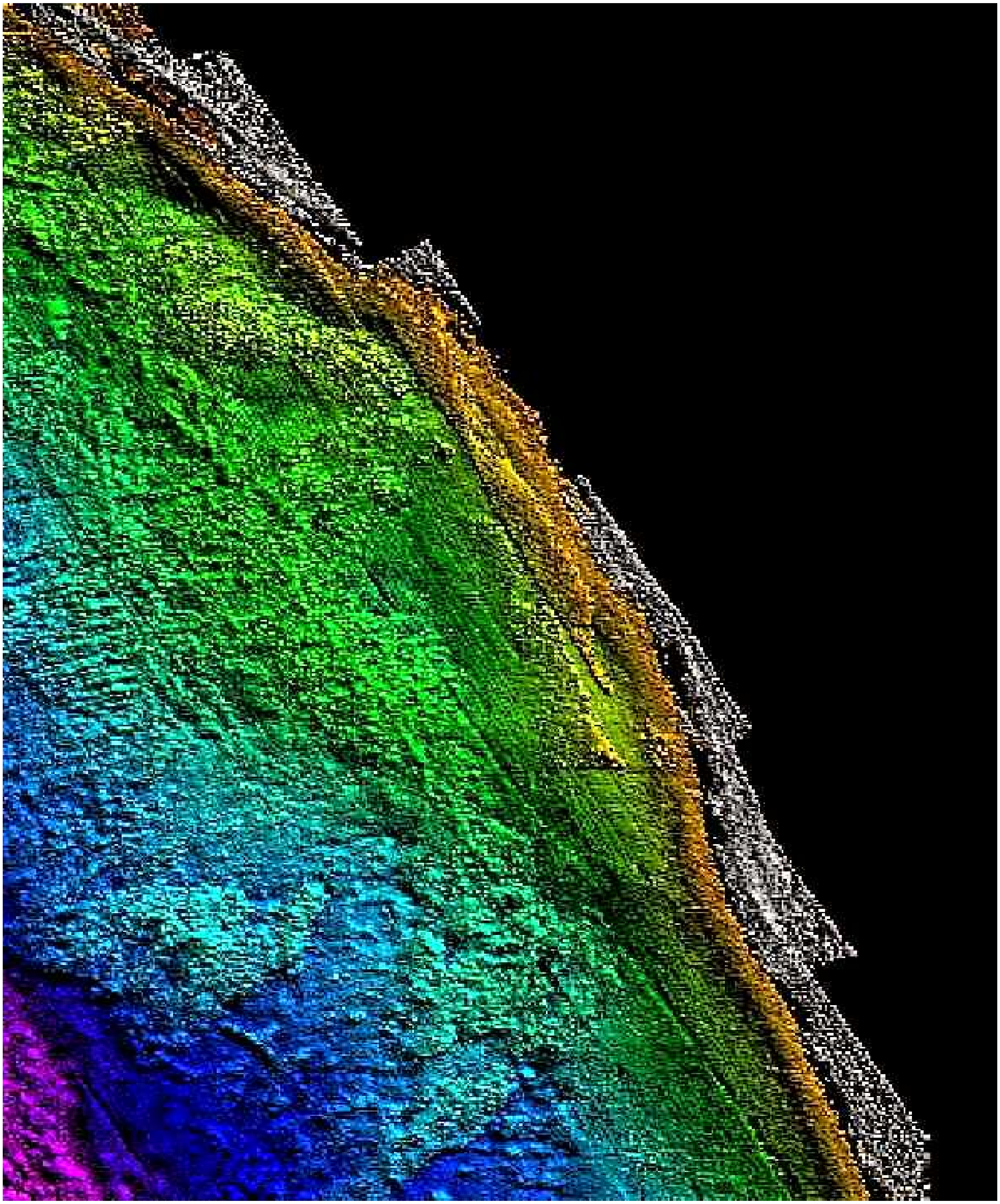


Figure 9. Majors Bay (Waiokapua Bay) Kauai showing near the shore seabed.

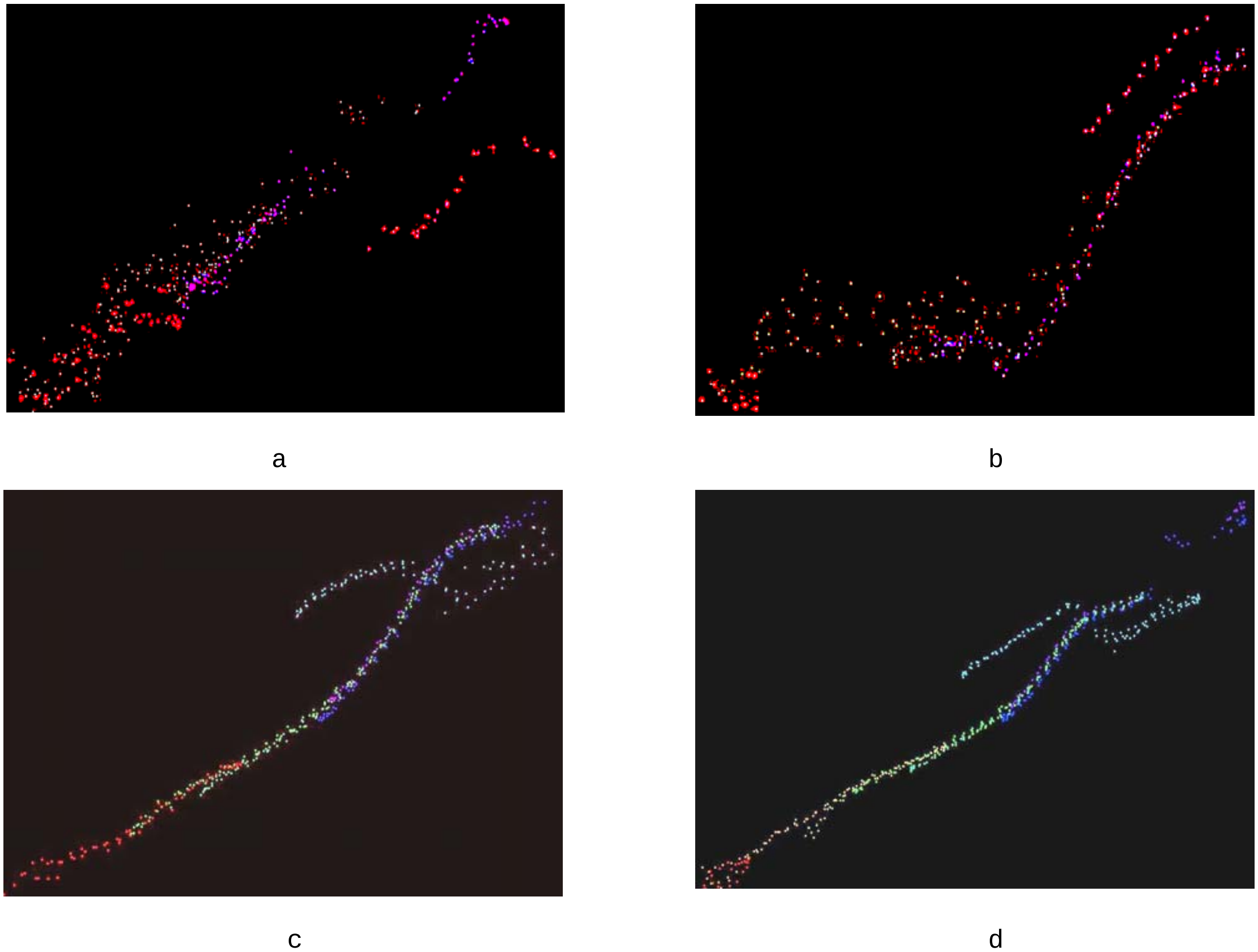


Figure 10. Series of near shore seabed to beach profiles from the area of Majors Bay (Waiokapua Bay) Kauai depicted in Figure 9. Insets a-d are west to east cross sections. Colors represent datasets from different days. These cross sections cover a time span of 6 weeks.

11.0 Charted and Uncharted Wrecks and Obstructions

Targets are listed in Appendix D. Other than what is listed, no other wrecks, objects or targets, charted or uncharted, were detected or observed with the LIDAR system.

12.0 Charted and Uncharted Lights, Buoys and Piers

N/A

13.0 Ancillary Observations

13.1 Meteorological Data

N/A

13.2 Biological Observations

N/A

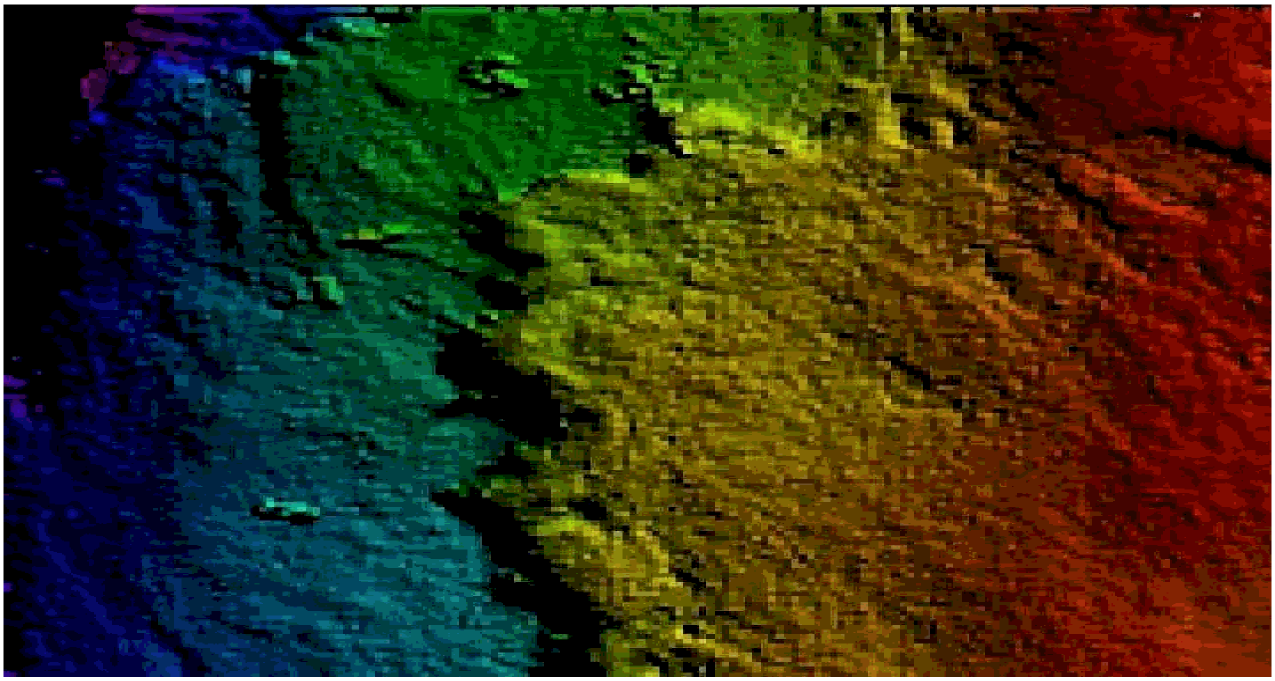


Figure 11. Wrecks and wreckage off Oahu's leeward west coast between Maili Pt. and Waianaae. Charted as fish haven and wrecks. One of these is believed to be the "Mali", a popular dive spot.

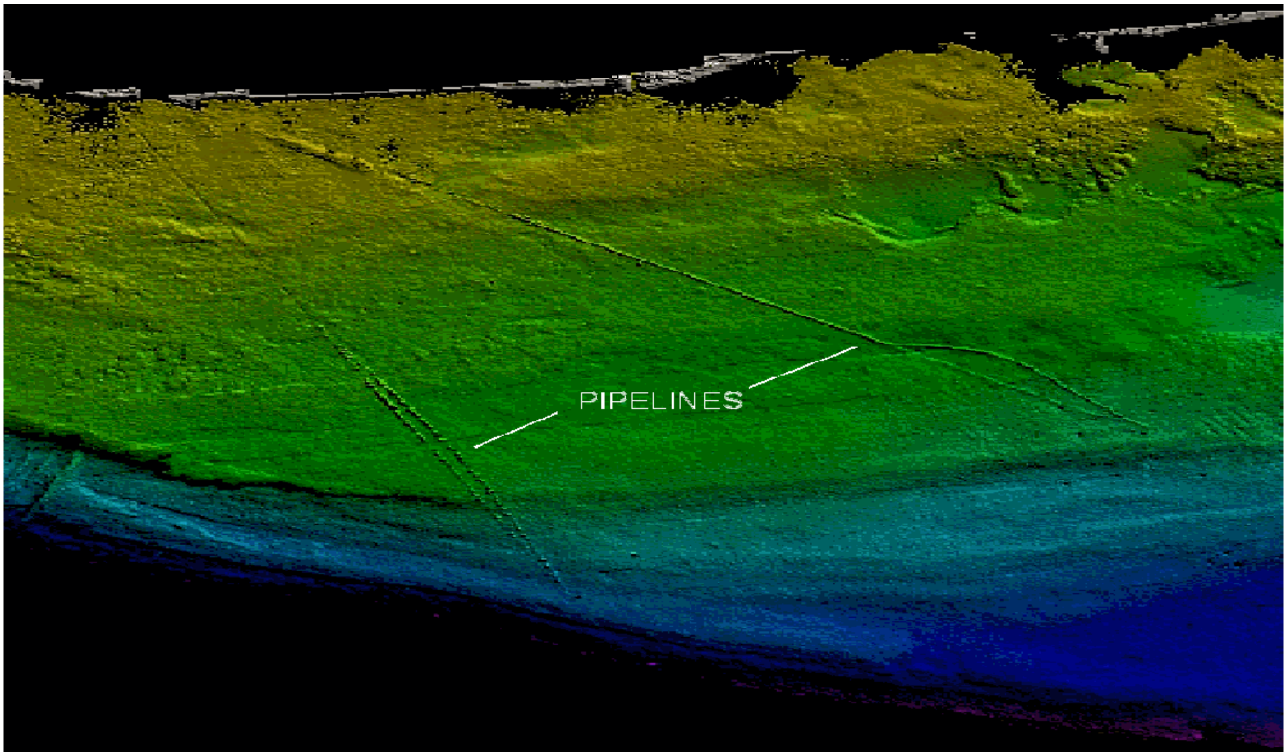


Figure 12. Offshore oil terminal pipelines off Barbers Pt. Oahu.

Figure 13. Barbers Pt. Oahu. Offshore oil terminal

14.0 Accuracy of Soundings

Sounding accuracy meets IHO Order 1 in all areas. The survey meets Order 1 in Navy areas and some USGS areas because of multiple flight coverage and object detection. IHO Order 2 in USACE and USGS areas due to lack of multiple coverage and inability to ensure 100% object detection.

14.1 Assessment and Evaluation

Assessment of the accuracy of 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.	Heave correction	+/- 0.10 m
e.	Roll, pitch, (gyro), seabed slope	negligible in relation to footprint
f.	Tidal Measurement	+/- 0.02 m
g.	Co-tidal corrections	+/- 0.10 m

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

14.2 SOUNDING ERROR BUDGET

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
d heave	0.0	0.0	0.0
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)	0.35	0.35	0.35
h seafloor slope 0	0.0	0.1	0.1
i seafloor slope 1:4	1.0	0.0	0.0
j seafloor slope 2:4	2.0	0.0	0.0
k seafloor slope 4:4	4.00	0.00	0.00
L	0.00	0.00	0.00
Combined total flat bottom $(\Sigma(a^2 + \ldots l^2)^{1/2})$	0.378	0.246	0.246
IHO Cat 1 Requirement $[+/-(a^2 + (b*d)^2)^{1/2}]$	0.502m	0.509m	0.542m
Standard Met?	YES	YES	YES

While some of the above estimates appear outside the tolerances normally expected of modern, well-calibrated digital equipment, the Error Budget table is intended to highlight possible error margins in what appears initially to be sound, well-calibrated, methodically generated data. Even overall sounding accuracy would still satisfy IHO Cat 1 requirements in all but the deepest (and therefore less critical) areas of the survey. Further comments on the above variables follow.

14.1.1 Draft Correction

Not applicable for LIDAR. System flies, doesn't float.

14.1.2 Depth Measurement

System accuracy (depth resolution) for the LIADR 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.

14.1.3 Light Velocity Correction

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 are not a limiting factor for LIDAR data and errors attributed to velocity of light variability can be considered non-existent.

14.1.4 Heave Corrections

Not applicable for LIDAR data. However, aircraft platform motion is compensated for by an aircraft-mounted inertial navigation system. This resolves undulations in the flight path. Aircraft movement outside of normal parameters result in "jerk' flags and rejected data.

14.1.5 Tide Corrections

The estimated error for observed tides is 0.025 meters (1 SIGMA). This is considered pragmatic, given that the maximum range of tides in the area seldom exceed 0.8 meters. A similarly small margin of error for co-tidal corrections (0.35 meters) was calculated from comparison of a gauge installed on the leeward side on the island and the zone-corrected reference tide station data, and was the maximum difference. 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.

14.2 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 0.38 meters and is therefore within the IHO accuracy limits for Order 1 surveys. As has been discussed, it is considered that the estimated accuracy 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 be reduced with tide gauges installed on all sides of the islands.

15.0 Positional Accuracy

Overall accuracy was not normally checked against independent navigational aids. Numerous distinct, well delineated shoreline features, such as piers, bulk heads, jetties on Oaho and Kauai were positioned with a hand held Rockwell-Collins Plugger (un-keyed) GPS receiver. These features seen in the data were then compared to the position obtained with the hand held GPS. No positioning discrepencies were found. Crossline, swath overlap comparison checks on the sounding data and multiple coverage over objects also allowed a degree of trust in positional integrity to be reached. Sounding reduction and navigational accuracy were assessed as adequate for the survey and to meet order 1 requirements.

15.1 Offsets

None

15.2.1 Assessment

Positions were obtained from the Ashtech Z-12 GPS receiver onboard the survey aircraft. The receiver was set up in the DGPS mode and received, via VHF radio modem, correction data from the US Coast Guard Hawaii beacons. 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.

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 (est. USCG DGPS)
Heading error	0.5 m
Roll/Pitch error (beam pointing error)	0.26 m

(less than 0.05 degrees, less than 26 cm @ 300 meters altitude)

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.

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.

16.0 Summary/Closing Remarks

16.1 Participants

NAVOCEANO, USACE, John Chance and Associates

16.2 Customer

16.3 Diary of Notable Events

16.4 Performance

The survey platform performed exceptionally well with no downtime due to aircraft problems. The LIDAR system and its associated systems was another matter, but performed fairly well throughout the period, though there were several down periods and the laser head had to be swapped out occasionally.

16.5 Deliverables

16.6 Conclusions

In spite of significant mission creep, a very successful and productive operation that demonstrated the feasibility of multi-agency cooperation for large survey projects.

APPROVAL SHEET
W00140 – W00144

Evaluated by:

Digitally signed by Andrew Clos
DN: cn=Andrew Clos, o=NOAA, ou=NOS-PHB, email=andrew.clos@noaa.gov, c=US
Date: 2008.11.26 11:29:05 -08'00'

Andrew Clos
Physical Scientist (Hydrographer)
Pacific Hydrographic Branch

Review by:

Digitally signed by Kurt Brown
Date: 2008.11.26 11:34:28 -08'00'

Kurt Brown
Hydrographic Team Leader

Cartography

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

Compiled by:

Date: 2008.11.26 11:22:21 -08'00'

Rick Shipley
Cartographer
Pacific Hydrographic Branch

Reviewed by:

Gary C. Nelson
2008.11.26 12:28:45 -08'00'

Gary Nelson
Cartographic Team Leader
Pacific Hydrographic Branch

Approval

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

Digitally signed by David Neander
DN: cn=David Neander, o=Pacific Hydrographic Branch, ou=NOAA/NOS/OCS/HSD, email=dave.neander@noaa.gov, c=US
Date: 2008.11.26 12:33:06 -08'00'

David O. Neander
CAPT., NOAA
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Reason: AWOIS and Surf Check complete
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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. W00140, W00141, W00142, W00143, W00144

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
19347	10/23/08	R. Shipley	~~Full~~ Part ~~Before~~ After Marine Center Approval Signed Via
			Drawing No. PARTIAL application of soundings and
			curves from smoothsheet.
19348	10/9/08	R. Shipley	~~Full Part Before After Marine Center Approval Signed Via~~
			Drawing No. PARTIAL application of soundings AND
			curves from smoothsheet.
19350	10/3/08	R. Shipley	~~Full~~ Part ~~Before~~ After Marine Center Approval Signed Via
			Drawing No. PARTIAL application of soundings AND
			curves from smoothsheet.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
			Full Part Before After Marine Center Approval Signed Via
			Drawing No.
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SUPERSEDES C&GS FORM 8352 WHICH MAY BE USED