Final General Reevaluation Report
and
Final Environmental Impact Statement

on

Hurricane Protection and Beach Erosion Control

WEST ONSLOW BEACH AND NEW RIVER INLET
(TOPSAIL BEACH), NORTH CAROLINA

Appendix R

Nearshore Hardbottom Survey

Background

As identified in the Draft GRR and EIS for the West Onslow Beach and New River Inlet (Topsail Beach) Shore Protection Project, "shallow limestone and siltstone rock units offshore of Topsail Beach dominate and control the near surface geology and submarine landscape (~>-28 ft). The Topsail Beach shoreface consists of a thin patchy veneer of modern sediments covering the low relief Oligocene limestone and siltstone hard bottoms This thin veneer of sediment is ephemeral and easily reworked during storms; thus, exposing rock units in areas where the sediment cover is thin. The nearshore hard bottom features are generally low relief with isolated scarp formations." Though the best available data regarding hard bottom resources off of Topsail Island does not suggest the presence of high relief hard bottom within the -23' depth of closure limits calculated for the project, to more accurately assess potential project impacts to hard bottom resources, a nearshore hard bottom survey was performed. In spring 2006, prior to commencement of the survey contract, a detailed flowchart identifying the order of work and data collection process was submitted to the NMFS and NCDMF for their approval. The contract scope of work consisted of a two phased effort to locate and quantify "potential hard bottom" sites within the project impact area utilizing side scan sonar (phase 1), and if targets were identified, multibeam survey techniques to assess the bathymetry (i.e. relief) (phase 2) (Attachment 1).

Methods and Results

<u>Phase one</u> – Sidescan survey

Phase one of the nearshore survey commenced in July 2006 and was comprised of 6 planned survey lines spaced 320' apart (100m) in depths ranging from ~5' MLLW to ~30' MLLW (Attachment 2). The distance between survey lines was calculated in separate zones of relatively equal depths using 42 times the water depth for multibeam and 394' swaths (120m) for sidescan as indicated on the NOAA digital nautical chart 11541_4.kap. The total area of the survey encompassed 3.2 square miles. Sidescan sonar is a marine geophysical technique use to map underwater topography and for identifying features on the surface of water body bottoms. Generally, hard materials provide high amplitude echoes and soft, fine grained materials provide weak signals. As a result, side scan sonar provides a visual representation of the change in density of the surface material of a water body bottom. Interpretation of the sidescan sonar data identified several areas which had higher density material than the adjacent area. These high backscatter "finger-like" projections were located cross-shore throughout the survey area (Figure 1). Based on these density differences, the areas of high backscatter were considered "potential hard bottom" and were delineated to calculate total area of each feature. Generally, the "potential hard bottom" targets identified started approximately 800 ft offshore (2004 wet/dry line) and extended to the end of the survey, located approximately 1800 ft offshore (2004 wet/dry line).

<u>Phase two</u> – Multibeam survey

To further investigate the bathymetry of these target areas, the phase two multibeam survey was initiated, extending from January 26 – February 6th 2007. The multibeam survey was comprised of 18 planned survey lines (6 lines per survey area) spaced 70' to 90' apart to obtain 100% seafloor coverage (Attachment 3). The total area of the survey encompassed 0.85 square miles with a total of 57 line miles and employed a Simrad EM3002 shallow water multibeam sonar system to collect spatially dense bathymetric data across 0.85 square miles of seafloor for the development of an accurate surface model. Data interpretation of seafloor bathymetry indicated that areas of high backscatter with cross-shore orientation identified in the phase one side scan sonar survey were areas of gradual seafloor depressions with approximately 1.5' vertical relief per 330' horizontal distance (Figure 1).

<u>Surface Sediment Samples</u>

In order to further characterize the substrate of these depressional features, the Corps coordinated with NOAA Fisheries to gather surface sediment grab samples while performing dives as a component of the NOAA Fisheries lionfish study (Figure 2). Samples were retrieved from both within and outside of the identified depressions. Sediment samples retrieved outside of the depressions (areas of low backscatter) were characterized as fine grained sand; whereas samples retrieved from within the depressions (areas of high backscatter) were generally a coarser sandy shell hash and, in two samples, contained small (3.0" x 2.0") limestone cobbles. According to Dr. Bill Cleary (Personal Communication, March 2007), these small cobbles are likely eroded pieces of known limestone outcrops located further offshore. Divers collecting the sediment samples noted that, for the locations where samples were collected, the areas where visually characterized as sandy substrate with no significant relief or ledges and no significant fish assemblages (Ron Sechler, Personal Communication, 04 April 2007).

Discussion

The depressional features identified in the phase two multibeam survey are consistent with previously identified "rippled scour depressions (RSD)" (Cacchione *et. al.*, 1984; Thieler *et. al.*, 1999; Thieler *et. al.*, 2001), "ripple channel depressions (RCD)" (McQuarrie, 1998), or "sorted bedform"(Murray and Thieler, 2004) features. Though termed differently throughout the literature, for the purposes of this assessment, RSD, RCD, and sorted bedforms will be considered interchangeable terms to identify the same geologic feature. On the Pacific Coast, Cacchione *et. al.* (1984) identified surficial sedimentary features of the shoreface and inner shelf environments with slight topographic expressions (~1 m total relief) about 100-200 m wide and extending hundreds to thousands of meters in the cross-shore direction. These features were composed of course sand (in some cases shell hash and gravel) and arranged into large wave generated ripples. Termed, "Rippled Scour Depressions (RSD)" these features were attributed to areas of intensified cross-shore flow that preferentially winnow fine material, leaving a course lag parallel to flow. Similar geologic features were later identified throughout the Atlantic coast, including off the coast of North Carolina and South Carolina (McQuarrie, 1998; Thieler *et. al*., 1999; Thieler *et. al*., 2001).

According to McQuarrie (1998), an approximately 102 km2 area was surveyed using sidescan sonar, high resolution seismic, and vibracores on the shoreface and inner shelf of Onslow Bay. This study characterized the inner shelf off Topsail Beach as Tertiary and Pleistocene outcrops with a thin, discontinuous, loose surficial sheet of sediment. In addition to continuous quaternary fluvial channels traced shore perpendicular across the shore face, wave and current action on the shoreface generates “ripple channel depressions (RCD’s)” on the shoreface. Vibracore and surface sediment samples within and outside of these features are consistent with RSD sediment data identified in other studies (Cacchionne *et. al*., 1984; Thieler *et. al*., 1999; Thieler *et. al*., 2001).

A significant amount of historic side scan data has been collected offshore of Topsail Beach (1992, 1994, and 1996) (Rob Thieler, Personal Communication; McQuarrie, 1998). This historic data matches well with the July 2006 side scan data providing some additional insight to the offshore extent and stability of these features. Considering that the data are spread over a 15 year timeframe and imagery still matches well, it appears that these features are fairly stable, at least over a decadal time frame (Rob Thieler; Personal Communication), suggesting that these features are maintained by the localized interaction of oceanographic processes and poorly sorted bed material.

Side scan imagery from Theiler *et. al*. (1999) identified subtle shore oblique bathymetric expressions of high acoustic reflectivity dominating the shoreface and inner shelf of Wrightsville Beach, NC and Folly Beach, SC. The depressional features had 1 m vertical relief across widths of 100’s of meters and were associated with RSD’s as defined by Cacchione *et. al*.(1984). –According to Thieler (1999), individual RSD’s were approximately 40-100 m wide on Wrightsville Beach, NC and Folly Beach, SC and are up to 1 m deep on the upper shoreface, but have a much more subdued (~50 cm) bathymetric expression further offshore. Most depressions develop just outside the surf zone at 3-4 meters water depth and extend into the inner shelf at 15 m. Vibracore data from Thieler *et. al*. (2001) indicate that these RSD features are floored by course sand, shell hash, and quartz gravel and are surrounded by areas of fine sand. These study sites appear to be relatively stable or represent a recurring, preferential morphologic state to which the seafloor returns after storm induced perturbations. This apparent stability is interpreted to be the result of interactions at several scales that contribute to a repeating, self-reinforcing pattern of forcing and sedimentary response which ultimately causes the RSD’s to be maintained as bedforms responding to both along-and across shore flows. According to Dr. Bill Cleary (Personal communication), the presence of RSD’s/Sorted bedforms as identified through side scan imagery off Topsail Beach are ubiquitous from Topsail beach through Wrightsville Beach. Side Scan sonar imagery identifying the same features exists for Figure eight Island and also Lee/Hutaff island.

Murray and Thieler (2003) reviewed data within Wrightsville Beach, NC RSD’s and did not indicate any significant offshore-directed currents as identified by Cacchione *et. al*. (1984), suggesting the dominance of along-shelf transport rather than cross shelf flow.

These depressional features are independent of geologic factors and are a result of oceanographic process such as the interaction of waves, mean currents, and poorly sorted bed material in a moderately high-energy environment. Considering that their observations suggested the dominance of along-shelf transport rather than cross-shelf flow and transport, Murray and Thieler (2004) adopted the term "sorted bedforms" to describe the features off Wrightsville Beach and elsewhere.

The North Carolina Coastal Habitat Protection Plan (CHPP) was adopted by the North Carolina Marine Fisheries, Environmental Management, and Coastal Resources Commissions in December 2004. The CHPP identifies six types of habitats that produce North Carolina's coastal fisheries resources including shell bottom, sea grasses, wetlands, hard bottoms, soft bottoms, and the water column. Rippled scour depressions are identified as soft bottom habitat in Chapter 6 of the CHPP under the subsection titled "Ocean Intertidal Beaches and Subtidal bottom:"

> *"The surf zone is the shallow subtidal area of breaking waves seaward of the intertidal beach. Within the surf zone, longshore sandbars frequently develop and shift seasonally in response to wave energy. Seaward of the surf zone, the subtidal bottom consists of a series of minor ridges and swales. Ripple scour depressions, ranging from 130–330 ft (40–100 m) in width and up to 3 ft (1 m) in depth, occur along the southern portion of the coast and are perpendicularly oriented to the beach, extending to the base of the shoreface (Thieler et al. 1995; Reed and Wells 2000). These features are located adjacent to areas experiencing chronic severe beach erosion, and may be indicative of rapid offshore transport of sand during storms (Thieler et al. 1995)."*

According to the CHPP, RSD's are not considered Essential Fish Habitat (EFH), Habitat Areas of Particular Concern (HAPC), Primary Nursery Area (PNA) or Strategic Habitat Area (SHA). Though soft bottom habitat is probably the most resilient to physical alterations because of its lack of structure and dynamic nature, it plays a vital role as nursery and foraging grounds for fish and invertebrate species. Benthic soft bottom habitat within the project, area (Sections 2.01.8 and 2.01.9) and the potential biological impacts of beach nourishment (Sections 8.01.6 and 8.01.7) are identified in the Draft GRR and EIS for the West Onslow Beach and New River Inlet (Topsail Beach) Shore Protection Project.

Conclusion

Based on the data collected through sidescan and multibeam survey techniques, the Corps concludes that no hard bottom features are located within the -23 depth of closure limits of the West Onslow Beach and New River Inlet (Topsail Beach) Shore Protection Project. After review of the available literature, the high backscatter depressional features identified through side scan and multi beam sonar as well as the surface sediment samples collected within and outside of theses features are consistent with previous descriptions RSD, RCD, and sorted bedform features. Furthermore, these features are identified in the North Carolina CHPP as soft bottom habitat and are not considered EFH, HAPC, PNA, or SHA. Impacts to soft bottom habitat are discussed in detail in Sections Sections 2.01.8 and 2.01.9 and 8.01.6 and 8.01.7 of the Draft GRR and EIS.

Within the -23' depth of closure limit of the project area, nourished sediment will move offshore as the constructed beach profile equilibrates to a more natural beach profile. The total area of the RSD, RCD, sorted bedform features that occurs within the -23 ft. depth of closure limits is 0.3834 acres. Though nourished sediment could gradually move within the depressional features, it is likely that the features will be maintained as a preferential morphologic state through the repeating, self-reinforcing pattern of forcing and sedimentary response which causes the RSD's to be maintained as sediment starved bedforms responding to both along-and across shore flows (Thieler *et. al*., 2001).

Literature Cited

Cacchione D. A., D. E. Drake, W. D. Grant, and G. B. Tate. 1984. Rippled Scour Depressions on the Inner Continental Shelf Off Central California. *Journal of Sedimentary Petrology*. Vol. 54, No. 4, p. 1280-1291.

McQuarrie M. E. 1998. Geologic Framework Short-Term, Storm-Induced Changes in Shoreface Morphology: Topsail Beach, NC. *Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Environment in the Graduate School of Duke University*.

Murray A. B. and E. R. Thieler. 2004. A New Hypothesis and Exploratory Model for the Formation of Large-Scale Inner-Shelf Sediment Sorting and "Rippled Scour Depressions." *Continental Shelf Research*. 24: 295-315.

Street, M. W., A.. S. Deaton, W. S. Chappell, and P. D. Mooreside. 2005. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC. 656 pp.

Theiler E.R., P. T. Gayes, W. C. Schwab, and M. S. Harris. 1999. Tracing Sediment Dispersal on Nourished Beaches: Two Case Studies. *Coastal Sediments*. New York, ASCE, p. 2118-2136.

Thieler E. R., O. H. Pilkey, Jr., W. J. Cleary, and W. C. Schwab. 2001. Modern Sedimentation on the Shoreface and Inner Continental Shelf at Wrightsville Beach, North Carolina, USA. *Journal of Sedimentary Research.* Vol. 71, No. 6, p. 958-970.

E. Robert Thieler. Personal Communication. 01 March 2007.

W. J. Cleary. Personal Communication. March 2007.

Ron Sechler. Personal Communication. 04 April 2007.

http://pubs.usgs.gov/of/1998/of98-596/

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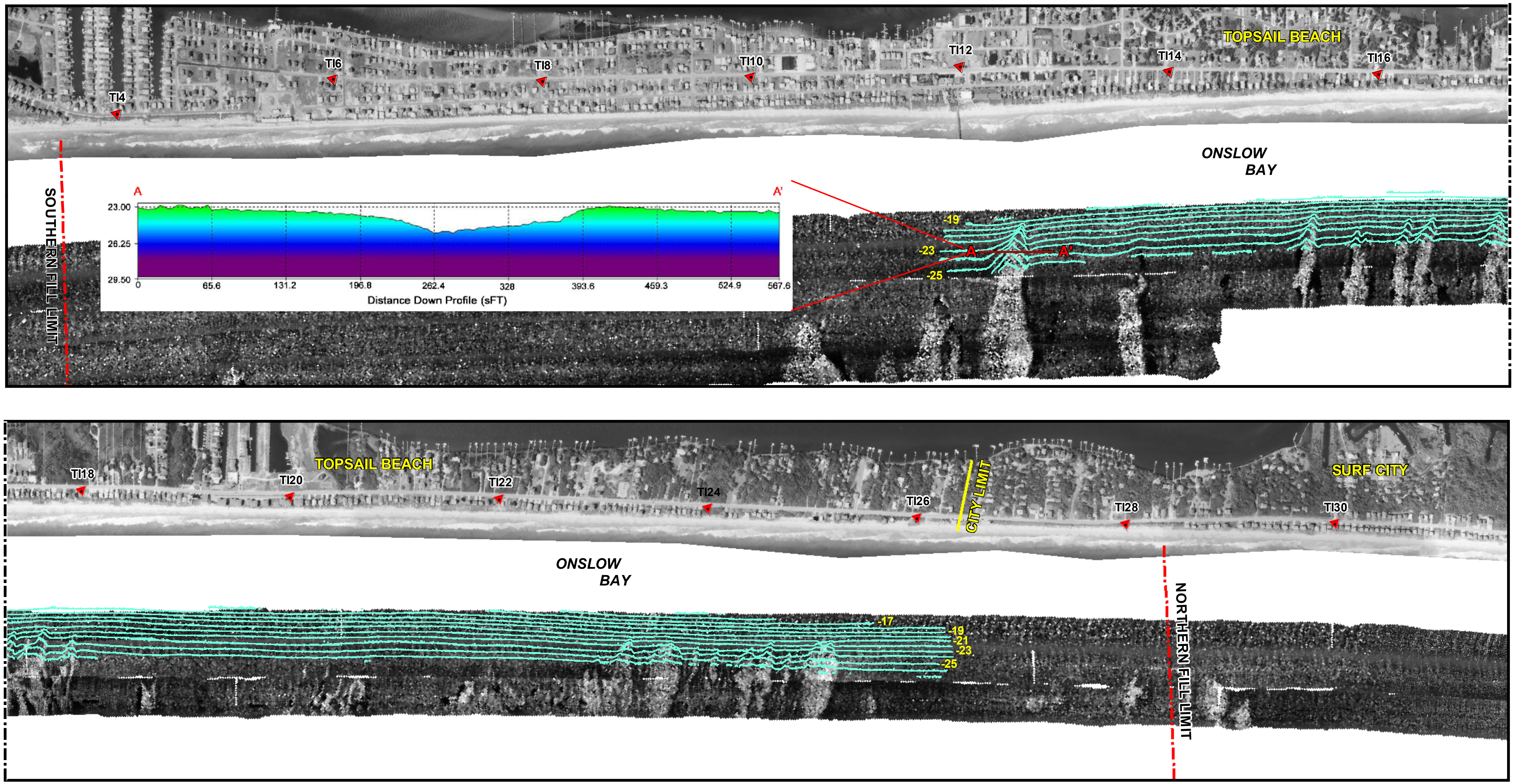
Appendix R - Nearshore Hardbottom Survey

Figure 1 -
Sidescan Sonar and Multibeam Survey Results
(Figure prepared by
Coastal Planning and Engineering, Inc. (CPE))



NOTES

1. COORDINATES SHOWN HEREON ARE IN FEET BASED ON THE NORTH CAROLINA STATE PLANE COORDINATE SYSTEM, NORTH AMERICAN DATUM OF 1983 (NAD 83).
2. AERIAL PHOTOGRAPHY PROVIDED BY PENDER COUNTY GIS DEPARTMENT, DATE FLOWN 2003.
3. BATHYMETRIC CONTOURS AND MULTIBEAM SURVEY RESULTS PROVIDED BY USACE WILMINGTON DISTRICT ON FEBRUARY 5, 2007.
4. APPROXIMATE LOCATION OF A - A' LINE INTERPRETED BY CPE FROM GRAPHIC PROVIDED BY USACE- WILMINGTON DISTRICT ON FEBRUARY 5, 2007.

LEGEND

- CITY LIMIT
- (NGVD) BATHYMETRIC CONTOURS
- FILL PLACEMENT LIMIT
- USACE BASELINE STATIONS

N

0 500 1,000 Feet

1 inch equals 1,000 feet

TITLE:

TOPSAIL BEACH
INTERIM (EMERGENCY) BEACH FILL PROJECT
POTENTIAL HARDBOTTOM INVESTIGATION

CPE

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 02/28/07	BY: HMV	COMM NO: 3700	FIGURE 2

G:\North Carolina\TOPSAIL\370008_TOPSAIL_BEACH_DRAFT_STATE_EIS_MXD\TOPSAIL_POTENTIAL_HARDBOTTOM_INVESTIGATION_CONTOURS_020707.mxd

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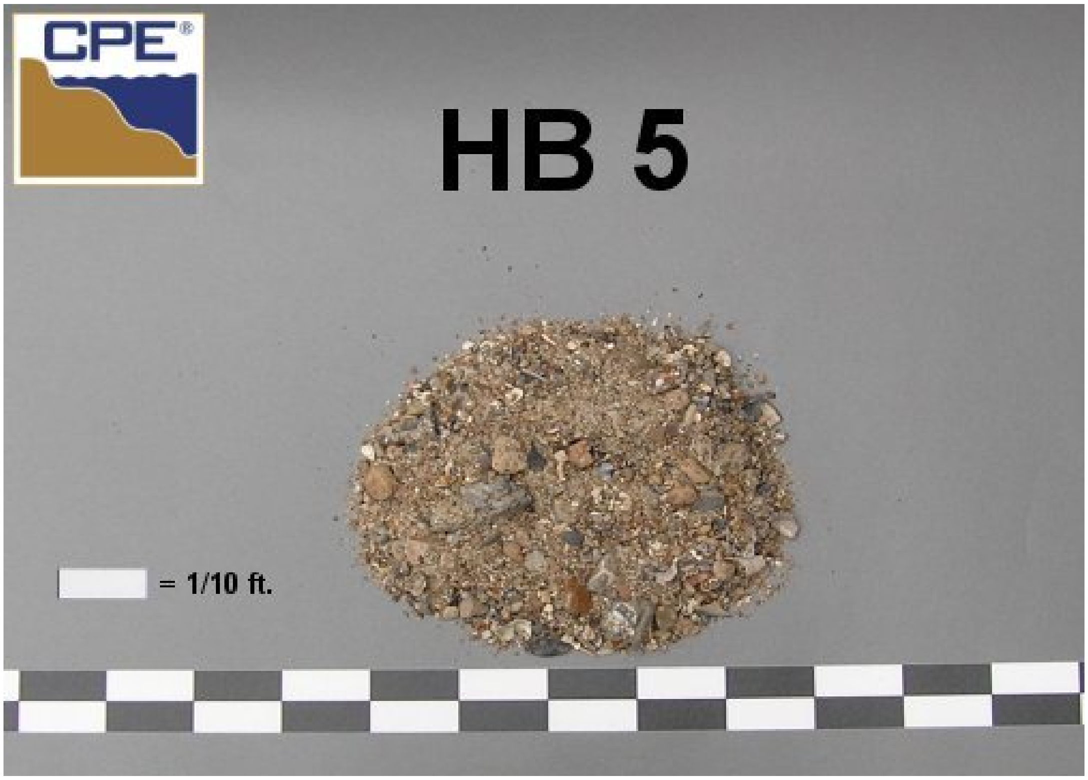
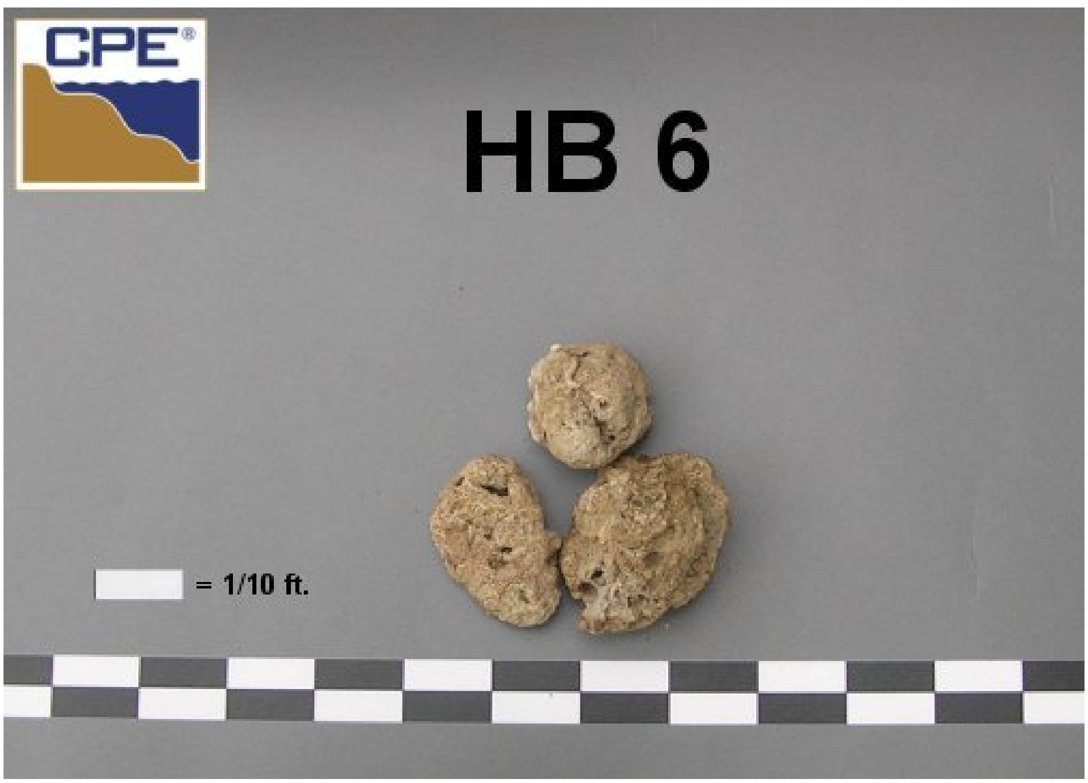
Appendix R - Nearshore Hardbottom Survey

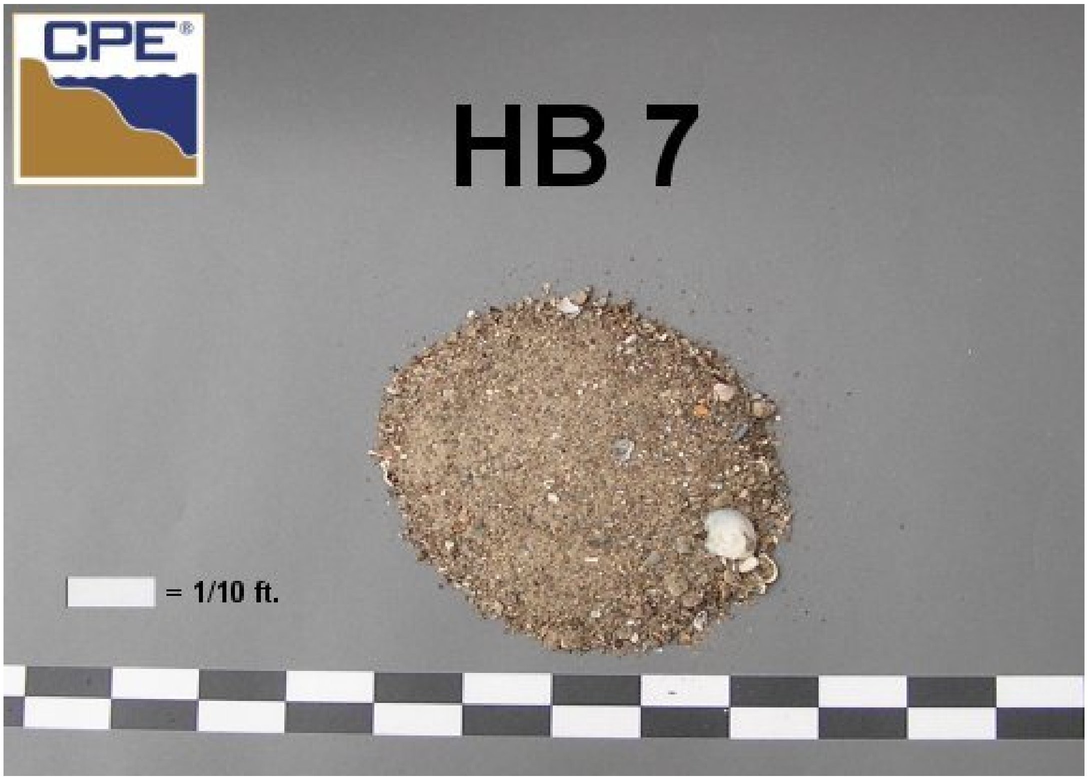
Figure 2 -
Surface Sediment Samples
(Samples provided by NOAA Fisheries
and Prepared by CPE)


CPE®
B 7
= 1/10 ft.


CPE®
SAND 6
= 1/10 ft.


HB 5
= 1/10 ft.

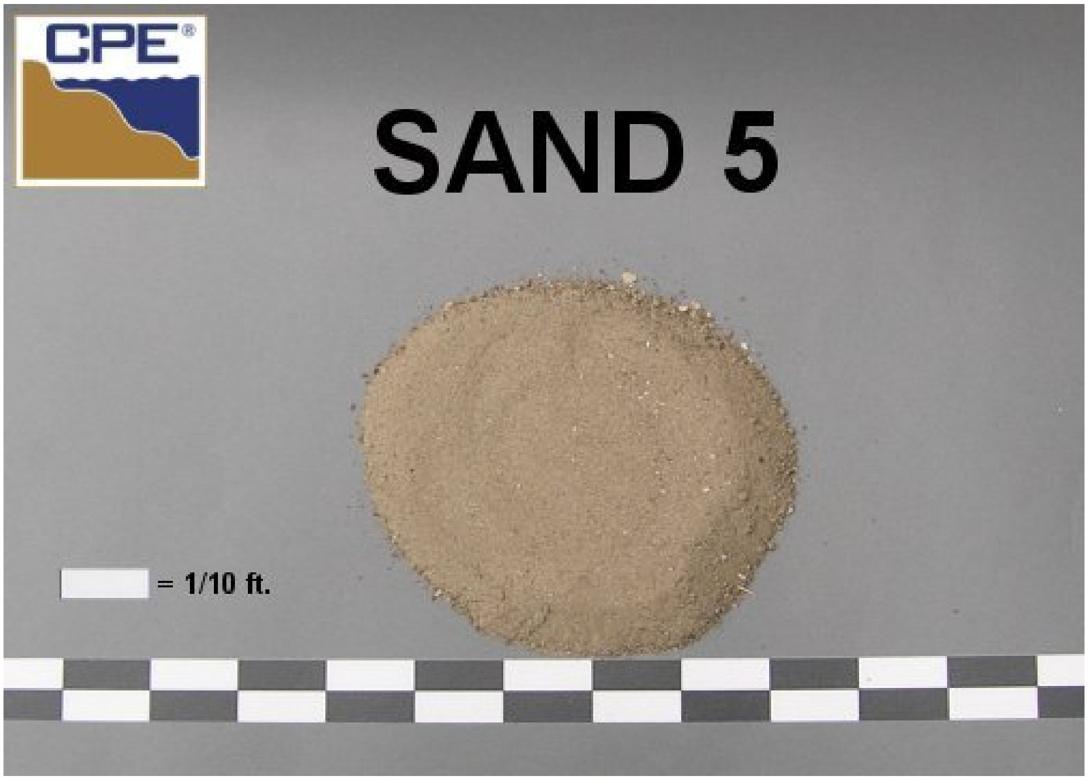

HB 6
= 1/10 ft.


HB 7
= 1/10 ft.


HB 8
= 1/10 ft.


CPE
LEDGE NW/SE
= 1/10 ft.


CPE
S 8
= 1/10 ft.


CPE®
SAND 5
= 1/10 ft.

Hardbottom Samples Descriptions
Provided by Coastal Planning & Engineering, Inc.

***B 7**
Sand fine grained; trace silt; trace shell hash; trace shell fragments less than 0.5”; dry Munsell color 2.5Y-6/2 (light brownish gray); (SP)

HB 5
Sandy shell hash; trace silt; little shell fragments up to (1.5”x1.0”); little rock fragments up to (1.0”x0.5”); dry Munsell color 2.5Y-6/2 (light brownish gray); (SW)

HB 6
Rock fragments up to (3.0”x2.0”); dry Munsell color 2.5Y-6/2 (light brownish gray); (GP)

HB 7
Sand fine grained; trace silt; little shell hash; little shell fragments up to (1.25”x1.0”); trace rock fragments up to (0.75”x0.75”); dry Munsell color 2.5Y-6/2 (light brownish gray); (SW)

HB 8
Sand fine grained; trace silt; little shell hash; trace shell fragments up to (1.0”x0.25”); trace rock fragments less than 0.5”; dry Munsell color 2.5Y-6/2 (light brownish gray); (SP)

Ledge
Rock fragments up to (4.0”x2.0”); dry Munsell color 2.5Y-5/3 (light olive brown); (GP)

***S 8**
Sand fine grained; trace silt; trace shell hash; dry Munsell color 2.5Y-6/2 (light brownish gray); (SP)

Sand 5
Sand fine grained; trace silt; trace shell hash; trace shell fragments less than 0.5”; dry Munsell color 2.5Y-6/2 (light brownish gray); (SP)

Sand 6
Sand fine grained; trace silt; trace shell hash; dry Munsell color 2.5Y-6/2 (light brownish gray); (SP)

Note: All sample ID’s correspond with the labels in the sample bags collected by NOAA Beaufort Lab. Descriptions with an (*) do not correlate with the sample ID scheme in the following list:

1	"Waypoint"	"top	**hb1**"	-77.622088262,34.362191058,-39.002
2	"Waypoint"	"top	**hb2**"	-77.611498152,34.372483661,-38.997
3	"Waypoint"	"top	**sand1**"	-77.620527963,34.363067025,-39.002

4	"Waypoint"	"top **sand2**"	-77.609439885,34.373824985,-38.997
5	"Waypoint"	"top **hb3**"	-77.600864633,34.380487246,-38.996
6	"Waypoint"	"top **sand3**"	-77.602553114,34.379422632,-38.996
7	"Waypoint"	"top **hb4**"	-77.593423632,34.387143005,-38.993
8	"Waypoint"	"top **sand4**"	-77.591244488,34.388177325,-38.993
9	"Waypoint"	"top **hb5**"	-77.557183922,34.412300961,-38.989
10	"Waypoint"	"top **sand5**"	-77.558889942,34.411057190,-38.989
11	"Waypoint"	"top **hb6**"	-77.540319151,34.422212860,-38.988
12	"Waypoint"	"top **sand6**"	-77.542931892,34.420921214,-38.988
13	"Waypoint"	"top **hb7**"	-77.516600906,34.436573086,-38.986
14	“Waypoint”	"top **hb8**"	-77.511003899,34.440165572,-38.985
15	“Waypoint"	"top **sand7**"	-77.519887527,34.434428320,-38.987
16	"Waypoint"	"top **sand8**"	-77.505406886,34.442926963,-38.986
17	"Waypoint"	"**ledgeNW/SE**"	-77.536716667,34.418533335,-38.996

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Appendix R - Nearshore Hardbottom Survey

Attachment 1 -
Sidescan Sonar and Multibeam Survey Scope of Work

SCOPE OF WORK
NEARSHORE HARD BOTTOM SIDESCAN SURVEY
TOPSAIL ISLAND, NORTH CAROLINA

1. General. The Contractor shall acquire Sidescan Sonar Data along Topsail Island, North Carolina for the purposes of identifying and mapping potential Hard Bottom Areas. The longshore limits of the data collection extend form New Topsail Inlet to the Surf City/North Topsail town line as identified on the Government furnished map. The offshore limits shall extend from the mean low water contour to the -25 feet NGVD 1929 contour as identified on the Government furnished map.

2. Survey Control. All horizontal and vertical control used for this survey shall be from the North Carolina or a Federal Agency Network and be of third order accuracy or better. All control loops must be tied to at least two or more control points. The Contractor shall furnish a list of all points used to the Government. All work shall be relative to NAD 1983 North Carolina State Plane Feet in the horizontal plane and NGVD 1929 in the vertical plane. The Government will provide control information for previously established Control Points along the length of the project area.

3. Clearances. The Contractor shall acquire all Clearances necessary to obtain the required data. All discussions for access to private or public property or restricted waters or airspace must be included in the required weekly status report with name of person, address, and telephone number.

4. Required Deliverables. The Contractor is required to deliver Side Scan Mosaic Raster Data Sets, Shapefiles, Metadata Records, a Weekly Status Reports, and a Final Written Report.

4.1 Side Scan Mosaic Raster Data Sets. The Contractor shall deliver Georeferenced Mosaics of the Raster Data sets from the Side Scan Survey. The Raster Data sets shall depict the backscatter information used to map the potential hard bottom areas in the project area. The Raster Data Sets shall be in a format compatible with ESRI ArcView/ArcInfo Version 9.0.

4.2 Shapefiles. The Contractor shall deliver Polygon Shapefiles defining the potential hard bottom areas within the project area. The Shapefiles shall be in a format compatible with ESRI ArcView/ArcInfo Version 9.0.

4.3 Metadata Record. An FGDC compliant metadata record for each spatial data deliverable shall be created using ESRI ArcView/ArcInfo ArcCatalog version 9.0. Appropriate information shall be entered in all required fields. The Contractor shall attach the appropriate metadata record to each spatial data file using ArcCatalog so that no importing or formatting of the metadata record is required by the Government.

5. Weekly Status Report. **The Contractor is required to submit a Weekly Status Report each week, beginning on the Task Order Award Date, until all deliverables are received and accepted by the Government**. The Weekly Status Report shall be delivered via e-mail no later than 8:00 AM each Monday and shall document the Contractor's progress from the previous Monday through the previous Sunday. The status report shall itemize each scope item with percent of work complete and an estimated date of completion. The report shall also include the number and type of field crews working, a description of any problems and/or delays encountered, and any photographs of the site and/or significant site features (such as outlet structures, retaining walls, escarpments, etc.) and/or specialized data collection activities.

6. Final Written Report. A written report summarizing all data collection activities shall be submitted as a Portable Document File (PDF) and in bound hardcopy. The following items shall be included in the survey report:

- Written description of workflow to complete task order (start to finish) including flowchart diagram and detailed description of QA/QC process
- Dates and times of each data collection activity
- Atmospheric Conditions for each day of data collection activity
- All Horizontal and Vertical Control used including monument name, establishing agency, date established, description, and published horizontal and vertical values
- TBM descriptions with vertical values
- Copy of all field notes
- Complete and detailed list of all survey equipment used including copy of last factory calibration report
- Metadata Record as described in 4.3 above
- Photographs of the site and any significant features or data collection techniques used

7. Quality Control. If work is found to be in error, incomplete, illegible or unsatisfactory after assignment is completed, the Contractor shall be liable for all cost in connection with correcting such errors. Corrective work may be performed by Government personnel or Contractor personnel at the discretion of the Contracting Officer. In any event, the Contractor shall be responsible for all costs incurred for correction of such errors, including salaries, automotive expenses, equipment rental, supervision, and any other costs in connection therewith. All data and deliverables shall be reviewed for the following:

- Required coverage of the project limits
- Capture of all required features
- Required accuracies
- Required horizontal and vertical datum
- Adherence to the delivery order requirements

8. Technical POC. All technical questions concerning work under this task order shall be directed to Jim Jacaruso at (910) 251-4064.

9. Completion Date. All work required under this task order shall be **completed and delivered no later than 21 calendar days from the Task Order Award Date.**

This schedule is subject to adjustment by the Contracting Officer in writing.

10. Deliver To. All work shall be delivered to:

U. S. Army Corps of Engineers
Wilmington District
Attn: Jim Jacaruso, TS-EE
69 Darlington Avenue
PO Box 1890
Wilmington, NC 28402-1890

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Appendix R - Nearshore Hardbottom Survey

Attachment 2 - High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC July 2006 Survey Report

High-Resolution Remote Sensing of Potential Hard Bottom Habitats: Topsail Island, NC July 2006

Survey Report

Project No. DACW54-02-D-0006, Delivery Order 0035, Nearshore Hardbottom Sidescan Survey, Topsail Island, NC
G&O Project Number 146046.T35.6480.GEO

Submitted by:

GREENHORNE & O'MARA
CONSULTING ENGINEERS

With Subconsultant:

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

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Executive Summary

Geodynamics LLC was contracted on June 30th by the USACE Wilmington District through Greenhorne & O'Mara Inc. to perform a detailed side-scan sonar survey between New Topsail Inlet, NC and the Surf City, NC boarder. This high-resolution survey is phase one of a two phase effort to located and quantify potential hard bottom habitats by the US Army Corps of Engineers Wilmington District for future renourishment efforts in the region. To better assess hard bottom locations, provide increased positioning accuracy for the side-scan mosaic and to increase productivity for phase two, Geodynamics provided multibeam bathymetry acquisition and processing at no cost to the project.

The July 17-18 side-scan and multibeam surveys of the Topsail Island shoreface employed a Klein 3000 digital side-scan sonar and a Simrad EM3002 shallow water multibeam sonar system to collect spatially dense seafloor imagery and bathymetric data for the assessment of nearshore hard bottom habitats as described in the official Scope of Work (Appendix A). The dual frequency side-scan system runs at both 100 and 500 kHz nominal. In order to maximize the resolution of the system we brought the swath widths to 100m-150m (range of 50m-75m) and a pixel resolution of 4096. The multibeam system runs at 300 kHz and is compensated for motion and heading with an Applanix POS MV 320 v4 inertial navigation system. The EM3002 produces a swath of sonar approximately 4 times the water depth and collects approximately 400 soundings per square meter. Sound velocity was calculated using an Odom Digibar Pro sound velocity meter.

Tidal corrections and positioning information were acquired using a site calibrated Trimble 5700 Real-Time Kinematic GPS (RTK-GPS) system integrated with the POS MV 320 through a Pacific Crest PDL radio modem. The RTK-GPS system uses a land-based station coupled with a 25-watt radio and a Maxrad 5 dB high-gain antenna to broadcast the computed real-time horizontal and vertical corrections at 10 Hz to the survey rovers (hydro/topo survey platforms). To compute centimeter-scale position and elevation information, determine the relationship between WGS-84 and local grid coordinates, and to evaluate the local geoid-spheroid separation, we first performed a detailed network adjustment and site calibration. Information on the site calibration can be found in the corresponding section of this final report and published accuracies on each of the systems can be found in Appendix D.

Survey Preparation

Survey Area

Topsail Island, located approximately 20 miles northeast of Wilmington and separates Lee Island to the south and Onslow Beach to the north. The Topsail Island nearshore survey was comprised of 6 planned survey lines spaced 320' (100m) in depths ranging from ~5' MLLW to ~30' MLLW. The distance between survey lines was calculated in separate zones of relatively equal depths using 4 times the water depth for multibeam and 394’ swaths (120m) for side-scan as indicated on the NOAA digital nautical chart 11541_4.kap. The total area of the survey encompassed 3.2 square miles

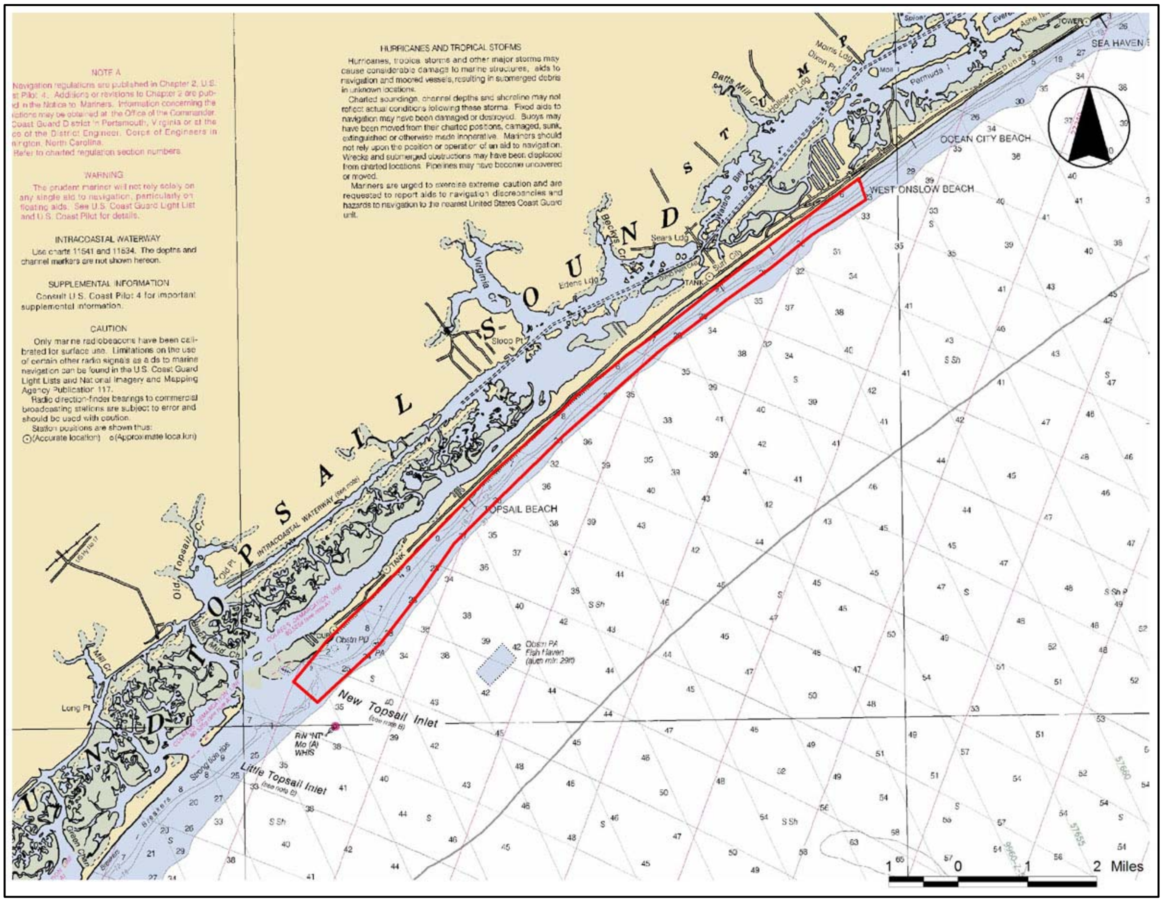


Figure 1. Topsail Island side-scan survey planning map illustrating the proposed survey extents.

RTK-GPS Survey Control & Multibeam Calibration

Introduction & Purpose

The most common problem in accurately measuring the seafloor with any sonar-based system, especially in and around a tidal inlet, is the calculation of the tidal elevation offset. Commonly a tide staff or gauge is deployed in one location near the survey site and is used to calculate the tides for the entire survey area. However, it is widely understood that non-linear tidal phenomena, phase lags and tidal gradients can drastically influence the tidal elevation spatially across a tidal inlet and therefore the use of a single point measurement is often unreliable.

To avoid these potential tidal elevation errors which can translate into significant departures from the true bottom depth, we use geodetic Global Positioning Systems (GPS) with real-time kinematic (RTK) baseline processing that is integrated with the multibeam and inertial navigation instruments. The motion and Geoid 03 compensated positions and orthometric elevations of the RTK-GPS data stream are tagged with each sonar ping. In effect, the RTK-GPS mounted on the hydrographic survey vessel acts as a roving tide gauge collecting the most accurate tidal measurements throughout the survey area.

Multibeam swath sonar systems combine a complex array of instruments, consisting of the transducer, motion sensor, gyrocompass, and geodetic GPS system. Standards developed by the International Hydrographic Organization (IHO), USACE Standards for Hydrographic Surveys, and the NOS Hydrographic Surveys Specifications and Deliverables for shallow water (<30 m) hydrography (IHO 1987; USACE 2003; NOS 2003) are used as the protocol for calibration. Proper alignment of these instruments with one another and with the vessel's reference frame is critical to achieve the high-accuracy required in the SOW. Calculation of the horizontal and vertical offsets between each of the instruments is followed by a series of sea-based measurements known as the patch test.

The patch test is performed to calculate several residual biases influenced by the dynamics of the survey vessel and the alignment of the instruments. Results of the patch test, documented in the following sections, are used to calculate a pitch, roll and heading offset and positioning time delay or navigation latency. Additional calibration measures are performed in the field including comparison of nadir depths with a lead line and frequent sound velocity profiles. The results of these daily field checks can be found in the html metadata file accompanying the final soundings.

To keep bathymetric accuracy the highest for phase one of this project we have kept the soundings in NAVD 88 until we can assess the best way to make this translation. Prior to phase 2 of multibeam acquisition we will need to model the difference in orthometric height between the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29) for each benchmark used in the site calibration. This can be completed with VERTCON 2.0 a datum transformation model considered accurate at the 2 cm (one sigma) level. According to studies by Milbert (1999), higher accuracy is particularly noticeable in the eastern United States but there will be some level of inaccuracy that we will attempt to quantify.

RTK-GPS Network Adjustment & Site Calibration

There are many environmental and operator-based influences that can affect the accuracy of RTK-GPS and the resultant baseline solutions (Bilker 2001; Trimble Navigation Limited 1998; Magellan Corporation 2001). Although RTK-GPS is an emerging tool among hydrographers, little attention has been given to an accuracy standard for this methodology—especially in the field of coastal mapping and monitoring (Morton et al., 1993). In an effort to limit operator error and to quantify daily environmental error, we have developed an internal standards protocol for RTK error estimation based on thresholds developed by the California Department of Transportation and the US Army Corps of Engineers (USACE) Topographic Accuracy Standards (CALTRANS 2002; USACE 1994).

The first step in our protocol is to determine an appropriate land-based GPS station that will provide the most accurate corrections and range to the outer limits of the survey area. We chose to use a location that that provided both exceptional range and benchmark quality that was situated on a circa 1940's rocket observation platform called "Tower 3".

The second step in our RTK-GPS protocol is to perform a detailed GPS site calibration prior to the collection of any hydrographic survey data. The site calibration is used to determine the basestation quality relative to the local network of NGS and NOS survey control and to analyze any potential spatial separations between the local geoid heights (GEOID 03) and ellipsoidal values (WGS-84) that may influence the resulting orthometric elevations. The calibration entails selecting the control to be used for the RTK-GPS basestation receiver and radio broadcast system and then checking at least three known geodetic benchmarks of exceptional horizontal and vertical quality within and even outside the survey boundaries. The benchmarks are occupied in "site calibration mode" over 300 epochs or approximately 3 to 5 minutes.

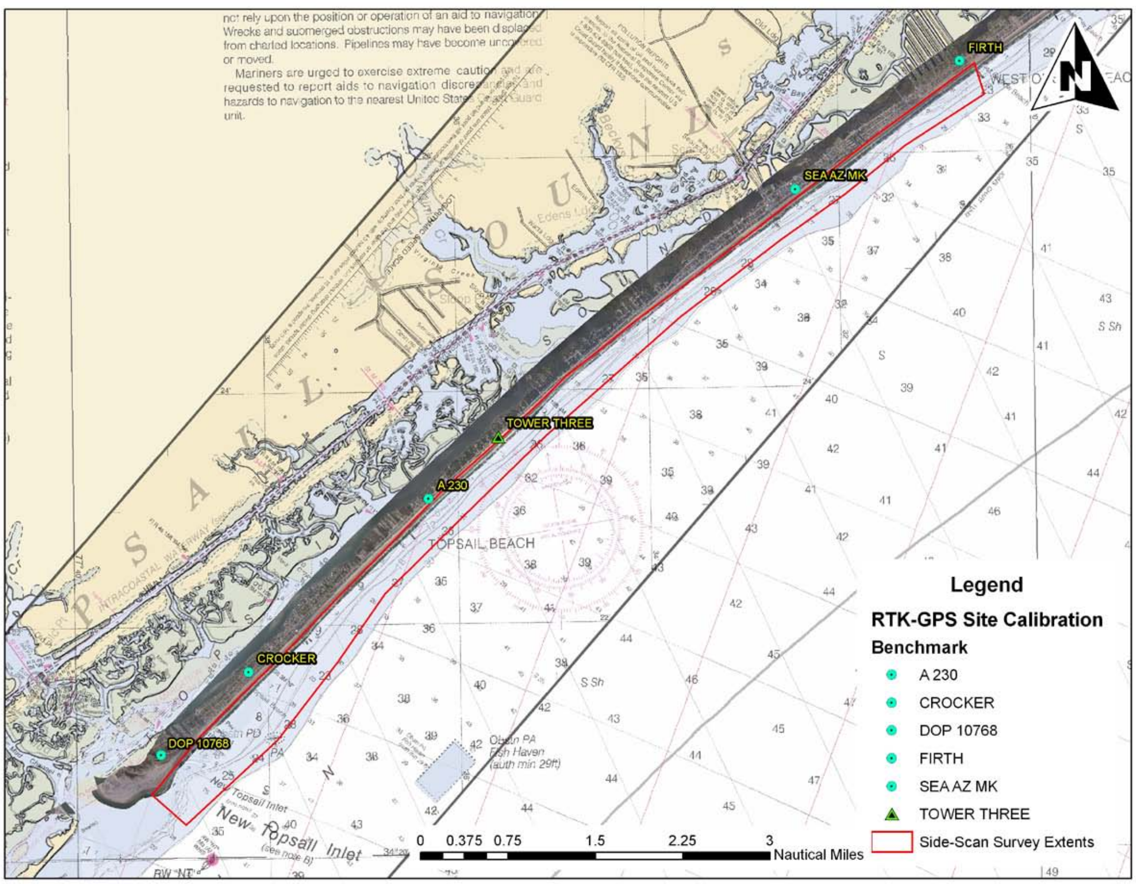


Figure 2. Topsail Island RTK-GPS site calibration map.

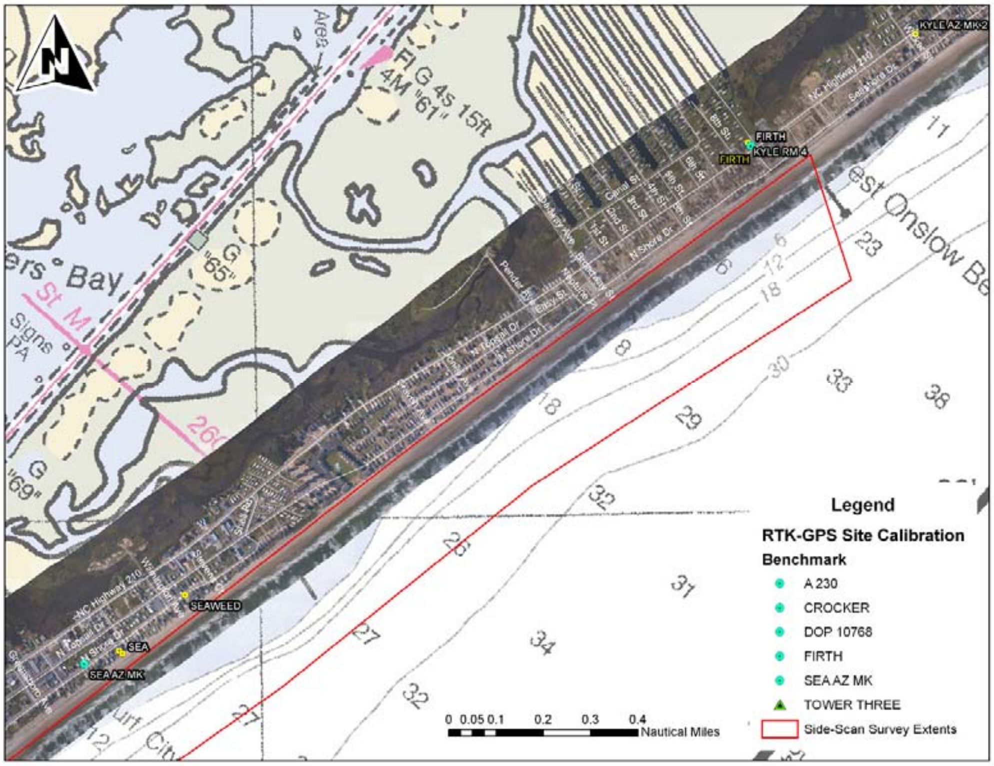


Figure 3. Topsail Island site calibration planning and control search map of the Surf City area.

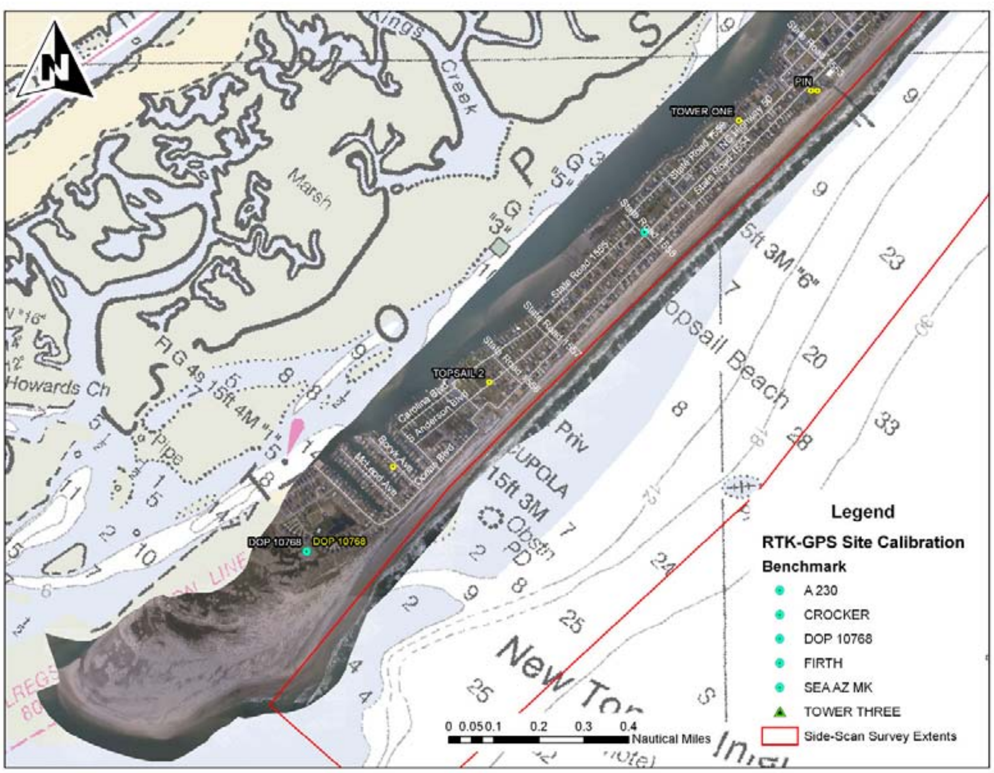


Figure 4. Topsail Island site calibration planning and control search map of the New Topsail Inlet area.

COMPLEX COASTAL CHANGE MADE CLEAR

RTK-GPS Pre-Survey Site Calibration

General

Date	6/10/2005 & 6/11/2006
Project	USACE Topsail Island Side Scan - phase 1
Surveyor(s)	Freeman / Bernstein
Equipment	Trimble 5700 Basestation, Trimmark III 25 watt RTK Radio, Maxrad 5dB gain Antenna, Zepher Geodetic base antenna, Trimble 5700 RTK rover, Zepher antenna
Weather	Sunny, Few Clouds, 84 F, ESE Wind 10-15 kts, humid
Units	Meters
Notes	Day 1 of site cal-initail Benchmark scouting and base feasibilty of using a tower. Basestation set on top of Tower 3. Permission granted by owner John Gresham (910-328-4471). Tower stairs are in tack and benchmark is accessible. No power on site. Day 2 of site cal-basestation setup, accuracy checks and range checks.
Coordinate System	NC State Plane, NAD83 (horiz), NAVD88 (vert)

Basestation Information

Designation	Tower Three 1947
PID	EA0695
Agency	CGS
Horiz Order	2
Vert Order	2
N	72282.902
E	738983.122
Z	15.434

Tower Three

Tower Three - looking NE

Benchmark Checks

Designation	DOP 10768
PID	AI0899
Agency	NCGS
Horiz Order	1
Vert Order	3

	Recorded	Published	Difference
N	67222.286	67222.119	-0.167
E	733619.27	733619.291	0.021
Z	2.341	2.31	-0.031

Notes	Benchmark is it the south end of Topsail Island behind cottage # 2125 A

DOP 10786 Benchmark

DOP 10768 BM Check

Benchmark Checks (cont.)

Designation	CROCKER		
PID	AI0831		
Agency	NCGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	68542.204	68542.046	-0.158
E	735010.538	735010.571	0.033
Z	1.351	1.33	-0.021
Notes	Benchmark is at intersection of Crocker and S. Anderson		

Crocker Benchmark

Crocker BM Check

Designation	A 230		
PID	EA0696		
Agency	CGS		
Horiz Order	1		
Vert Order	2		
	Recorded	Published	Difference
N	71298.722	71298.606	-0.116
E	737877.39	737877.413	0.023
Z	3.460	3.480	0.02
Notes	Benchmark is located in shrubs at 715 Shore Drive about 0.54 miles south of Catherine Drive.		

A 230 Benchmark

A 230 BM Check

Designation	FIRTH		
PID	AI0904		
Agency	NGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	78267.573	78267.452	-0.121
E	746327.18	746327.233	0.053
Z	1.234	1.20	-0.03
Notes	Benchmark is on NW side of W 9th St. North of Surf City.		

Firth Benchmark

Firth BM Check

Benchmark Checks (cont.)				
Designation	SEA AZ MK			
PID	AI0866			
Agency	NCGS			
Horiz Order	1			
Vert Order	3			
	Recorded	Published	Difference	
N	76227.279	76227.107	-0.172	Sea AZ MK Benchmark
E	743713.279	743713.317	0.038	
Z	2.605	2.57	-0.035	
Notes	Benchmark is located on the N side of house at 313 N. Shore Dr			Sea AZ MK MB Check

Multibeam Echosounder Calibration Report

Calibration Date:	June 24, 2006
Ship	
Vessel	RV 4-Points
Echosounder System	EM3002
Positioning System	POS MV (tightly coupled)-RTK GPS
Attitude System	POS MV
Sound Velocity Probe	Odem Digibar Pro (profiler) / Valeport Mini SVS (at head)

Annual		
Installation	x	
System change	x	
Periodic/QC		
Other		

Calibration type: Multibeam Sonar

The following calibration report documents procedures used to measure and adjust sensor biases and offsets for multibeam echosounder systems. This report has been adopted and modified from NOAA. Calibration must be conducted A) prior to CY survey data acquisition B) after installation of echosounder, position and vessel attitude equipment C) after changes to equipment installation or acquisition systems D) whenever the Hydrographer suspects incorrect calibration results. The Hydrographer shall periodically demonstrate that calibration correctors are valid for appropriate vessels and that data quality meets survey requirements. In the event the Hydrographer determines these correctors are no longer valid, or any part of the echosounder system configuration is changed or damaged, the Hydrographer must conduct new system calibrations.

Multibeam echosounder calibrations must be designed carefully and individually in consideration of systems, vessel, location, environmental conditions and survey requirements. The calibration procedure should determine or verify system offsets and calibration correctors (residual system biases) for draft (static and dynamic), horizontal position control (DGPS), navigation timing error, heading, roll, and pitch. Standard calibration patch test procedures are described in *Field Procedures for the Calibration of Multibeam Echo-sounding Systems*, by André Godin (Documented in Chapter 17 of the Caris HIPS/SIPS 6.0 User Manual, 2006). Additional information is provided in *POS/MV Model 320 Ver 4 System Manual* (10/2003), Appendix F, Patch Test, and the NOAA Field Procedures Manual (FPM, 2003). The patch test method only corrects very basic alignment biases. These procedures are used to measure static navigation timing error, transducer pitch offset, transducer roll offset, and transducer azimuth offset (yaw). Dynamic and reference frame biases can be investigated using a reference surface.

Pre-calibration Survey Information

Reference Frame Survey

RV 4-Points was surveyed by the National Geodetic Survey on February 15, 2006 for precise centerline and instrument locations. Steve Breidenbach performed the survey with a Trimble 5603 total Station.

(IMU, Ref Pt., and XY of CG are all co-aligned and attitude and position is valid at the sensor. The values below are entered in POSview software.)

Reference to IMU Lever Arm

X(m)	Y (m)	Z (m)
0	0	0

Reference to Pri. GPS

X(m)	Y (m)	Z (m)
1.849	-1.061	-1.724

IMU frame w.r.t. Reference frame

X(deg)	Y (deg)	Z (deg)
0	0	0

Reference to Sensor Lever Arm

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

Reference to CG

X(m)	Y (m)	Z (m)
0	0	0.313

Figure 5. Photo of the centerline and instrument survey by NGS.

Reference to Vessel (Pt of validation for attitude and nav)

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

__X__Measurements verified for this calibration.
___ __Drawing and table attached.
_____Drawing and table included with project report

POS MV Configuration File: 4_points_022806._*________________

Notes: _NGS vessel survey results were put in POSview and GAMS calibration was done on February 28, 2006___.

Calibration Area

Site Description

This patch survey was conducted in the Port of Morehead City's turning basin near Beaufort Inlet, North Carolina (N34 41 39.16 W076 40 07.53). This site was selected for its particular bottom features, such small scale ripple fields, sand waves (wavelength: ±5m, amplitude: ±0.15m), deep flat areas, and high slopes.

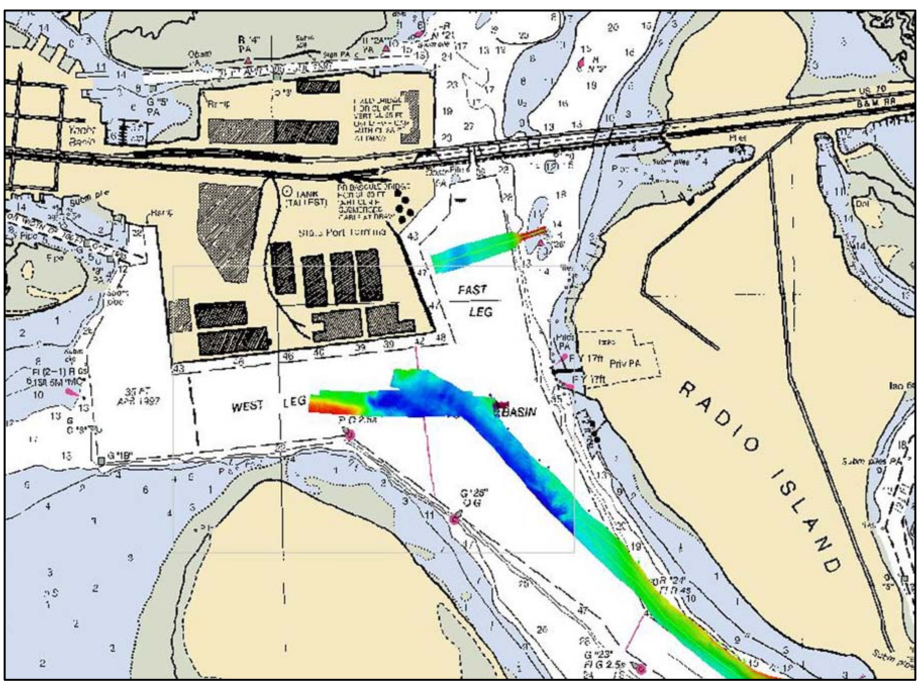


Figure 6. Map of the patch survey area within the Morehead City Turning Basin.

Survey Procedure

Vessel biases were determined through a patch test survey procedure. Data was acquired and analyzed in Kongsberg SIS package. The latency test was performed first by surveying the same survey line in the same direction at 2 different vessel speeds. The latency test was done twice to verify initial results. The pitch test was done second by surveying the same survey line in opposite directions at the same speed and evaluating the sloped portion of the survey line. The roll test was performed next by surveying the same survey line in opposite directions at the same speed and evaluating the deep flat portion of the survey line. The roll test was done twice to verify initial results. The yaw test was performed next by surveying 2 adjacent survey lines in the same direction, with similar speeds, with enough overlapping coverage such that the outer beams from each swath overlap (±40%).

Calibration Lines

Hypack Line	**Line File**	**Az.**	**Spd**	**Correction**			
				Pitch	Roll	Yaw	Latency
1	0000_20060301_163731_4points.all	57°	3.3kts				X
1	0001_20060301_164249_4points.all	57°	7.1kts				X
1	0002_20060301_165502_4points.all	237°	3.2kts				X
1	0003_20060301_165938_4points.all	237°	7.0kts				X
1	0002_20060301_155849_4points.all	237°	7.0kts	X			
1	0003_20060301_160222_4points.all	57°	7.0kts	X			
1	0000_20060301_172142_4points.all	57°	7.0kts		X		
1	0001_20060301_172427_4points.all	237°	7.0kts		X		
1	0000_20060301_183521_4points.all	237°	7.0kts		X		
1	0001_20060301_183741_4points.all	57°	7.0kts		X		
8	0001_20060301_191059_4points.all	280°	7.0kts			X	
7	0002_20060301_191957_4points.all	100°	7.0kts			X	

Sound Velocity Correction

Measure water sound velocity (SV) prior to survey operations in the immediate vicinity of the calibration site. Conduct SV observations as often as necessary to monitor changing conditions and acquire a SV observation at the conclusion of calibration proceedings. If SV measurements are measured at the transducer face, monitor surface SV for changes and record surface SV with profile measurements.

Sound Velocity Measurements

Time	**Max Depth**	**Surface SV**	Change Observed	**Position**	
				Latitude	Longitude
14:52:00	15.5m	1490.2		34 42.9705	76 41.6239
Continuous SV at head			<4 m/s throughout entire calibration		

Data Acquisition and Processing Guidelines

Initially, calibration measurement offsets should be set to zero in vessel configuration files. Static and dynamic draft offsets, inertial measurement unit (IMU) lever arm offsets, and vessel reference frame offsets must be entered in appropriate software applications prior to bias analysis. Perform minimal cleaning to eliminate gross flyers from sounding data.

Navigation Timing Error (NTE)

Measure NTE correction through examination of a profile of the center beams from lines run in the same direction at maximum and minimum vessel speeds. NTE is best observed in shallow water.

Transducer Pitch Offset (TPO)

Apply NTE correction. Measure TPO correction through examination of a profile of the center beams from lines run up and down a bounded slope or across a conspicuous feature. Acquire data on lines oriented in opposite directions, at the same vessel speed. TPO is best observed in deep water.

Transducer Roll Offset (TRO)

Apply NTE and TPO corrections. Measure the TRO correction through examination of roll on the outer beams across parallel overlapping lines. TRO is best observed over flat terrain in deep water. An additional check for TRO adjustment can be performed by running two lines parallel to a sloped surface.

Transducer Azimuth Offset (TAO or yaw)

Apply NTE, TPO and TRO corrections. Measure TAO correction through examination of a conspicuous topographic feature observed on the outer beams of lines run in opposite directions.

Patch Test Results and Correctors

Evaluator	NTE (sec)	TPO (deg)	TAO (deg)	TRO (deg)
Bernstein/Hohing	0.00	0.00	0.00	-0.65
Final Values	0.00	0.00	0.00	-0.65

Corrections Calculated in:	
Caris	
ISIS (BathyPro)	
Other	SIS

NOTE: TRO bias of -0.65 was put in SIS software.

Evaluator: Dave Bernstein
Reviewed by: Dave Bernstein
Accepted by: Dave Bernstein
Date accepted: June 25, 2006

Graphical Examples of Calibration Acceptance

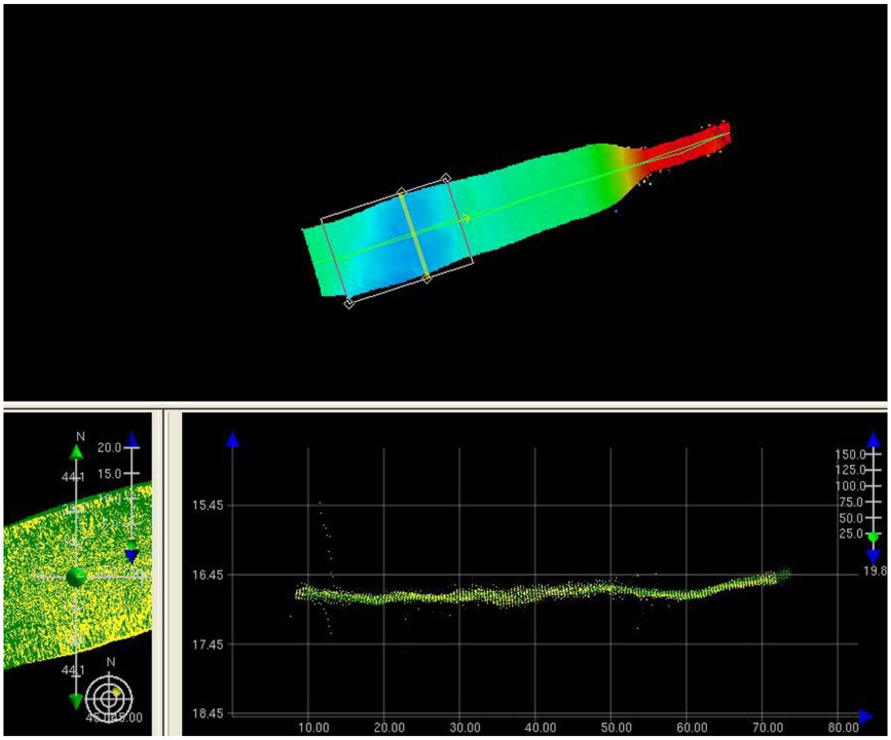


Figure 7. Caris screen grab illustrating acceptance of roll calibration.

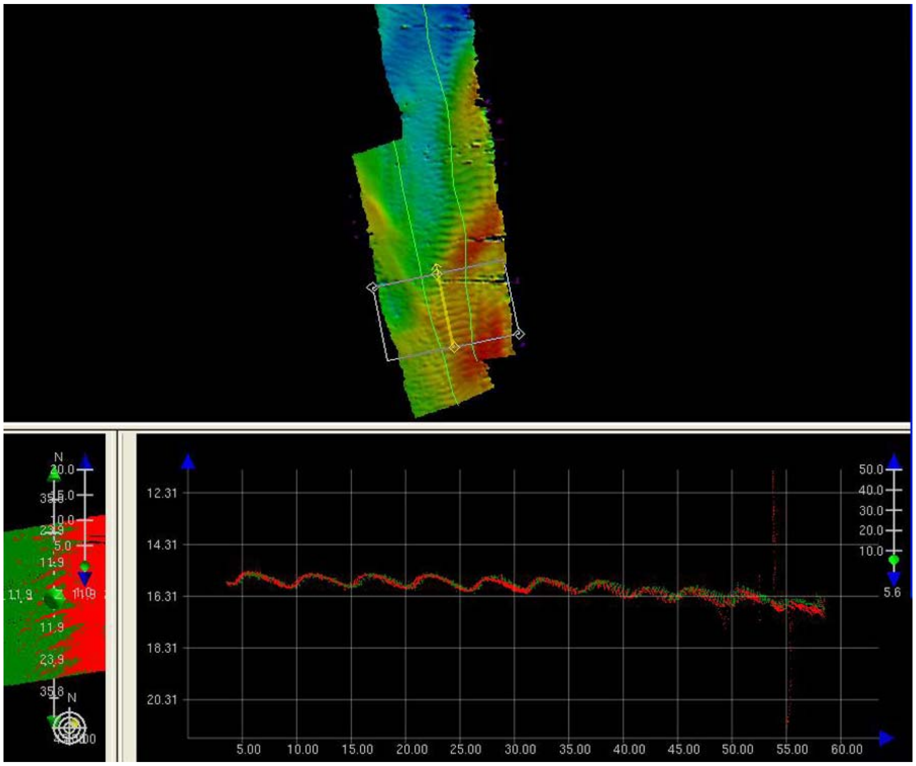


Figure 8. Caris screen grab illustrating acceptance of yaw calibration.

Data Processing Routines & QA/QC Information

Introduction

Processing high-density multibeam bathymetry and backscatter data requires a multitude of processing routines and data quality analyses. The following section will detail all aspects of data post-processing for the Beaufort Inlet multibeam surveys. Also presented in this section is detailed QA/QC information and analysis generated throughout the various processing procedures.

Bathymetry Processing

The multibeam collects swath widths approximately 4 times the water depth. The portions of swath, mainly in the outer beams, that exhibit areas of inconsistent data are clipped and not included in the final digital file. Sounding track lines are generally parallel to each other and parallel to the seafloor contour. Sinuous lines and data acquired during turns are not included in the final processed data. To meet the accuracy and resolution standards for measured depths specified in the USACE Hydrographic Surveying Manual and the NOS Hydrographic Surveys, Specifications and Deliverables Manual, measured echosounder depths were corrected for all departures from true depths attributable to the method of sounding or to faults in the measuring apparatus. These corrections are subdivided into four categories, and are listed below in the sequence in which they were applied to the data.

1. Instrument error corrections: included to account for the sources of error related to the sounding equipment itself.

2. Vessel offsets: added to the observed soundings to account for the depth of the echosounder below the water surface, positioning of the motion reference unit, and GPS antenna.

3. Velocity of sound correctors: applied to the soundings to compensate for the fact that echosounders may only display depths based on an assumed sound velocity profile while the true velocity may vary in time and space.

4. Heave, pitch, roll, heading and navigation latency corrections: applied to the multibeam soundings to correct for the effect of vessel motion caused by waves and swells, the error in the vessel's heading, and the time delay from the moment the position is measured until the data is received by the GPS receiver.

Multibeam Data Processing Steps in CARIS HIPS software:

The EM3002 sonar system has a unique arrangement of data flow. Most settings that influence the data are put in before and during a survey and therefore are not a factor in data processing (these include vessel offsets, lever arms, vessel biases, timing biases, and survey sound velocity). Vessel attitude is also processed real-time during a survey.

Post-processing of multibeam data consist of attitude and navigation editing, merging, swath editing, area-based editing, and exporting of final data.

1. Attitude & Navigation Editing: Errors or gaps in attitude and navigation information causing errors in soundings are edited.

2. Merging: Computing and integrating the GPS tide in the sounding data. Additional sound velocity corrections are made if needed in this phase. Draft changes for datum conversions are made here as well.

3. Total Propagated Error (TPE) is calculated

4. Swath- and beam-based filters and TPE (IHO standards) filters are applied.

5. Swath Editing: Swaths are edited for erroneous data if needed

6. Base or CUBE Surface is created for area- and CUBE-based editing.

7. Area-based editing using the subset editor to edit/check erroneous data only within the desired subset.

8. CUBE filtering (if needed)

9. Recompute TPE

10. Recompute CUBE and/or base surface

11. Final export of base surface to XYZ decimated soundings (1m).

NOTE: Bathy is delivered in NAVD 88 until we determine if phase 2 will require the NGVD 29 vertical datum. Also, bathy data maybe adjusted in phase 2 once we get some overlapping coverage to determine slight offsets that may need to be applied for roll due to the towing of the side-scan sonar.

Side-Scan Processing

1. Side scan is replayed (ISIS) and slant range corrected. Areas that have lost bottom track data are manually digitized to replace lost altitude data.

2. Appropriate image corrections are determine in ISIS and defined for the mosaic procedure.

- A threshold of 4 was used for all files incorporated in the mosaic. This means the 8 bit or 16 bit data is shifted by 4 bits to correct the histogram when the data is played for mosaic.

- A “STANDARD: TVG correction with a Pixel to Pixel Balance correction was applied to all files in the mosaic. This correction implemented a 4% darkness and a 10% decay rate.

3. The data is then mosaiced using ISIS to play back the data and Delphmap Mosaic to create the mosaic file.

All of the mosaic setting and corrections are applied in Delph Mosaic.
- layback = 4.5m
- X shift = 4.3m
- set data resolution 50 cm for channels 1-2 15cm for channels 3-4
- cover up for overlapping lines
- fill gaps between pings
- use course made good for heading (heading not as useful due to unknown declinations to the klein mag compass)

During this stage, the depth, delay, and duration settings are altered for each file played back in order to provide adjacent lines with specific coverage (overlap) in ISIS.

4. The mosaic in Triton DDS_VIF format is then exported to Geo-Tiff file format with associated .world file.

Typical Side-Scan Artifacts

Feature Accuracy Information: Side-scan sonar artifact information has been synthesized from the Handbook of Seafloor Sonar Imagery, Blondel & Murton, Geoff Shipton at Triton Imaging, and from out past experience with these data.

The Klein 3000 is a digital side-scan sonar system capable of producing digital image maps of the seafloor from reflected sound waves or acoustic backscatter from the seafloor. These images are created by transmitting a series of sound pulses and recording their echoes from the seafloor as the survey vessel moves across a set course. The sound source and receivers are built into a "tow fish" that moves through the water at varying depths and distances from the survey vessel dependent on the water depth. The returned signal is then recorded by shipboard computers with an amplitude range of 0-255 with strong returns recorded as higher values and weak returns recorded as lower values. The darkness or brightness of a side-scan mosaic is a function of the gradient or slope of the seafloor, surface roughness, and the sediment characteristics such as texture which can all be interpreted by a marine geologist.

The main advantage of side-scan sonar over the backscatter product generated from multibeam sonar is the greater coverage that can be achieved (ex. in 10m of water = 40m for multibeam and up to 300m (although this dataset uses a swath width of 120m for higher detail) with side-scan) and a more detailed image of the seafloor. However, side-scan data tends to be much noisier and contains far more artifacts than multibeam. Below are some of the major artifacts to be expected in any side-scan mosaic.

Heave & Motion Artifacts: In a perfect scenario side-scan would be collected in flat calm conditions with zero boat motion that would translate into the towed vehicle. In addition, towing a side-scan into shallow water creates additional heave artifacts due to the short tow. Flat calm conditions rarely happen in an oceanic environment and really never happen when approaching the nearshore environments where waves begin to propagate. Heave artifacts are caused by changes in pitch due to tugging on the vehicle line. At the point where the fish moves through the horizontal (Pitch = 0) the sonar beam strikes the bottom at a right angle and the return path is directly along the axis, which gives a good return. Either side of the zero pitch point the returns become weaker. The effect on the record is banding in the across track direction. Aside from slight pitch corrections made in the processing software (ISIS in this case) there is nothing that can be done to correct for the fact that the point where the return comes from moves fore and aft as the pitch changes. Roll, Pitch, Yaw can all be taken into account in post processing to some reasonable level; however, the towfish based altimeter and flux gate compass are not to the standard of those used for compensating bathymetric data.

Running Parallel to a Slope Artifacts: Depending on how steep the slope is you will see a stronger return on the uphill slope and a weaker return on the downhill slope. How much this affects the image will depend on two things; how steep the slope and how reflective the seafloor. The slope could, in some cases, decrease the grazing angle sufficiently that the sound simply bounces off completely and hardly anything gets back. This angle varies with different bottom types. The artifact that can be generated in this scenario, provided there is a highly reflective bottom (which we see in several areas at Topsail) is a two toned effect on the area of interest. There are a few independent gain settings for each sonar channel that can help; however, applying different gain settings for each opposing line becomes a bit black magic and hence we don't typically tweak these settings beyond a certain point.

Sea Surface Reflection Artifacts: In shallow water applications such as the Topsail Island project side-scan sonar imagery can be corrupted by multiple reflections from the sea surface. The first reflection is formed when the sonar beam reflects once from the seafloor and once from the sea surface. This artifact can manifest itself as bright lines parallel to the sonar track, at a distance from the sonar track roughly equivalent to the water depth. If the swath is wide enough subsequent multiples will also be present as equidistant bright lines parallel to the first reflections. They primarily occur in areas with flat and smooth sedimentary features or from white capping of waves on the surface. A few of these artifacts can be seen in the inshore side-scan line at Topsail.

Water Column Artifacts: Artifacts related to the propagation of the acoustic pulse in the water column from the sensor to the seafloor and back can be attributed to two sources. The first are variations in the structure of water column due to density variations, salinity variations and temperature variations. Depending on the depth, a certain amount of thermocline layers will modulate the depth and angle at which the acoustic rays propagate. These artifacts are generally at the far range of the swath and look similar to linear bedforms. The second artifact that can be produced from speed of sound variations are derived from the presence of bubbles in the water. This may come from the wake of the survey vessel or from cavitation caused by the ships propellers. High-frequency systems such as the Klein 3000 are sensitive to bubbles and cause the sonar beams to become partially dispersed and partially reflected before they reach the seafloor. The artifact that can be created in this case is random data gaps at all ranges. In the Topsail data there is no indication that thermoclines are playing a role in artifact generation (sound velocity measurements for multibeam do not indicate any presence of thermoclines); however, prop wash may be the cause for some random gaps in across track data.

Radiometric Artifacts: The most frequent cause of systematic radiometric artifacts reside in the acquisition system itself. Connections between the cable and topside computers, broken points in cable, faulty grounds, etc. Another cause is interference between other acoustical systems. Although we turn off our shipboard singlebeam sonar since this is a known point of origin for artifact we are running the Simrad EM3002 multibeam sonar simultaneously which might create a small level of cross-talk. We have never seen this in the data per say but there are some slight noise artifacts on the edges of some swaths that might be attributed to cross-talk between the two systems. Another possible radiometric artifact is the rapid attenuation of the backscattered signal when the sonar platform goes up or down too rapidly or an abrupt change in seafloor depth. This change is usually too localized and rapid to be corrected with the normal time-varying gain (TVG).

Geometric Artifacts: Side-scan data can become distorted by the variations in the horizontal and vertical movement of the towfish such as those created by motion; however, variations in the survey vessel speed, if not taken into account properly, can cause distortion in the along-track direction. If the platform speed assumed during processing is higher than the actual value the swath lines will be positioned too far away from each other, and the image will be stretched along-track. Conversely, if the platform speed is lower, the swath lines will be positioned too close to each other, and the image will be compressed along-track. Discrepancies between matching seafloor morphology will be the result. Since we collected multibeam sonar simultaneously we were able to use the cm-scale positioning from the RTK-GPS to align each successive swath.

Examples of Known Artifacts in Topsail Side-Scan Data

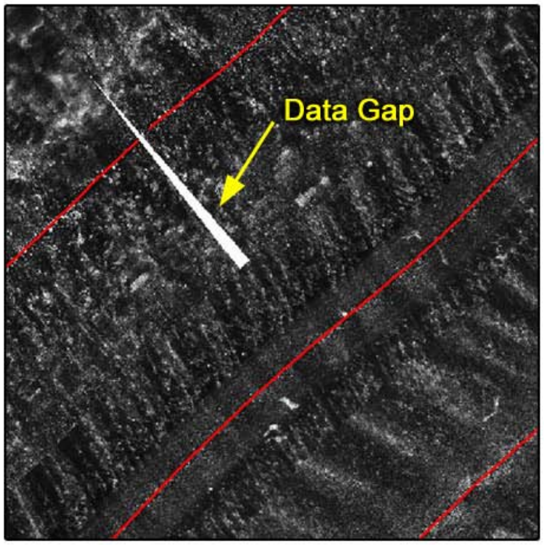


Figure 9a. Data Gap in side-scan record.

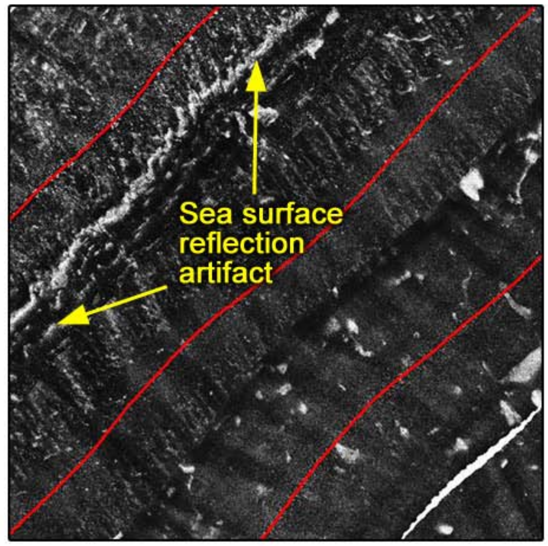


Figure 9b. Sea surface reflection artifact.

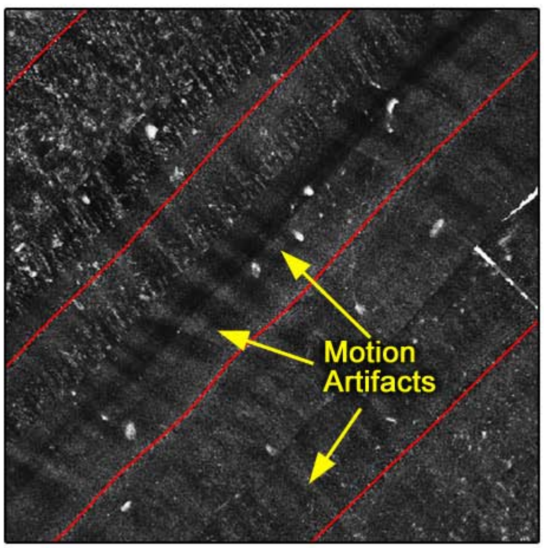


Figure 9c. Artifacts produced by vessel-towfish motion.

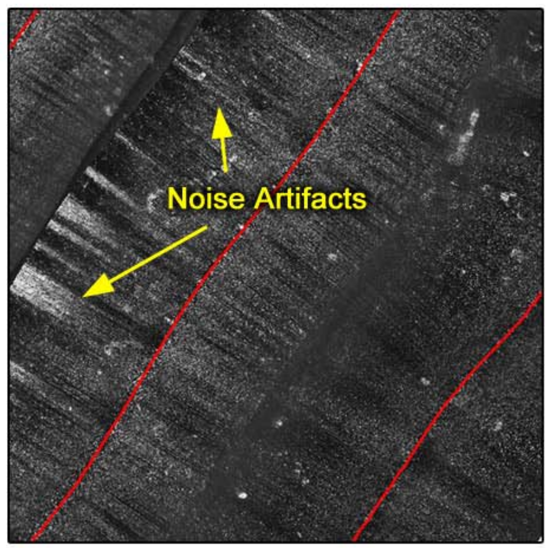


Figure 9d. Noise artifacts.

Potential Hardbottom Identification

To facilitate maximum efficiency in identifying hardbottom regions for phase 2 of the project we completed a QTC analysis of the backscatter which fell outside of the official SOW. Data from this analysis is provided on the accompanying DVD and the Quester Tangent report is provided in Appendix E. Preliminary results of the QTC unsupervised classification show several classes that exist on areas of known artifact. However, visual inspection of the data shows that QTC Class 4 correlates to our interpretation of potential hardbottom regions.

In order to synthesize these data into a structure to identify potential hardbottom regions and to eliminate much of the noise present in these data we manually digitized the areas that we feel have the most potential of being hardbottom. To provide a more quantitative digitization we used both the QTC Class 4 data and some preliminary analysis completed in Triton SeaClass software.

Between the three preliminary analyses it appears that most all of the potential hardbottom regions exist starting approximately 800 ft offshore (2004 wet/dry line) to the end of the survey which is approximately 1800 ft offshore (2004 wet/dry line). There are a few areas on the inshore seam, from approximately 300 ft to 800 ft from the 2004 wet/dry line, that exhibit a differing signature from the surrounding seafloor. It is thought that these areas are likely artifact since we have compared the overlapping multibeam backscatter and there are no correlations that can be made between the two. However, closer inspection may be required during phase two in an effort to eliminate these zones as possible hardbottom.

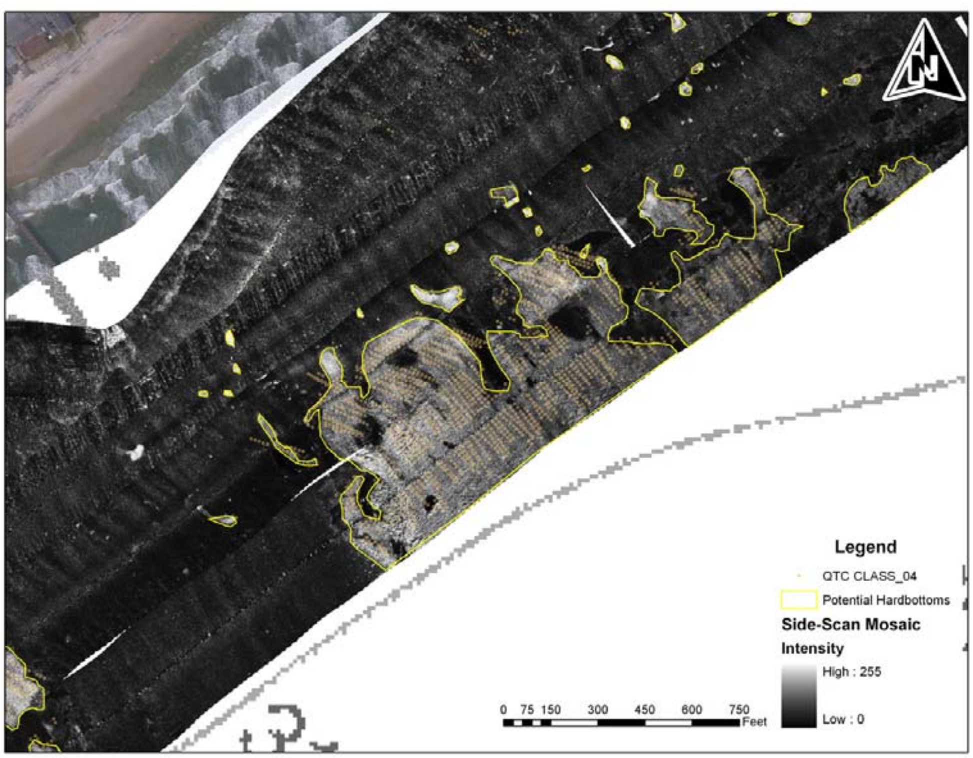


Figure 10. Map illustrating potential hardbottom areas.

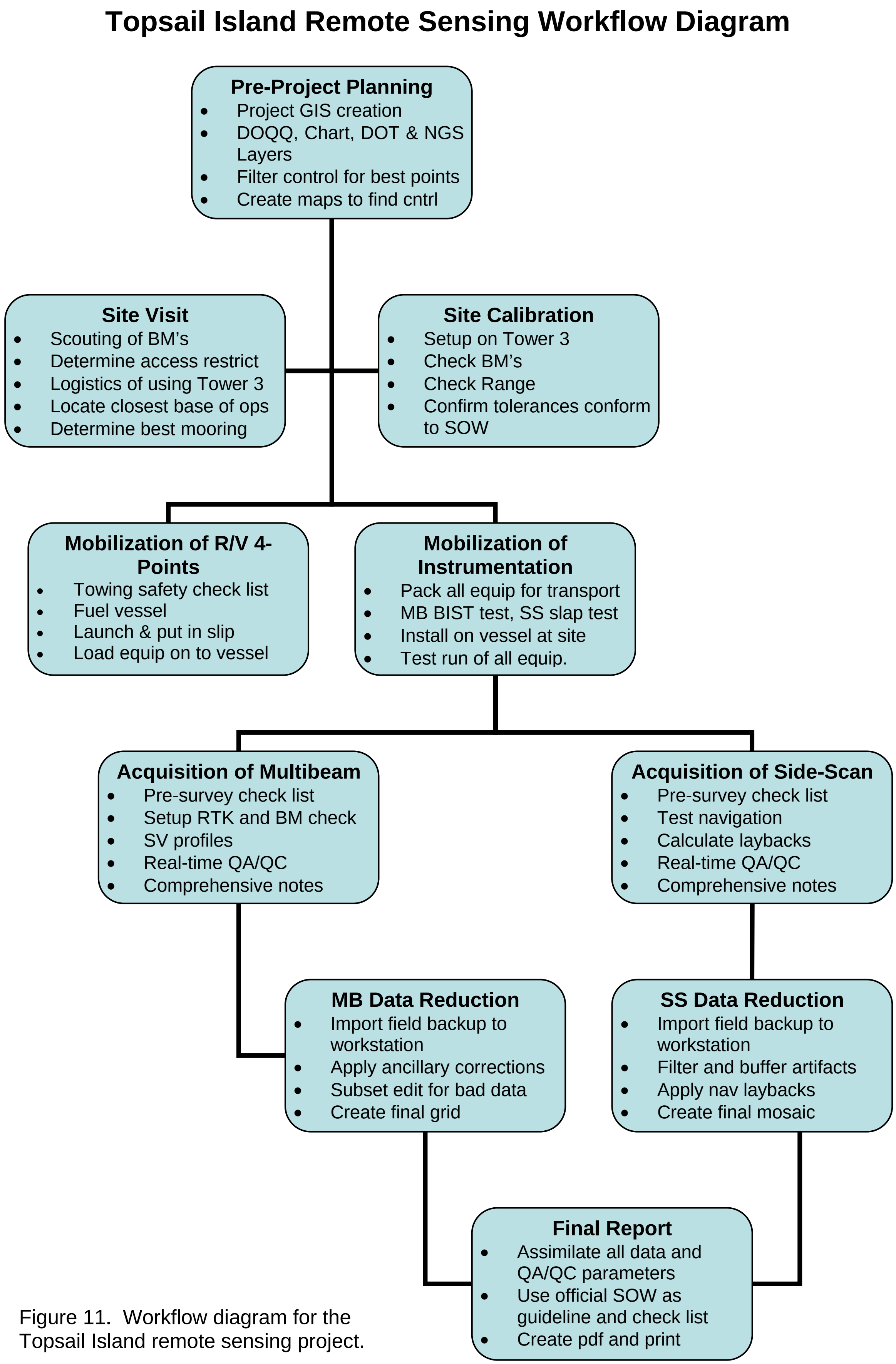


Figure 11. Workflow diagram for the Topsail Island remote sensing project.

Topsail Island Remote Sensing QA/QC Workflow Diagram

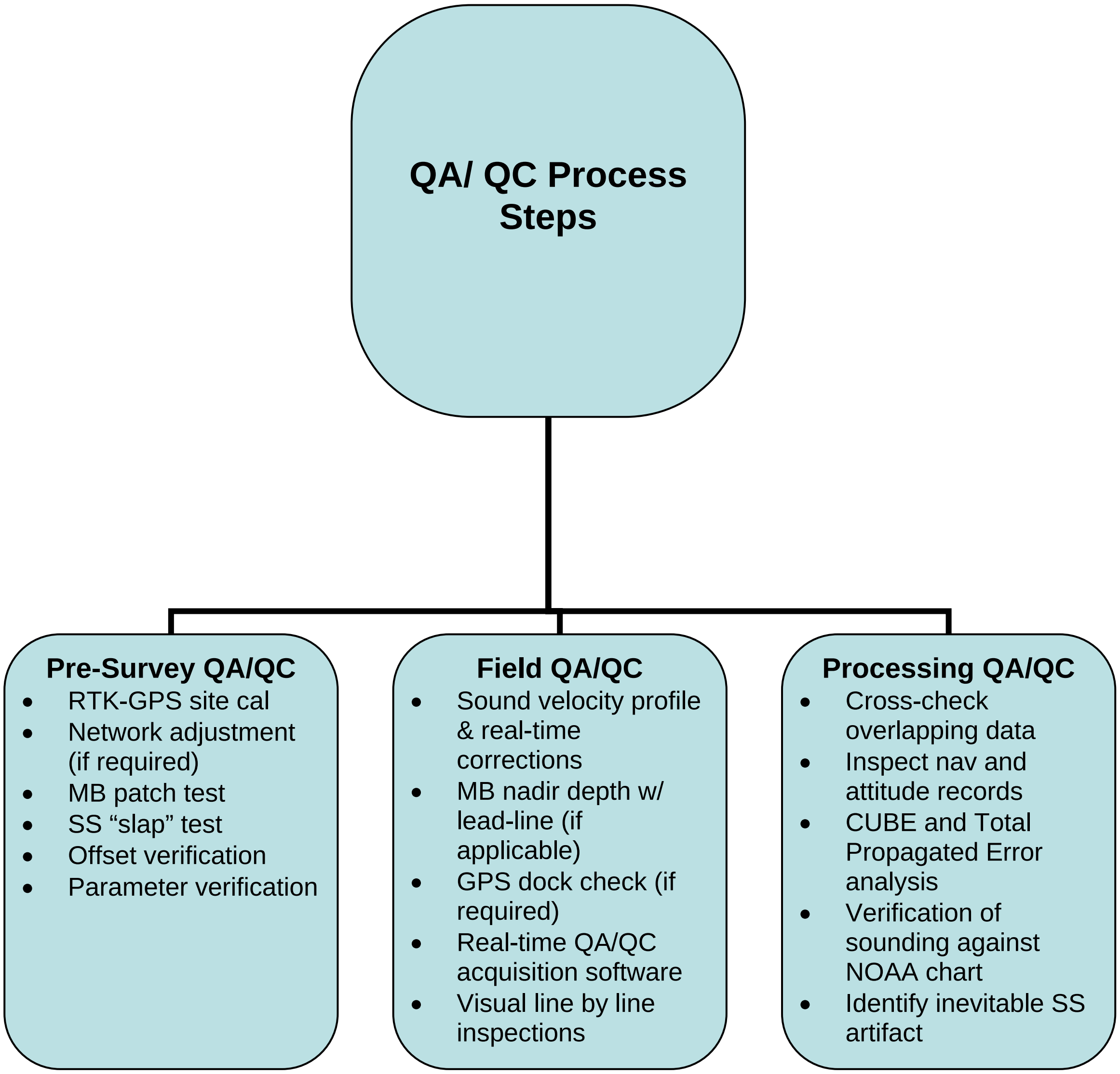


Figure 12. QA/QA Workflow diagram for the Topsail Island remote sensing project.

Graphical Summary of Deliverables

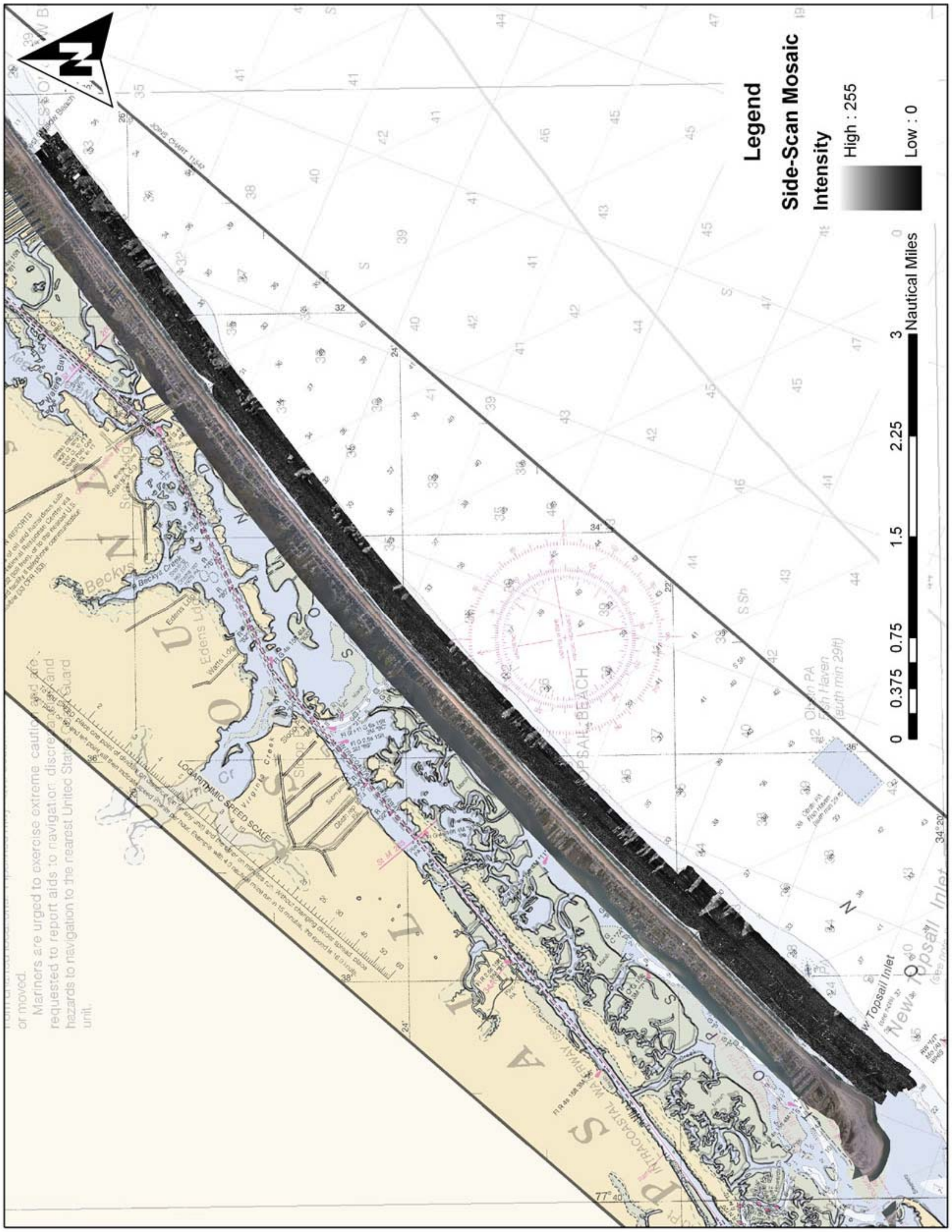


Figure 13. Side-scan sonar mosaic.

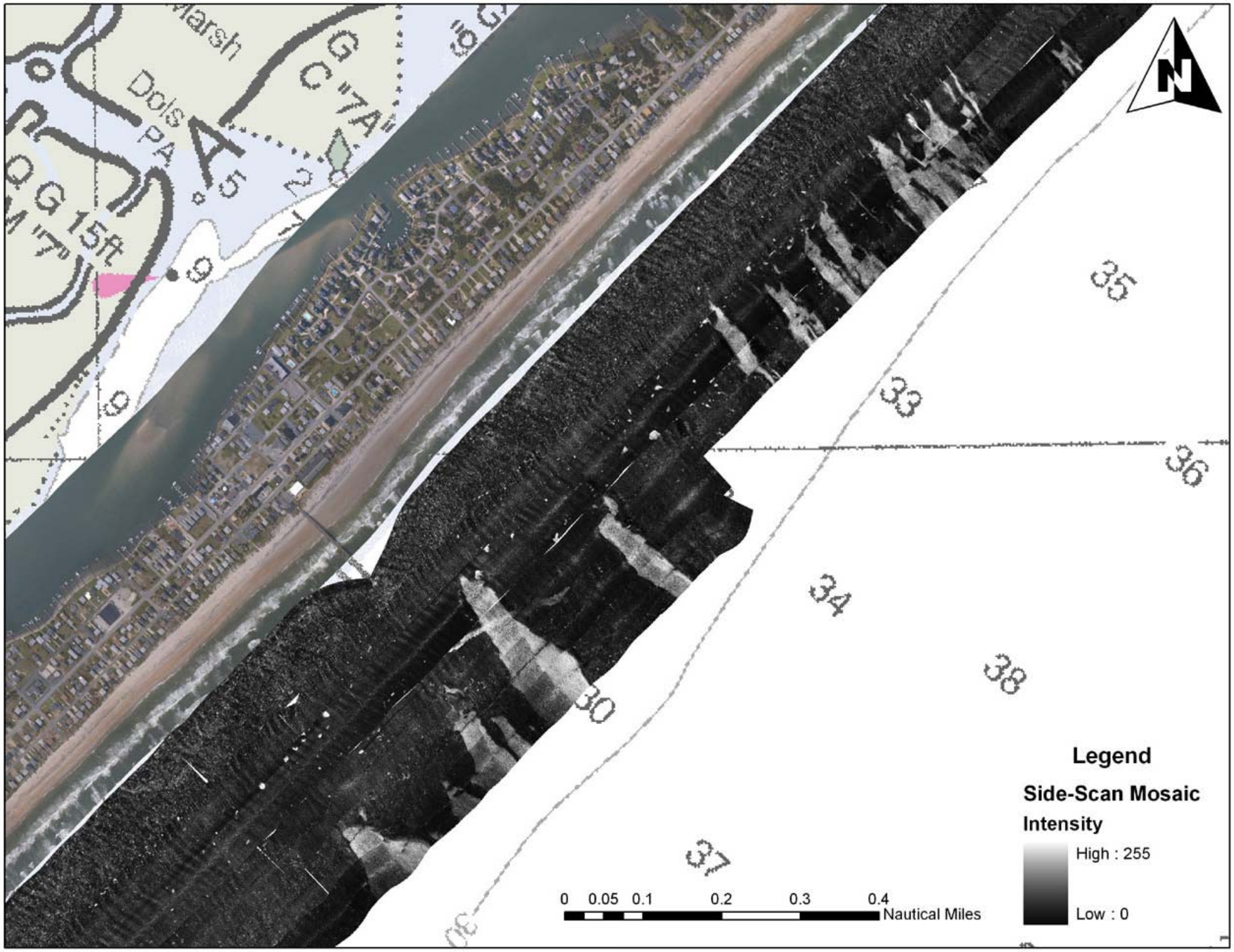


Figure 14. Close-up view of the side-scan sonar mosaic in the sourth portion of the survey area.

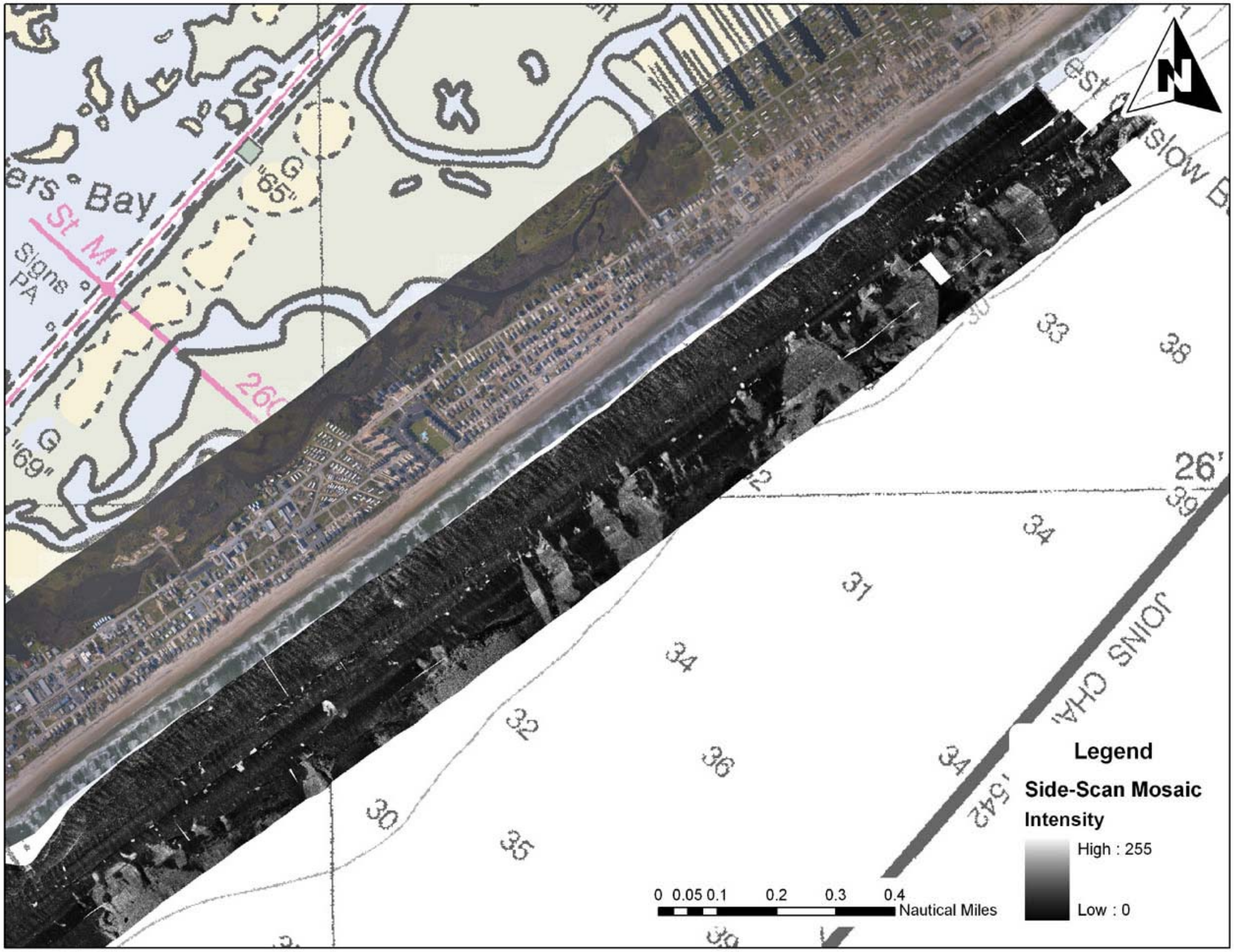


Figure 15. Close-up view of the side-scan sonar mosaic in the north portion of the survey area.

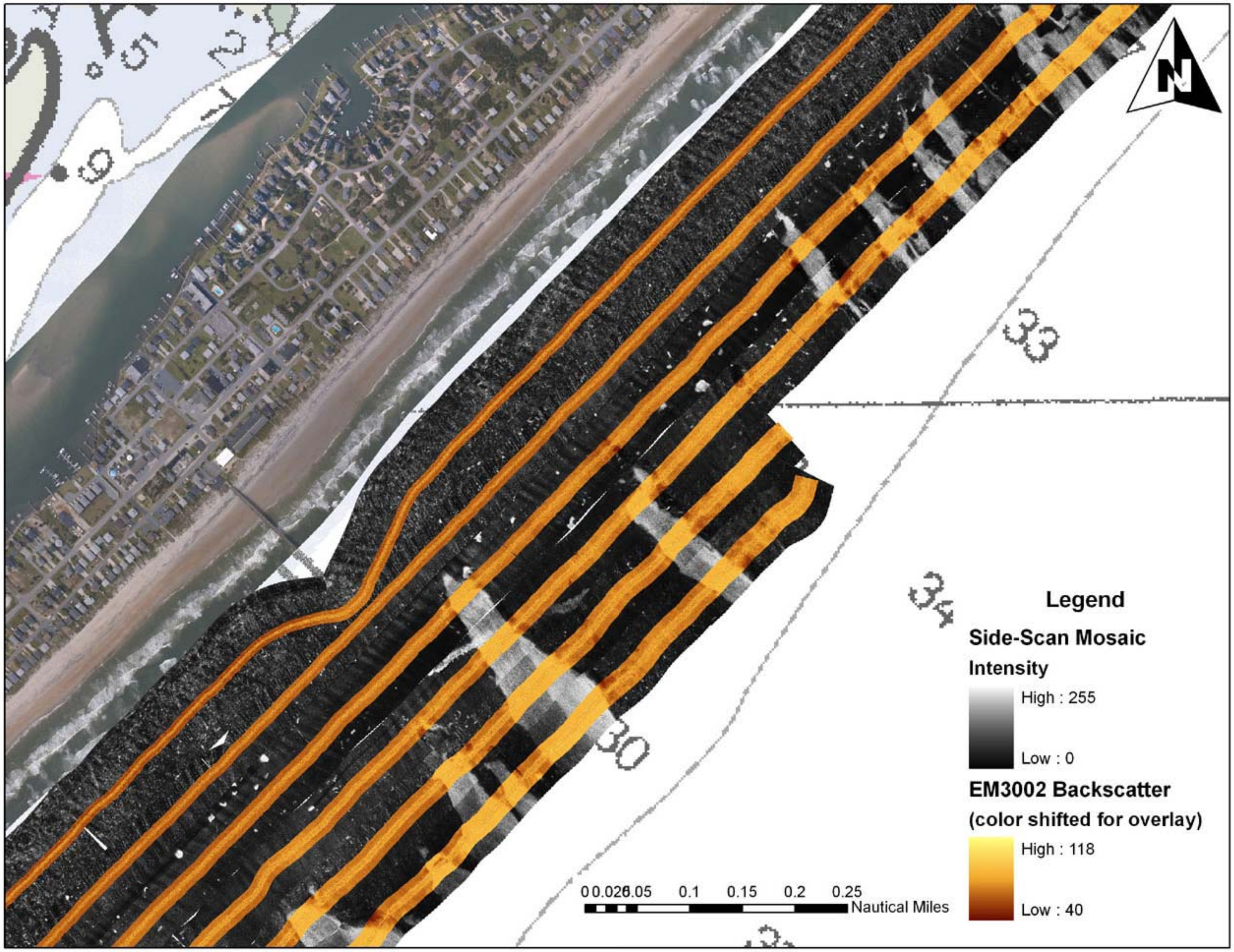


Figure 16. Side-scan sonar mosaic overlaid with EM3002 backscatter data. Alignment of features between datasets illustrates excellent positioning calculation for the side-scan mosaic.

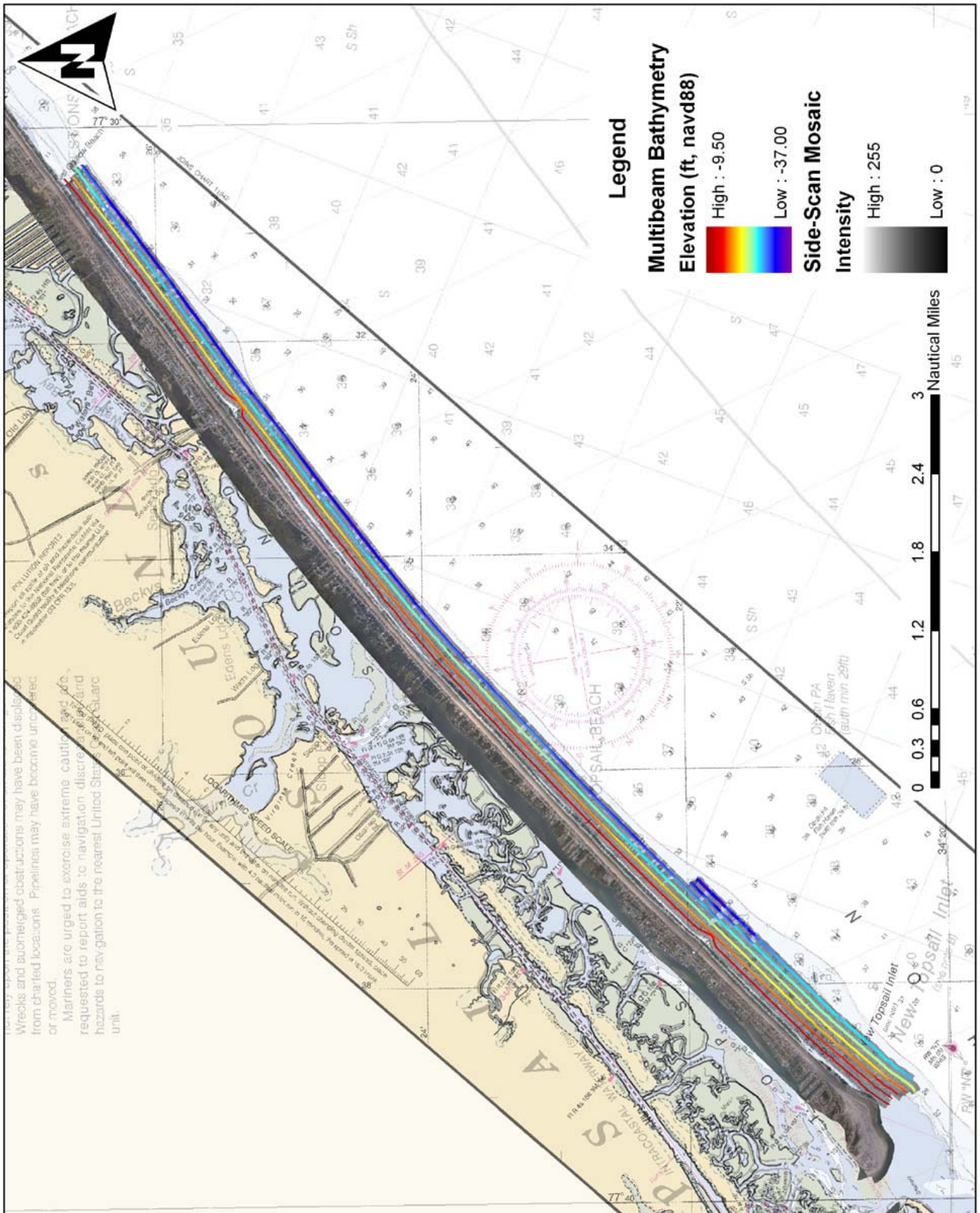


Figure 17. EM3002 Multibeam bathymetry.

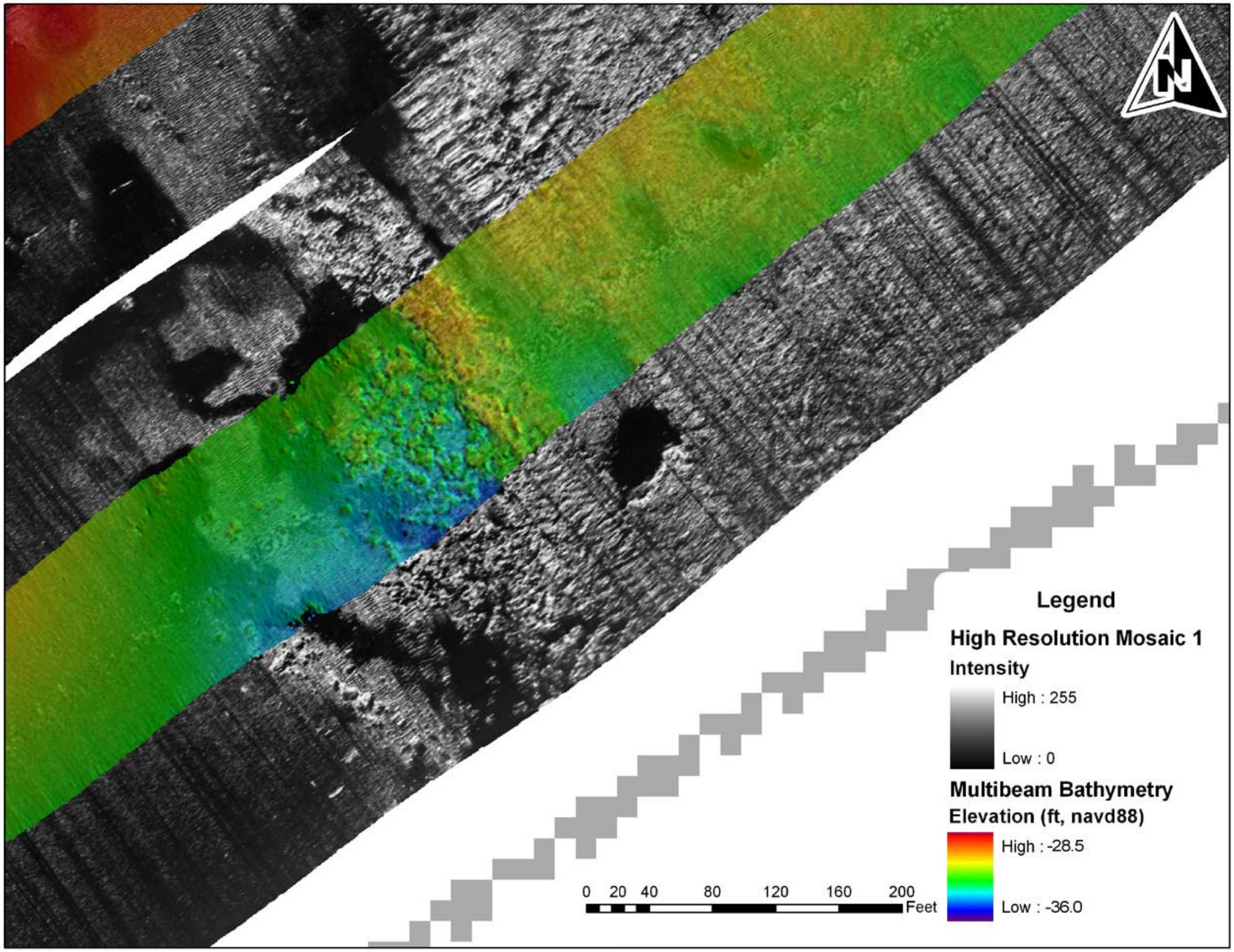


Figure 18. Rendered bathymetry overlaid on high-resolution side-scan sonar imagery. Map illustrates a low-relief hardbottom and sediment interface.

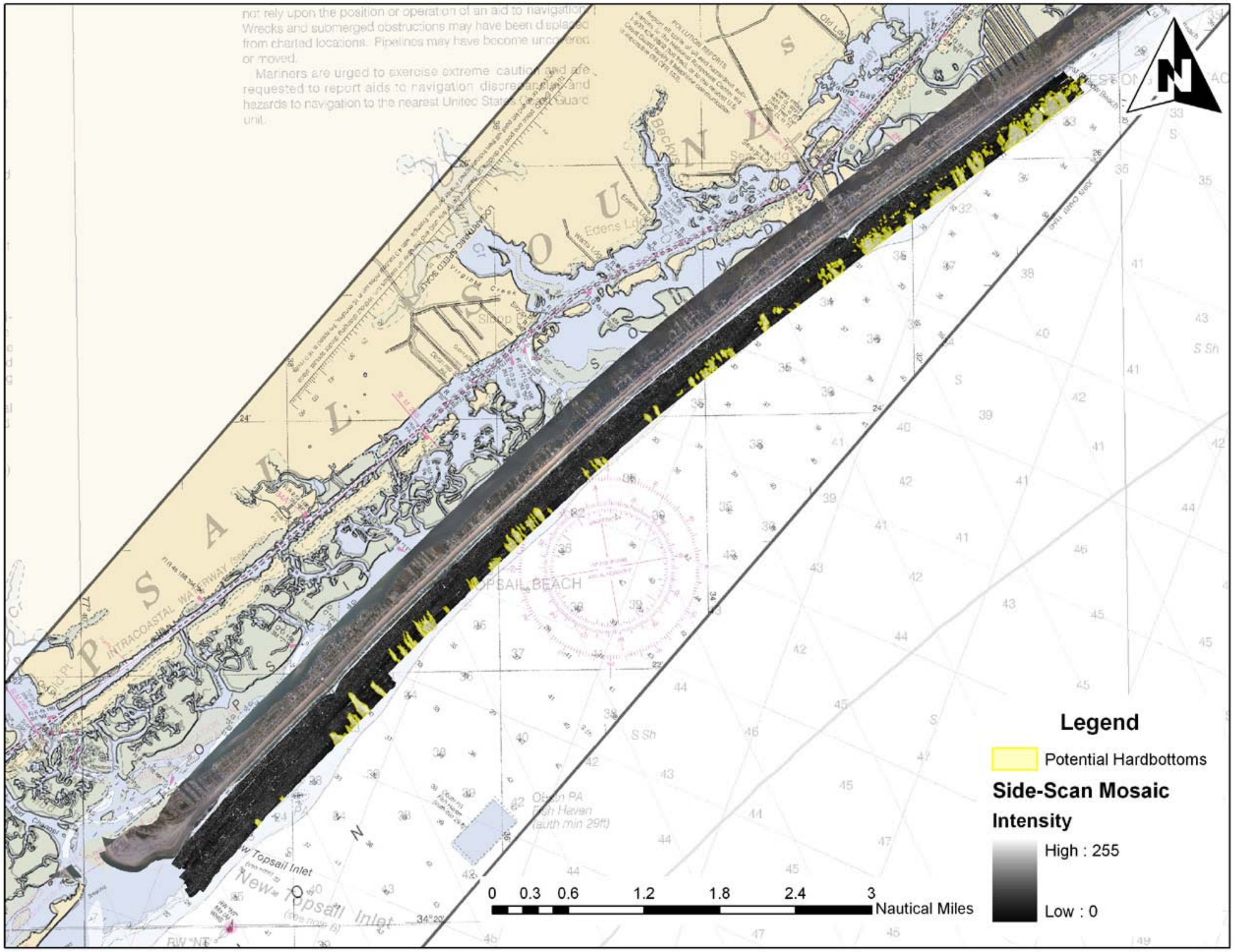


Figure 19. Side-scan sonar mosaic overlaid with polygon shapefile of potential hardbottom areas.

Appendix A – Official USACE Scope of Work

SCOPE OF WORK
NEARSHORE HARD BOTTOM SIDESCAN SURVEY
TOPSAIL ISLAND, NORTH CAROLINA

1. General. The Contractor shall acquire Sidescan Sonar Data along Topsail Island, North Carolina for the purposes of identifying and mapping potential Hard Bottom Areas. The longshore limits of the data collection extend form New Topsail Inlet to the Surf City/North Topsail town line as identified on the Government furnished map. The offshore limits shall extend from the mean low water contour to the -25 feet NGVD 1929 contour as identified on the Government furnished map.

2. Survey Control. All horizontal and vertical control used for this survey shall be from the North Carolina or a Federal Agency Network and be of third order accuracy or better. All control loops must be tied to at least two or more control points. The Contractor shall furnish a list of all points used to the Government. All work shall be relative to NAD 1983 North Carolina State Plane Feet in the horizontal plane and NGVD 1929 in the vertical plane. The Government will provide control information for previously established Control Points along the length of the project area.

3. Clearances. The Contractor shall acquire all Clearances necessary to obtain the required data. All discussions for access to private or public property or restricted waters or airspace must be included in the required weekly status report with name of person, address, and telephone number.

4. Required Deliverables. The Contractor is required to deliver Side Scan Mosaic Raster Data Sets, Shapefiles, Metadata Records, a Weekly Status Reports, and a Final Written Report.

4.1 Side Scan Mosaic Raster Data Sets. The Contractor shall deliver Georeferenced Mosaics of the Raster Data sets from the Side Scan Survey. The Raster Data sets shall depict the backscatter information used to map the potential hard bottom areas in the project area. The Raster Data Sets shall be in a format compatible with ESRI ArcView/ArcInfo Version 9.0.

4.2 Shapefiles. The Contractor shall deliver Polygon Shapefiles defining the potential hard bottom areas within the project area. The Shapefiles shall be in a format compatible with ESRI ArcView/ArcInfo Version 9.0.

4.3 Metadata Record. An FGDC compliant metadata record for each spatial data deliverable shall be created using ESRI ArcView/ArcInfo ArcCatalog version 9.0. Appropriate information shall be entered in all required fields. The Contractor shall attach the appropriate metadata record to each spatial data file using ArcCatalog so that no importing or formatting of the metadata record is required by the Government.

5. Weekly Status Report. **The Contractor is required to submit a Weekly Status Report each week, beginning on the Task Order Award Date, until all deliverables are received and accepted by the Government**. The Weekly Status Report shall be delivered via e-mail no later than 8:00 AM each Monday and shall document the Contractor's progress from the previous Monday through the previous Sunday. The status report shall itemize each scope item with percent of work complete and an estimated date of completion. The report shall also include the number and type of field crews working, a description of any problems and/or delays encountered, and any photographs of the site and/or significant site features (such as outlet structures, retaining walls, escarpments, etc.) and/or specialized data collection activities.

6. Final Written Report. A written report summarizing all data collection activities shall be submitted as a Portable Document File (PDF) and in bound hardcopy. The following items shall be included in the survey report:

- Written description of workflow to complete task order (start to finish) including flowchart diagram and detailed description of QA/QC process
- Dates and times of each data collection activity
- Atmospheric Conditions for each day of data collection activity
- All Horizontal and Vertical Control used including monument name, establishing agency, date established, description, and published horizontal and vertical values
- TBM descriptions with vertical values
- Copy of all field notes
- Complete and detailed list of all survey equipment used including copy of last factory calibration report
- Metadata Record as described in 4.3 above
- Photographs of the site and any significant features or data collection techniques used

7. Quality Control. If work is found to be in error, incomplete, illegible or unsatisfactory after assignment is completed, the Contractor shall be liable for all cost in connection with correcting such errors. Corrective work may be performed by Government personnel or Contractor personnel at the discretion of the Contracting Officer. In any event, the Contractor shall be responsible for all costs incurred for correction of such errors, including salaries, automotive expenses, equipment rental, supervision, and any other costs in connection therewith. All data and deliverables shall be reviewed for the following:

- Required coverage of the project limits
- Capture of all required features
- Required accuracies
- Required horizontal and vertical datum
- Adherence to the delivery order requirements

8. Technical POC. All technical questions concerning work under this task order shall be directed to Jim Jacaruso at (910) 251-4064.

9. Completion Date. All work required under this task order shall be **completed and delivered no later than 14 calendar days from the Task Order Award Date.**

This schedule is subject to adjustment by the Contracting Officer in writing.

10. Deliver To. All work shall be delivered to:

U. S. Army Corps of Engineers
Wilmington District
Attn: Jim Jacaruso, TS-EE
69 Darlington Avenue
PO Box 1890
Wilmington, NC 28402-1890

Appendix B - Benchmark Descriptions

NGS Mark Designated Tower Three (1947)

DESIGNATION: TOWER THREE (used for survey control basestation)
PID: AEA0695
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 23 35.96043(N) 077 35 34.60089(W) ADJUSTED
NAVD 88: 15.434 (meters) 50.64 (feet)

LAPLACE CORR: -2.78 (seconds) DEFLEC99
GEOID HEIGHT: -37.37 (meters) GEOID03
DYNAMIC HT: 15.419 (meters) 50.59 (feet) COMP
MODELED GRAV: 979,654.0 (mgal) NAVD 88
HORZ ORDER: SECOND
VERT ORDER: SECOND CLASS 0


DMA Mark Designated DOP 10768 (1981)

DESIGNATION: DOP 10768
PID: AI0899
STATE/COUNTY: NC/PENDER
USGS QUAD: HAMSTEAD (1970)

Current Survey Control:
NAD 83(1986): 34 20 54.15165(N) 077 39 07.26281(W) ADJUSTED
NAVD 88: 2.31 (meters) 7.6 (feet) ADJUSTED

LAPLACE CORR: -3.37 (seconds) DEFLEC99
GEOID HEIGHT: -37.32 (meters) GEOID03
DYNAMIC HT: n/a (meters) n/a (feet) COMP
MODELED GRAV: n/a (mgal) NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD

NCGS Mark Designated Crocker (1988)

DESIGNATION: CROCKER
PID: AI0831
STATE/COUNTY: NC/PENDER
USGS QUAD: HAMSTEAD (1970)

Current Survey Control:
NAD 83(1986): 34 21 36.36724(N)   077 38 12.12062(W)   ADJUSTED
NAVD 88: 1.33 (meters)   4.4   (feet) ADJUSTED

LAPLACE CORR: -3.41 (seconds)   DEFLEC99
GEOID HEIGHT: -37.34 (meters)   GEOID03
DYNAMIC HT: n/a (meters)   n/a (feet)   COMP
MODELED GRAV: n/a   (mgal)   NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD

CGS Mark Designated A 230 (1947)

DESIGNATION: A 230
PID: EA0696
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 23 04.52612(N)   077 36 18.42596(W) ADJUSTED
NAVD 88: 3.480 (meters)   11.42   (feet) ADJUSTED

LAPLACE CORR: -2.97 (seconds)   DEFLEC99
GEOID HEIGHT: -37.36 (meters)   GEOID03
DYNAMIC HT: 3.476 (meters)   11.40 (feet) COMP
MODELED GRAV: 979,654.2   (mgal)   NAVD 88
HORZ ORDER: FIRST
VERT ORDER: SECOND   CLASS 0

NGS Mark Designated Firth (1988)

DESIGNATION: FIRTH
PID: AI0904
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 26 46.68504(N)   077 30 43.60383(W)   ADJUSTED
NAVD 88: 1.20 (meters)   3.9   (feet) ADJUSTED

LAPLACE CORR: -1.31 (seconds)   DEFLEC99
GEOID HEIGHT: -37.40 (meters)   GEOID03
DYNAMIC HT: n/a (meters)   n/a (feet)   COMP
MODELED GRAV: n/a   (mgal)   NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD

NCGS Mark Designated Sea AZ MK (1988)

DESIGNATION: SEA AZ MK
PID: AI0866
STATE/COUNTY: NC/PENDER
USGS QUAD: HOLLY RIDGE (1997)

Current Survey Control:
NAD 83(1986): 34 25 41.73477(N)   077 32 27.16683(W)   ADJUSTED
NAVD 88: 2.57 (meters)   8.4   (feet) ADJUSTED

LAPLACE CORR: -1.79 (seconds)   DEFLEC99
GEOID HEIGHT: -37.40 (meters)   GEOID03
DYNAMIC HT: n/a (meters)   n/a (feet)   COMP
MODELED GRAV: n/a   (mgal)   NAVD 88
HORZ ORDER: FIRST
VERT ORDER: THIRD

Appendix C– Field Notes, Daily GPS Quality & Copy of Field Book

geodynamics — COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Survey GPS Check	X	n/a	n/a	Δ0.017m
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			

Survey Operations		Latitude (Northing)	Longitude (Easting)	Value
Input Initial SV cast in SIS Runtime	X	34 20 42.48	077 38 46.45	1542.0
SV Cast #1	X	34 20 42.48	077 38 46.45	1542.0
SV Cast #2	X	34 23 49.52	077 34 57.73	1542.6
SV Cast #3	X	34 26 27.46	077 30 47.34	1543.7
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes	
Project	USACE Topsail SS1
Survey Area	Southern 11miles of Topsail nearshore
Sea State	2' SSE swell, glassy (am), surface wind chop by 2 pm
Wind	N 5 kts to variable (am), SE 10kts by 2pm)
Air Temperature	75 F(am), 91 F (pm)
Sea Temperature	
Tides	L: 8:55 am H: 2:54pm EST
Survey Features & Navigational Aids	N/A
Comments	- NAV from POS into ISIS for Side Scan at 19200 intermitten. Used Hypack NMEA out at 9600 for SS NAV. Can't split to auto helm. Get powered splitter operational. - Tide too low for acqusition in the nearshore first thing in am. Starting on mid lines - Trawling activity in Northern reach of survey bounds. Look for trawl scars in data - Water clarity excellent for this region. No New river water in place? - Check for new version of ISIS for Neuse River project. Improved bottom track?

Line Name	MS/CL	Direction	Notes
0	MS	NE	HP 7 7:04 am EST Start line
1	MS	NE	cont - SS swath at 90m
2	MS	NE	cont
3	MS	NE	cont
4	MS	NE	cont
5	MS	SW	HP 9 (spacing 100m)- start 9:10am EST
6	MS	SW	cont - SS swath at 135m
7	MS	SW	cont
8	MS	SW	cont
9	MS	NE	HP 11 (spacing 100m) - start 11:10am
10	MS	NE	HP 11 cont - SS swath at 135m
11	MS	NE	HP 11 cont
12	MS	NE	HP 11 cont
13	MS	SW	HP 5 - inshore line (same swath 135m)
14	MS	SW	HP 5
15	MS	SW	HP 5
16	MS	SW	HP 5
17	MS	NE	HP 13
18	MS	SW	HP 15
End Survey Day 6:50pm			
Side Scan Operation Notes			
23.5 ft length on tow line from block			
Position is 4.3m to STBD of Ships NAV PT			

Comments:
- We got a 3:40am start
- Setup basestation by 4:15am
- After another "slap test" of side-scan we left the dock at ~ 4:35am
- Made it to the New Topsail Inlet crossing at AIWW by 5:15am and out the inlet by 5:30am
- On the first line by 5:45am but having nav problems since ISIS won't take the string at 19200
- Finally were able to split nav from Hypack at 9600 but can't use auto helm. :(
- First line by 6:50am

Acquisition comments:
- Inshore lines have slight artifacts due to shallow water and possible aeration of water in surfzone
- Mid water lines looking a little cleaner
- Imaging old pilings from piers. very cool.
- Very distinct returns on possible hard bottoms in NorthEastern section of survey area. Low relief in bathy.
- Getting quite hot in cabin by 11am. Call Danny M. @ new AC unit.
- Using a 100m range on the inshore lines and ~ 120m on the outside. Overlap looking great.
- Slight seabreeze kicking up around 3pm. Data still looking good though......
- Finished acquisition by ~ 6pm. Headed back to dock.
- Layback calculations and geometry in field book.

USACE TOPSAIL SS 1 6-11-06

SITE CAL

BASE = TOWER THREE 1947

DOP 10768 (1,3)

67222.119 N	67222.286
733619.291 E	733619.270
2.31 m	2.341
PUB	

CROCKER (1,3)

68542.046	68542.204
735010.571	735010.538
1.33	1.351
pub.	

A230

	722
71298.606	71298.768 TOPO
737877.413	737877.388
3.480	3.452 390
	3.460 CNTRL

1.21 ↑ 1.95 →

~~PUL~~ 15

3263

FIRTH (1,3) steel rod

78267.452 78267.573

746327.233 746327.180

1.20m 1.234

PUB rec

SEA AZ MK

76227.107 76227.279

743713.317 743713.279

2.57 2.605

pub rec

AI 0866

1,3 NCGS

USACE Topsail Side Scan

July 17, 2006

mobilization

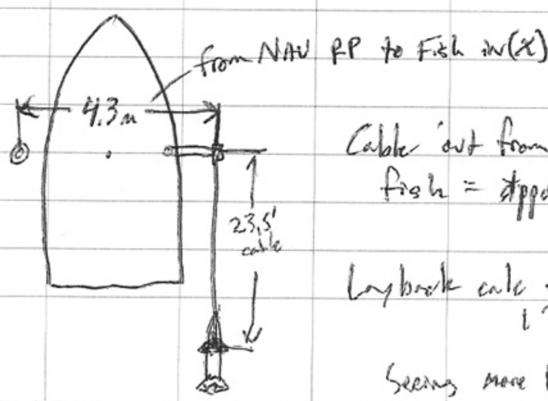
- left PKS ~ 12:15pm after USACE estimate
- Got boat in water + slip ~ 2:00pm
- Set up base on Tower 3
  - ~ checked mark ~ 1.3cm!

- Set side scan + tested MB at Dock
- Turned off base and charge batteries for Survey

July 18, 2006

- left dock at 4:00am
- for survey notes see digital survey log!

Side Scan Measurements



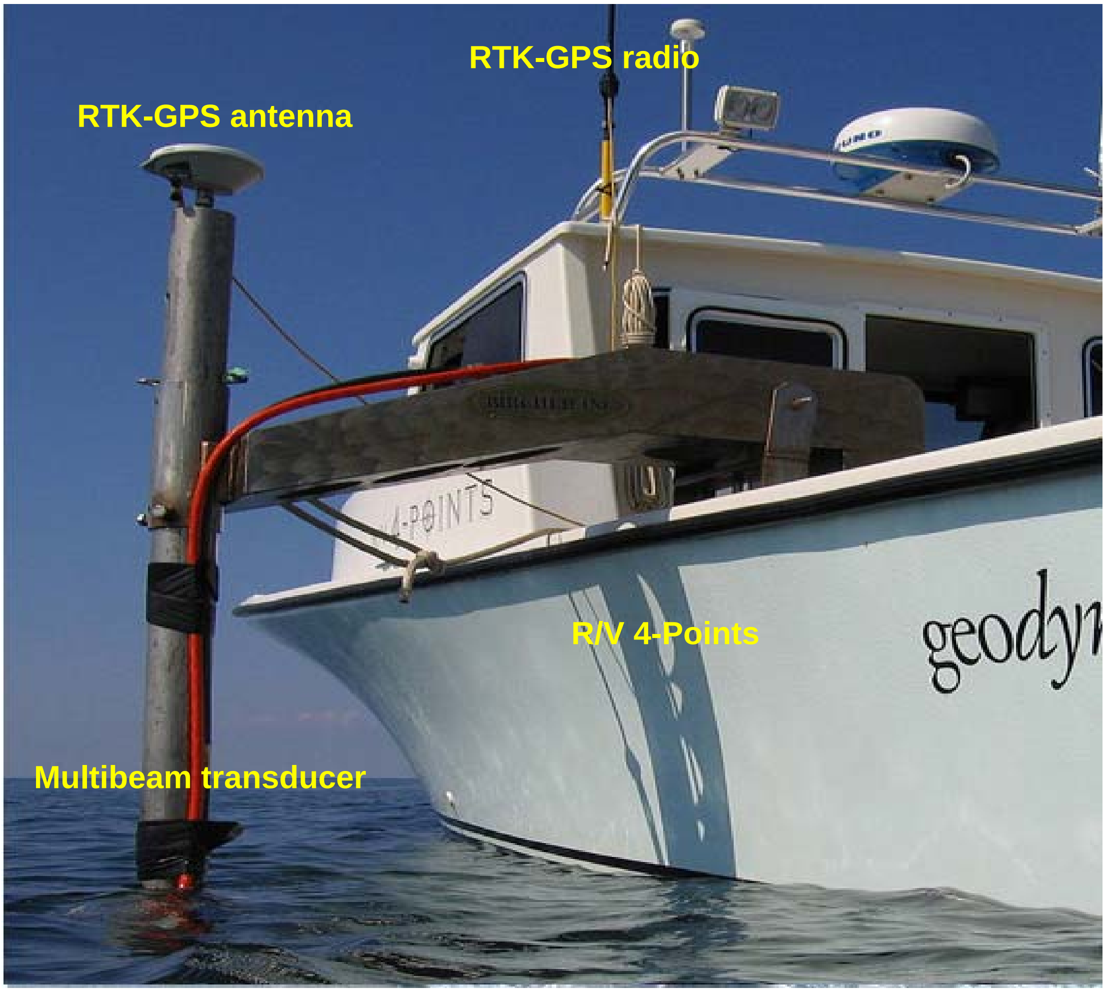
Cable out from block to fish = approx. 23.5'

Layback calc would come to: 12.5 m roughly

Seeing more like 6 in data

Appendix D - *R/V 4-Points* Setup & Instrument Accuracies

Multibeam Deployment



Side-Scan Deployment

Survey Instruments & Published Accuracies

Survey Vessel

The research vessel *4-Points* is a custom fiberglass survey boat designed specifically for shallow water sonar and acoustical operations. The vessel is 25' long with a 10' beam; the bottom tapers from a deep "Carolina" style Vee to a relatively flat-bottomed stern that provides a shallow draft of approximately 1.2'. Twin 140 four-stroke engines, hung on a stainless steel bracket, power the vessel. All electronics and generators are grounded to the sea via a bottom mounted bonding plate to eliminate all electrical noise. The transducer mount was engineered and designed at the University of North Carolina at Chapel Hill's Institute of Marine Science specifically for multibeam and ADCP surveys (Hench, et. al, 2000 "A portable retractable ADCP boom-mount for small boats". *Estuaries*, 23 (3): 392-399.). The mount was designed to keep the transducer below any potential bow wave and to also house the motion sensor directly over the transducer. Side-scan instrumentation is deployed, towed and retrieved from custom davit on starboard side.

Side-Scan Sonar Equipment

- **Klein 3000 side-scan sonar towfish**
  - Frequency: 132 kHz and 445 kHz
  - Transmission pulse: tone burst selectable from 25-400 usec. Independent pulse for each frequency
  - Beams: horz-100 kHz 7 degrees, horz-500 kHz 21 degrees, vertical-40 degrees
  - Range: 100 kHz to 450m, 500 kHz to 150m
  - Multiplexer: T1, 1.5 MB/sec
  - Note: There are no calibration reports associated with side-scan

Multibeam Equipment

- **Simrad EM 3002 multibeam sonar transducer**
  - Multi-Frequency: in 300 kHz band
  - Max ping rate: 40 Hz
  - No. of beams/ping: 254 Roll and Pitch stabilized
  - Beam width: 1.5^o x 1.5^o
  - Beam spacing: 0.9^o
  - Depth range from sonar head: 1 to 150 m
  - Depth resolution: 1 cm
  - Depth accuracy: 5 cm RMS
  - Range sampling rate: 15 kHz
  - Bottom detection by phase or amplitude. Seabed imaging & classification with backscatter (sidescan-like) output.
  - Full swath width accuracy to the latest IHO standard

- **POS MV 320 v4 Main Specifications (with RTK Corrections)**

- Roll, Pitch accuracy: 0.02° (1 sigma with GPS or DGPS) 0.01° (1 sigma with RTK)
- Heave Accuracy: 5 cm or 5% (whichever is greater) for periods of 20 seconds or less
- Heading Accuracy: 0.02° (1 sigma) with 2 m antenna baseline, 0.01 (1sigma) with 4 m baseline
- Position Accuracy: 0.5 - 2 m (1 sigma) depending on quality of differential corrections 0.02 - 0.10 m (RTK) with input
- Velocity Accuracy: 0.03 m/s horizontal

- **Trimble 5700 dual frequency GPS system & RTK-Basestation**
  - Instrument used for positioning and tidal corrections
  - High precision L1 and L2 measurements
  - 24 channels L1 C/A code, L1/L2 full cycle carrier
  - Extremely low latency (20 milliseconds)
  - RTK-GPS accuracy depends on conditions such as multipath, obstructions, satellite geometry, atmospheric parameters and basestation control quality.
    - Published horizontal accuracy: 10 mm + 1ppm RMS
    - Published vertical accuracy: 20 mm + 1ppm RMS

- **Odom Hydrographics Digibar Pro sound velocity probe**
  - Sampling rate: 10 Hz
  - Depth accuracy: > 31 cm
  - Velocity accuracy: +/- 0.3 m/sec

Computers & Software

- Rack mounted multibeam acquisition PC
  - 3.0 GHz Intel Pentium 4 processors with 800 MHz system bus
  - 1 GB of RAM
  - Triton Elics International (TEI) Isis version 6.2 acquisition software
  - CARIS HIPS/SIPS processing software

- Rack mounted Simrad multibeam power unit
  - EM3002 controller and power modulator

- (3) Fujitsu pentop navigation PC
  - Hypack Max.

- (4) Dell high-end GIS processing workstations
  - Arcview 3.3, ArcGIS 9.1, Surfer 8.0, Trimble Geomatics Office, Matlab 12, TEI Bathypro and DelphMap, CARIS

Backup field & processing computers and instrumentation

- (2) Dell laptops

- (3) Fujitsu pentop
- (5) Maxtor 250 – 300 gigabyte external backup drive

Appendix E – QTC Report

Quester Tangent

SIDESCAN SEABED CLASSIFICATION

Processing of Klein 3000 data

Prepared for Geodynamics LLC

SC75-840C

Issue Date: July 28, 2006

Making Data Intelligent™

DATE	REVISION	DESCRIPTION
06.07.28	R00	Original Issue

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EXECUTIVE SUMMARY

Quester Tangent received approximately 5 GB of Klein 3000 XTF data acquired on July 18, 2006 by Geodynamics LLC from the Topsail, NC area. The data are from the first survey of a 2-phase project. The data were processed in QTC SIDEVIEW, automated seabed classification for sidescan sonar imagery. Although the overall results were less than satisfactory due to the challenges of acquiring sidescan data in a shallow water, very dynamic environment, some specific classes such as reef areas were well demarcated. Specific issues relating to original data quality and recommendations for improvement are outlined in the report.

INTRODUCTION

The following report describes the classification of a set of sidescan data using QTC SIDEVIEW. The original data were acquired using a Klein 3000 sidescan and provided to Quester Tangent on 2 DVDs in XTF format.

It is well known that the statistical characteristics of a sonar backscatter image depend on the bottom type. Even to a novice user, the texture differences between images of rocks, sand, and mud are readily apparent. Differences between silt and clay are less obvious. Statistical processing can capture many of the pertinent details of the interaction between the sound and the bottom and of its vertical relief. Multivariate statistics can then isolate those details that are rich in information about the bottom, producing features that contain the information necessary for accurate and reliable bottom classifications.

Image-based seabed classification is the segmentation of seabeds into discrete classes based on the characteristics of acoustic backscatter throughout a region. Segmentation is a valid and useful survey tool, even though it does not independently identify geophysical types. Dividing the seabed into classes is useful because seabed characteristics are relatively constant throughout a class and distinct from the characteristics of other classes. Therefore, the amount of ground truth that needs to be collected, visually or mechanically, is dramatically reduced. The strategy of identifying classes with a few samples and confidently extrapolating those characteristics throughout the acoustic classes is both scientifically valid and very cost effective.

The Quester Tangent approach to automated classification involves the data first being transformed into a format readable by QTC SIDEVIEW software. Both automatic and manual data quality assessment is performed throughout the process including the reformatting stage. Image patches or rectangles are placed on only the most suitable data. Features capturing the subtleties of image intensity and texture are generated. A statistical analysis helps to further refine the information to the point where classification can occur. Classification of the bottom that gave rise to these features is done by an automated clustering method that adapts to the characteristics of the multibeam or sidescan data set. Each cluster represents a bottom type, which can be identified based on ground truth; for example, photographs, grain-size analysis, or other local data. If the bottom type is known before classification, data from the areas of known sediment type can be used to build a catalogue, which would then be used to classify subsequent or archived data. This is called supervised classification. The alternative, unsupervised classification, forms the data into logical clusters that can then be identified based on ground truth. The effectiveness of unsupervised classification in uncovering practical and valuable information from the acoustic data has been demonstrated in many projects. This clustering technology, with its ability to easily perform supervised and unsupervised classification, forms part of QTC SIDEVIEW.

PROCESSING THE DATA

Loading Data

Backscatter images from a wide variety of sidescan systems can be loaded with position and ancillary data. Validation and quality control are important considerations. Backscatter data points can be flawed for various reasons, including tow fish and vessel motion, and interference from another sonar source. The data are cleaned to ensure the highest quality data available are presented to the classification. Data designated as not usable are captured in a mask. The mask is used to exclude regions of poor quality from further processing. QTC SIDEVIEW gives the user several cleaning options (Table 1).

Name	Function
Preserve Bottom Edits	The altitude line in the sidescan images may be edited. This function saves those edits.
Water Column Offset (m)	The water column must always be masked. This tool allows a specified distance from the altitude pick into the image to be masked.
Angle	The image can be masked using the sonar depression angle. The angle values are as follows: zero degrees is in the horizontal plane with the sonar and ninety degrees is directly below the sonar
Range (m)	Parts of the image can be excluded using absolute or percent range. All data greater than the specified range value will be masked.
Surface Echo (m)	The sidescan image may display some along track banding which does not represent the seafloor. This may be a result of surface echo. This tool allows for masking of this banding.
Preserve Border Edits	A tool is provided to edit the border in the sidescan images. This function saves those edits.
Despeckle	The program facilitates removal of speckle during feature generation. Despeckle level allows the user to choose the size of the median filter kernel (low, medium or high) used in the despeckle algorithm during feature generation.

Table 1: Cleaning tools.

Placing Rectangles

The seabed in the image is divided into rectangular patches. Patch placement depends on data quality through use of the mask. The mask and the user-selected patch sizing determine the number of patches per side (to port and to starboard). A class assignment will be generated for each patch.

Generate Features

A large number of features are extracted from the backscatter amplitudes in each rectangular patch of each image. QTC SIDEVIEW is able to use many features because Principal Components Analysis (PCA), in the next processing step, will select those combinations of features best suited to each data set.

For bottom classification, features are extracted from both backscatter image data and depth data using the following algorithms:

Basic Statistics: Mean, standard deviation, and higher-order moments are indicative of acoustic impedance changes and interface roughness

Quantile and Histogram: These measure the distribution of backscattered information intensities at low resolution.

Power Spectra: Fast Fourier Transforms (FFTs) are used to find power spectra, which describe statistical characteristics on many resolution scales.

Ratios based on Power Spectra (Pace): Ratios of log-normalised power in various frequency bands provide good discrimination for classifying images.

Grey-Level Co-occurrence Matrices: Grey-Level Co-occurrence Matrices (GLCMs) describe the amplitude changes over selected distances and directions in the image patch, and are widely used to assess texture.

Fractal Dimension: Fractal dimension is a sensitive measure of the distribution and structure of both backscatter and depth variations.

These features have been selected to capture as many useful aspects of the data as possible. As QTC SIDEVIEW was developed, the selection of features was frequently examined to determine which features were providing useful discrimination and to determine if any algorithm consistently produced redundant features. One interesting result from these studies was that mean intensity was rarely the sole determining feature in the overall classification process. It is combinations of intensity and texture that seem to drive classifications.

Multivariate Statistical Analysis

A major strength of QTC SIDEVIEW processing is the incorporation of multivariate statistical techniques as they permit the use of many features. Experience has shown that some features are important in what might be called the standard classifications: mud, sand, gravel, and so on. Others are important for more specialised classifications such as discriminating among sand/mud mixtures. For any particular data set, PCA selects the features that are most useful for the discrimination task at hand. Features that are close to constant are largely disregarded. Redundancies, that is, correlated features, are also acceptable, but only one remains significant. What is left is a reduced feature set that compactly describes the diversity of the data set. While some features may have little diversity or be tightly correlated when used to describe one set of seabed sediments such as open continental shelf sand and gravel, they may be found to give useful discrimination in other cases, such as on deltaic sediments. Thus, the connection between features and classification adapts to the character of the data set.

For each patch of each image, the features are calculated and then arranged as a row vector containing 132 elements. The name we give to these rows of features is Full Feature Vectors (FFVs). This information must be optimised or reduced without losing any details of the sediment. The dimension of the FFVs is reduced by multivariate statistical processing to isolate the combinations of features that are responsible for most of the diversity in the data set. In general, the top three combinations capture a very high percentage of the variance, so the rest of the combinations can be disregarded. These top three combinations are called Q-values.

The result of this reduction process is contained in the reduction matrix. Any FFV can be reduced to three Q-values by matrix multiplication. The reduction matrix is part of the catalogue used for supervised classification. New FFVs, derived from any subsequent acoustic survey, can be reduced to Q-values in this way as part of the supervised classification process. Alternatively, the multivariate statistical processing can be run on any partial or complete data set to find new information.

Cluster Analysis

The acoustic response - represented by Q1, Q2, and Q3 - from like seabeds will be similar. When plotted on a three-axis plot, called Q-space, points with similar values, for example from a single seabed type, form a cluster. Thus, data from three different seabeds form three clusters and new data points are classified based on their locations relative to the clusters in Q-space.

Each catalogue is specific to the sonar system used for data collection and may also be specific to particular operating conditions of that sonar.

Catalogues can be based on a set of sample sonar images or by sampling the whole data set. Over time, a library of classes could be produced from which various catalogues can be created, depending on the application. With the catalogue selected, the complete data file can be classified.

Classification of Seabed

Classify Seabed is the process of applying a catalogue to a data set. If the entire data set is used in an unsupervised classification process, the result is both a catalogue and a classified data set. Confidence and probability values are also calculated during Classify Seabed. If less than the entire data set was clustered, this step is used to classify all the data. Both these processes are unsupervised classification.

Catalogues can also be useful for supervised classification. In this process, each new patch is assigned to one of the clusters, or sediment types, based on a pre-existing catalogue.

Presentation

The final product is an ASCII comma-delimited file that can be imported into mapping software for the production of plots and 3D models. GIS systems are often used to demonstrate correlations between acoustic classes and other GIS layers. Another popular presentation is of the classifications draped over a bathymetric model of the surveyed area.

SIDESCAN DATA QUALITY

Data Challenges

The Klein 3000 data provided by Geodynamics presented significant quality challenges. The survey vessel was a small boat, operating in open seas with a substantial swell from the southeast. The maximum water depth was about 10 m. The sidescan was towed from a sheave supported overboard on the starboard side, on enough cable that it was about 6 m aft of the sheave (which was 4.3 m to starboard of the ship reference point). Other acoustic equipment that affected the sidescan images were an EM3002 on a pole on the vessel's port side and a sounder on the towfish.

Preparing the images for classification in QTC SIDEVIEW required an atypical amount of effort. Also, towfish instability introduced some artefacts into the images that could not be removed by pre-processing. These issues included:

Towfish yaw

Figure 1 shows towfish heading and yaw rate on a line from this survey. A heading is plotted for each ping time, and pings were 0.1 s apart. Because the horizontal beam width on the Klein 3000 is very small, yaw rates exceeding a few degrees per second can give non-recoverable gaps in images. The explanation goes like this: In plan view, sound is transmitted into a narrow fan. It takes a few milliseconds for sound to reach the seabed at typical ranges and for the echo to return to the towfish. The transmit and receive beams are identical, so as the towfish yaws they both sweep around. If they have swept more than some angle, the echo arrives at the towfish outside the receive beamwidth and is not recorded. The Klein 3000 has transmit and receive beamwidths of 0.3° (taken together, they give the advertised system beamwidth of 0.21°). It takes 67 ms for the round-trip to 50 m range. Thus echoes from 50 m are lost if the yaw rate exceeds 0.3°/0.067 s = 4.5 °/s. Much of the time, the yaw rates in Figure 1 are much larger than this. 31% of the time, they are less than 4.5 °/s. This is the primary explanation for bright and dark streaks in the outer parts of the images.

Towfish pitch

Erratic towfish motion is caused by vessel heave being transmitted down the towcable. This causes heave, which drives pitch unless the connection is precisely at the hydrodynamic centre of effort (which moves about, so this is impossible). Pitch and heave lead to yaw, roll, sway, and surge. Yaw has the most serious effect on the sonar image, with pitch second. In this survey, towfish pitch (Figure 2) had some effects, but it would be difficult to isolate these from those caused by yaw.

Towfish roll

Towfish roll does not lead to parts of the image going missing but can affect the image in other ways. The vertical beam pattern is very broad (about 40° for the Klein 3000), far exceeding any occurring towfish roll. However details of the beam pattern move across the image with roll. There is less backscatter amplitude near nadir to port, suggesting that this towfish tows slightly port up.

Low altitude

The towfish altitude, that is, its height above the seabed, ranged from 0 to 6.5 m during this survey, and was often only 2 m or so. At the ranges used, 50 or 75 m, the angle between the sound ray and the bottom, the grazing angle, is very small, less than 1° through most of the range. Very small grazing angles give very large shadows for even small bottom irregularities, and indeed big parts of these images are shadow. This is not ideal for acoustic seabed classification since the amplitude and texture of seabed backscatter from these areas have been lost.

Bottom Picking

There is a sounder on the towfish to record towfish altitude. This is often done on sidescan towfish because the sidescan transducers send very little power vertically down, meaning that the start of the sidescan seabed echo is often not a reliable measure of altitude. Altitude is needed for slant-range correction and for image compensation. (QTC SIDEVIEW does slant-range correction of classified positions, not of the image). During this survey, though, only an erratic small fraction of these altitudes was logged. This meant several hours of work manually tracing a bottom pick for each line.

Interference from a multibeam echosounder

Crosstalk between different acoustic systems operated simultaneously is often found, even if their primary frequencies are quite different. If one is an imaging sonar, interference is often called walkover, because the extraneous echoes appear atop the image. If the systems are unsynchronised, as they often are, the interference appears in regular patterns, loosely suggesting footprints. In this survey, the EM3002 on the port side walked over the port sidescan image. Typically, it can be seen only at ranges greater than about 40 m, because the sidescan gain increases with range. In some lines the walkover is a major interference; in others it can barely be seen. One reason may be that the towfish was astern of the multibeam, and thus receives the multibeam echoes only when yawed appropriately. Walkover can have a major effect on classification because it adds a major artificial texture. Either it has to be filtered away, or these regions must be excluded from the classification process. In QTC SIDEVIEW, the despeckle filter is effective at averaging away the walkover, but also smoothes the entire image. While this may have been effective in this survey, the approach that was taken was to mark a border on the images, the inner boundary at which the walkover appears. In 14 lines, borders were drawn on the port side at ranges near 40 m. On half of these, multipath reverberation caused some walkover to starboard at long ranges (where the gain is high), so border s were drawn near 60 m, typically, to exclude ranges beyond that from classification.

Wake

With the towfish 6 m aft of the sheave, the vessel wake was above it and to port. It could be seen clearly on six lines, at a range of 4 m. Eddies from the wake sometimes extended to almost 6 m. QTC SIDEVIEW contains a filter for this situation, called the surface-return filter. It was used to mask the image from 3.7 to 5.5 m on these lines. This filter operates on both sides, so the same mask had to be applied to the starboard image, even though it was not needed there.

Artificial samples at end of each ping

A common artefact in Klein imagery is that the last 40 or so samples of each ping are artificially large, often at or close to the maximum possible digital value. QTC SIDEVIEW has a filter for this. It was used to remove the last 3% of each ping from the region to be classified.

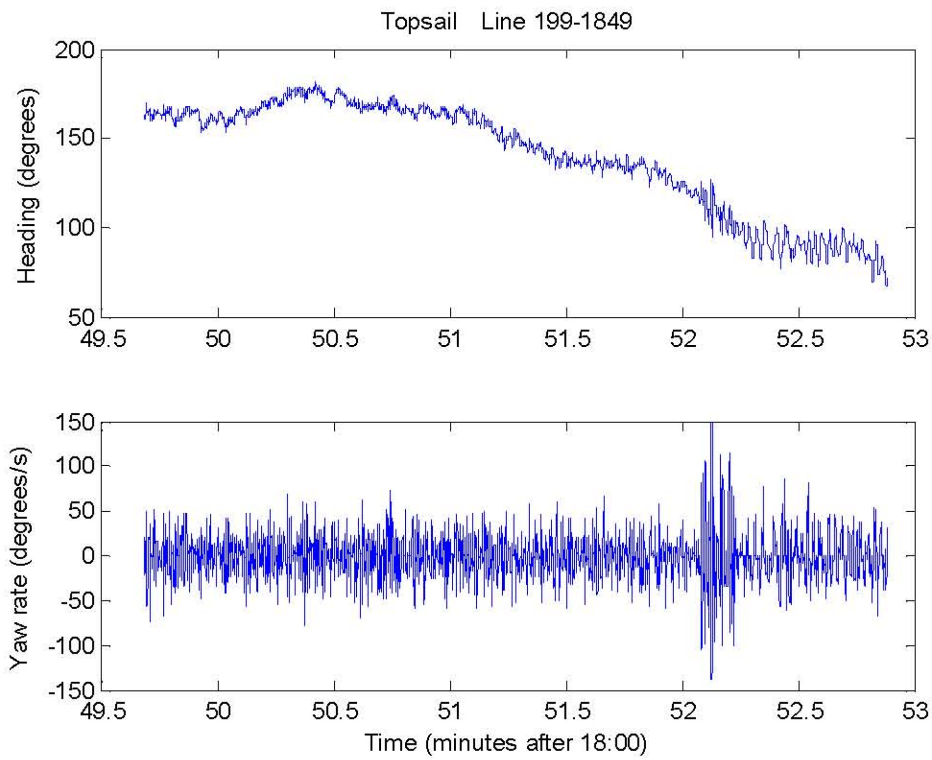

Figure 1: Towfish heading and yaw rate in a line of Topsail data set

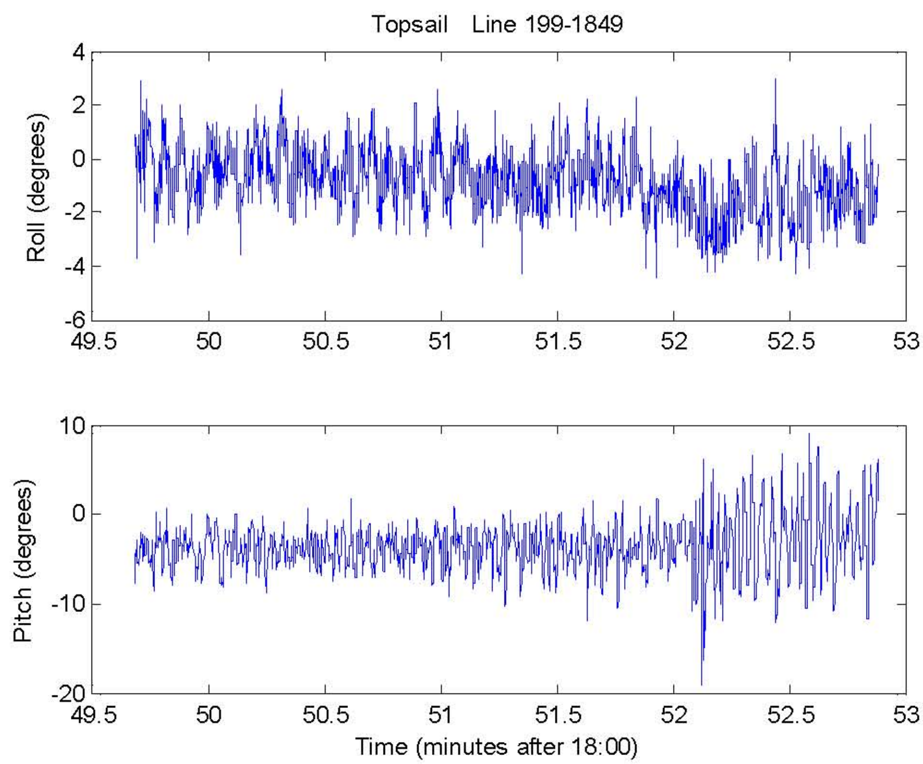

Figure 2: Towfish pitch and roll in a line of the Topsail data set

Individual Line Cleaning

Table 2 shows an assessment of each line and the cleaning process used for it. In addition, bottom picking was done for each line.

Line number	Sonar range (m)	Typical altitude (m)	EM3002 walkover on port image	Border cleaning applied	Wake cleaning applied
199-1104	50	0 – 4	> 40 m, important	Yes	Yes
199-1122	50	1.4 – 4	Not evident		
199-1139	50	0.8 – 2	Not evident		
199-1157	50	3 – 4	Not evident		
199-1214	50	2.5 – 4	Not evident		
199-1232	50	3	Not evident		
199-1312	75	4	> 50 m, important	Yes	
199-1317	75	3.5 – 5	Negligible		
199-1335	75	4	Negligible		
199-1353	75	4	Negligible		
199-1410	75	4	Negligible		
199-1428	75	4	Negligible		
199-1446	75	0 – 4	> 55 m, important	Yes	
199-1507	75	1.5	> 35 m, important	Yes	
199-1508	75		Issues with altitude	Ignore line	Ignore line
199-1509	75	2 – 4	> 45 m, important	Yes	
199-1527	75	4 – 5	> 60 m, important		
199-1545	75	5	> 60 m, important		
199-1603	75	5	Negligible		
199-1620	75	5.5 – 6.3	> 650 m, important		
199-1638	75	5.5 – 6.5	Negligible		
199-1656	75	6	Negligible		
199-1658	75	1 – 5	Negligible		
199-1701	75		Often on bottom	Ignore line	Ignore line
199-1703	75	1 – 2.5	> 40 m, important	Yes	
199-1720	75	1.4 – 4	> 40 m, important	Yes	
199-1738	75	1	> 40 m, important	Yes	Yes
199-1756	75	1 – 2	> 40 m, important	Yes	Yes
199-1814	75	1.5 – 3.4	> 40 m, important	Yes	Yes
199-1831	75	0.5 – 2.2	> 40 m, important	Yes	Yes
199-1849	75	1.3 – 4	> 40 m, important	Yes	Yes
199-1853	75	5	> 40 m, important	Yes	
199-1911	75	5	> 50 m, important	Yes	
199-1919	75	5	Negligible		
199-1920	75	4 – 5.5	Negligible		
199-1938	75	4	Negligible		

Table 2. Survey lines in Topsail data set

Processing Parameters

In addition to the line by line cleaning detailed in Table 2, Table 3 outlines additional cleaning parameters used. Rectangle size was 17 pixels along track by 129 pixels across track, which generated 388017 records. This represents an approximate seafloor footprint of 4.0 metres by 4.0 metres.

Name	Value
Preserve Bottom Edits	Yes
Magnetic Variation	24^0
Angle	As specified in Table 2
Range (m)	As specified in Table 2
Surface Echo (m)	Yes, where applicable
Preserve Border Edits	Yes
Despeckle	No

Table 3: Cleaning parameters.

Additional Filtering

Additional filtering of the FFV data was done as follows:

Time

From 18:49:40 to 18:54:10, to remove the 180° turn in the southwest corner. Filtered 3082 records.
From 19:19:13 to 19:22:22, to remove the 180° turn part ways up the east edge. Filtered 686 records.

Slant range

Slant range > 50 m. Filtered 70873 records. This aids somewhat in reducing range dependence, in that it hides the longest-range rectangles.

CLASSIFICATION RESULTS

Prior to the presentation of the classification results it helps to understand the nature of the backscatter from the entire survey area. This is important when analyzing the relationship between the geology, its backscatter response and the results of the automated classification. This is accomplished by the generation of a backscatter mosaic as shown in Figure 3.

Unsupervised classification was applied on a line by line basis and 8 classes were identified. The results are presented in Figure 4 as a series of data points, where individual points are assigned a class. Additionally, the data can be interpolated to provide a gridded plot suitable for overlay on bathymetry. QTC CLAMS was used to generate such a plot (figure 5). The class colours used in Figure 5 are termed "similarity colours". Acoustically similar seabeds are displayed using similar colours. It is important to understand that the plot is a map of acoustic diversity. It is incumbent on the interpreter to assign labels such as "reef" to the classes based on an interpretation of the original backscatter data or ground truth data.

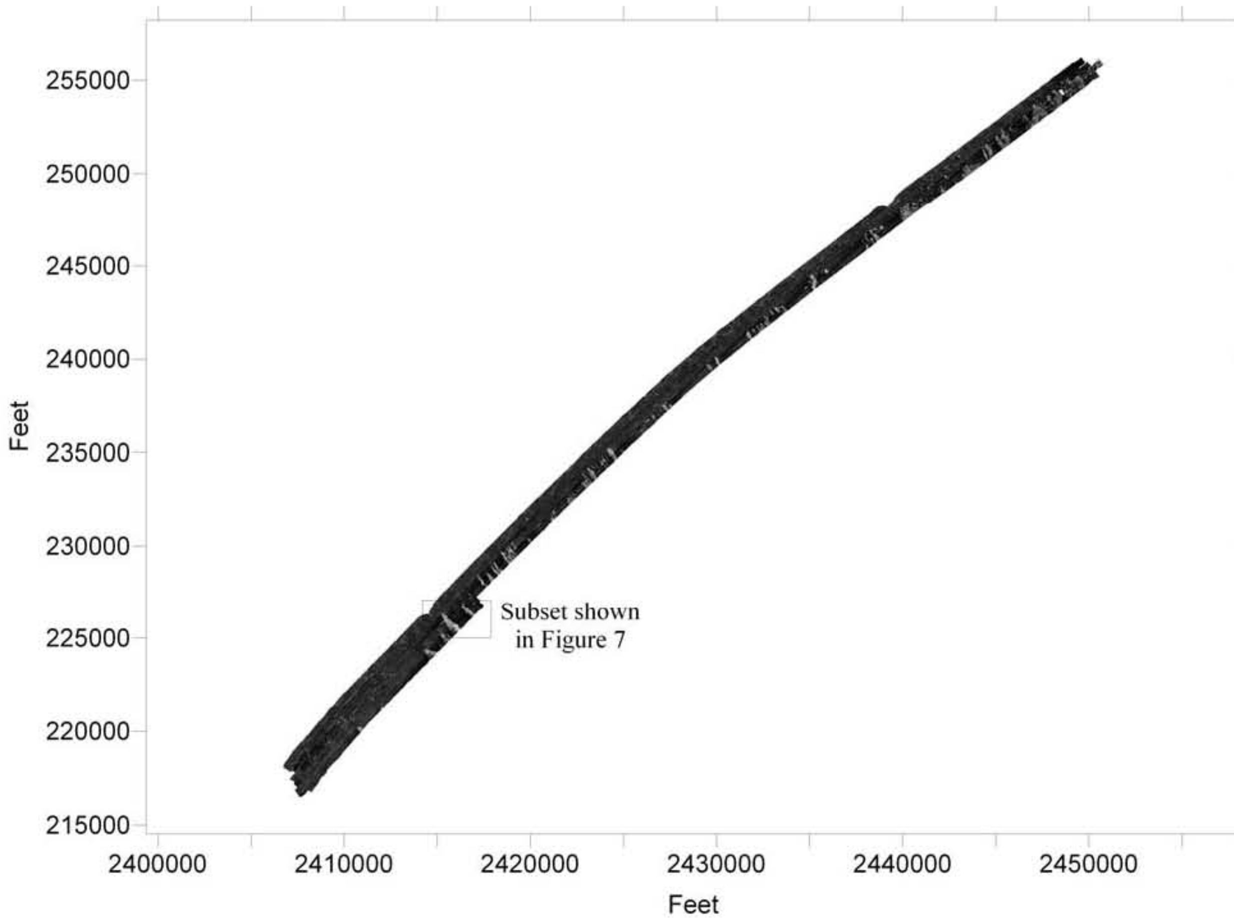

Figure 3. : Backscatter Mosaic of "Topsail" survey area. (source: Geodynamics Group)

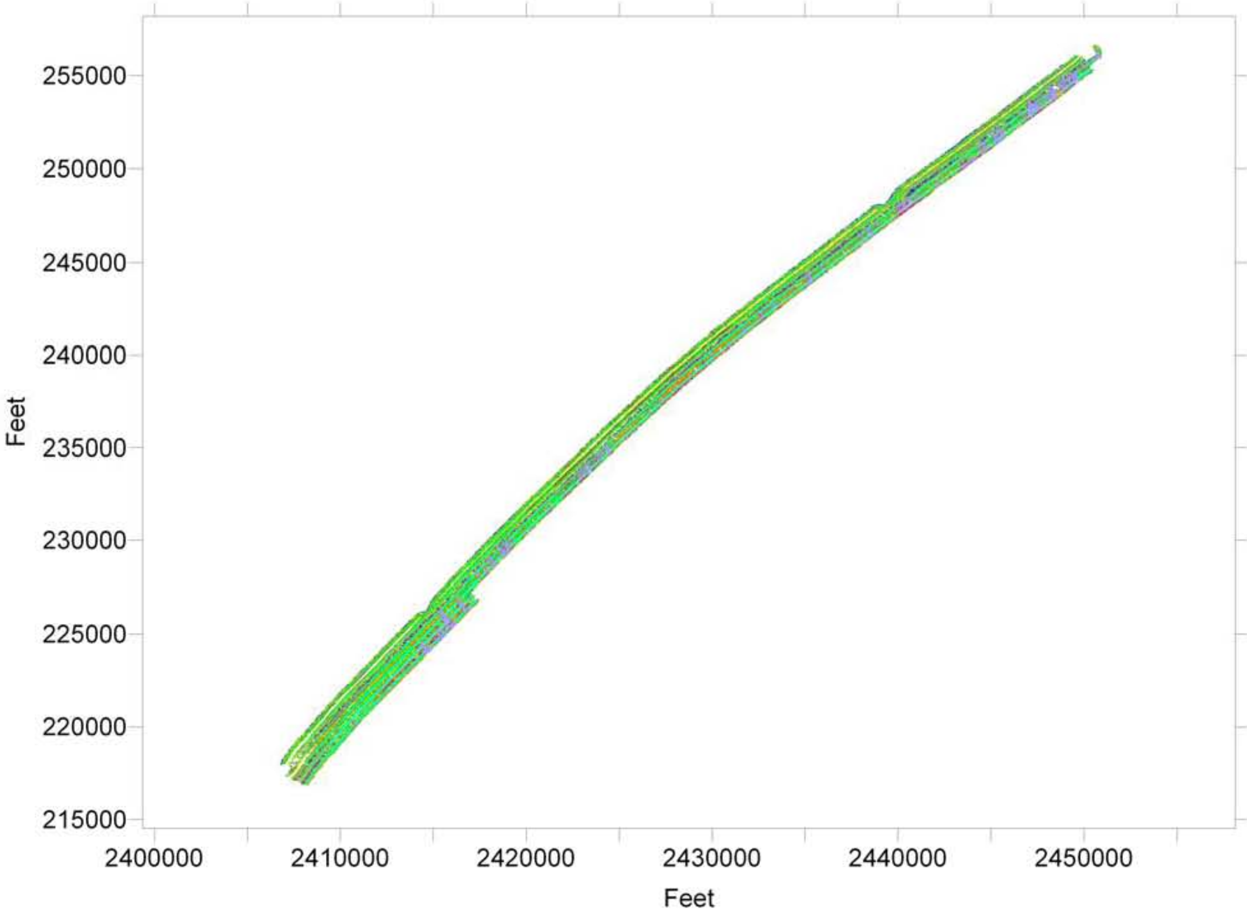

Figure 4: Acoustic Classes Overlaid on Bathymetry

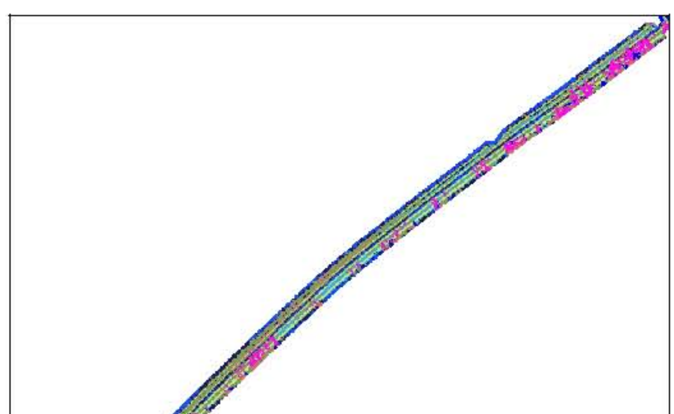

Figure 5 Interpolated classified point data set.

The results were not of the high quality normally achieved when processing data in QTC SIDEVIEW. Several examples of Klein 3000 data in XTF format have been processed previously with excellent results. The striping in the classification particularly evident on Figure 5 is a result of the original data quality. The classification has nevertheless identified the reef areas as a unique class, as shown in Figure 6.

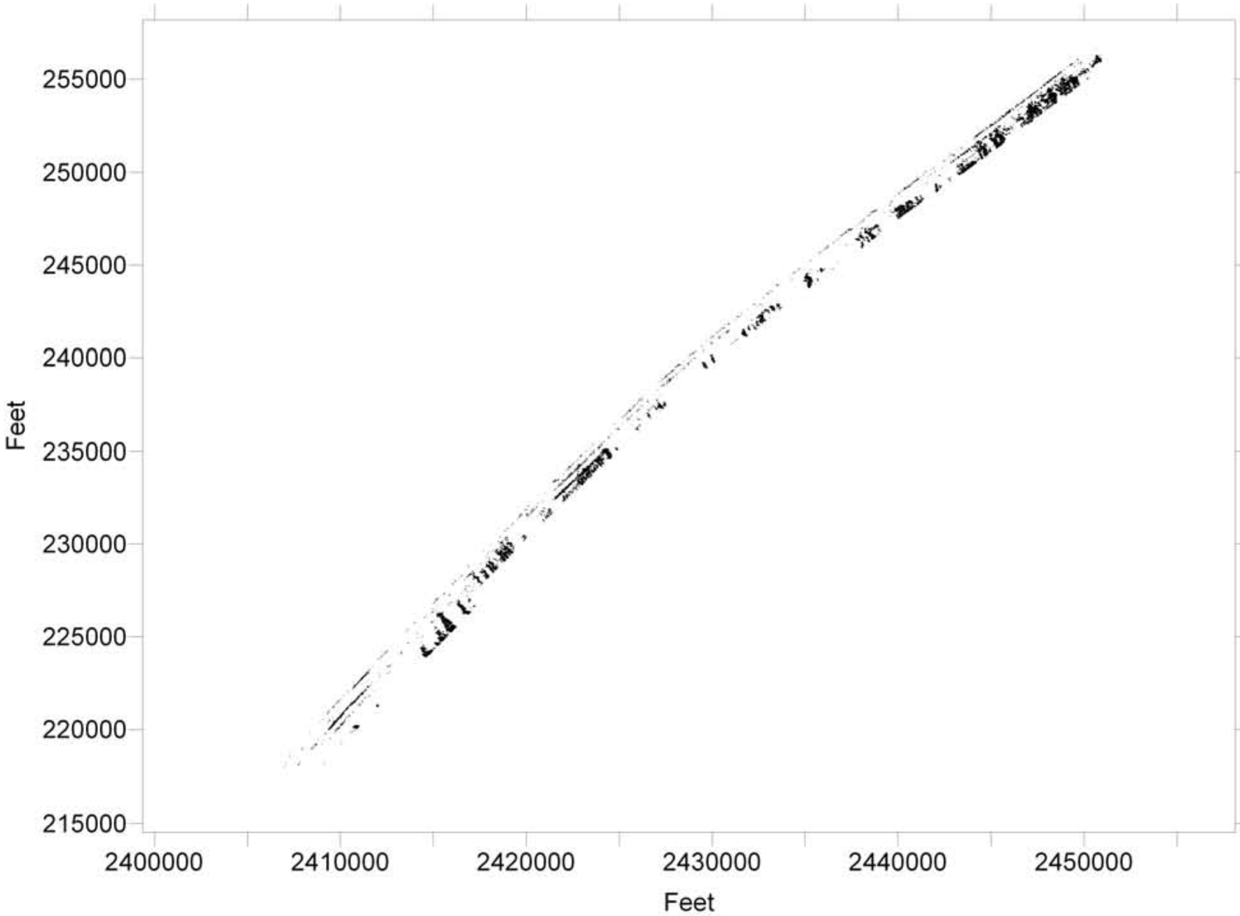

Figure 6: The results of automatic classification showing only Class 5 which is interpreted as reef.

A subset of the imagery is shown in Figure 7. The individual records associated with each original rectangular patch on the image are plotted on the backscatter mosaic. There is a clear correlation between the high intensity backscatter interpreted as reef and the purple class. The other note is the apparent offset in the heading causing the records associated with each ping to be somewhat oblique to vessel track.

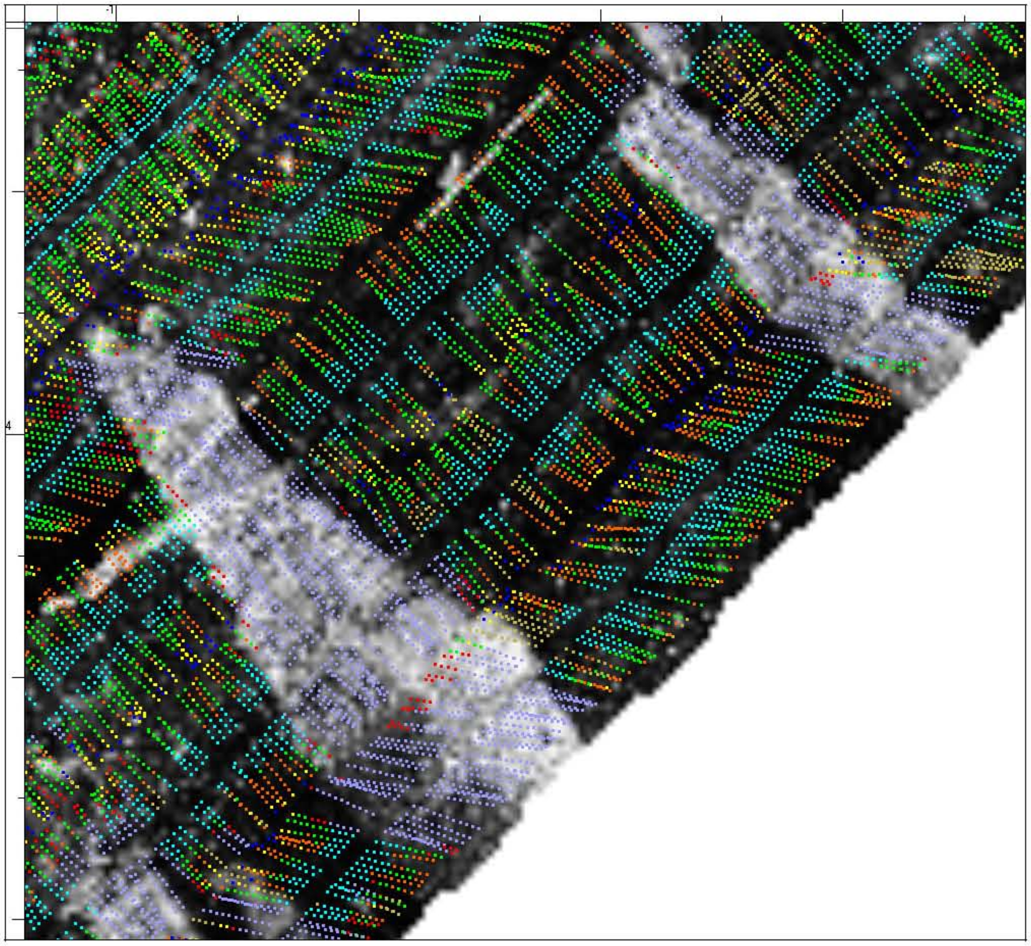

Figure 7: Class 5 interpreted as reef only. The purple class (Class 5) correlates with the reef class seen on the sidescan sonar mosaic. Please see Figure 3 for location of this area.

DISCUSSION AND RECOMMENDATIONS

While there are numerous challenges relating to the acquisition of sidescan sonar, data perhaps the two that stand out are the stability of the towfish and the towfish altitude. Given the environment in which the data were collected this is not surprising. Indeed, the results as shown in the sidescan sonar mosaic are quite acceptable for manual interpretation of the geology. The combination of these acquisition challenges however, diminish the ability automatic classification of all except for the most broad features (e.g. reefs) and perhaps even the subtleties of the geology as interpreted by a marine geologist or geophysicist.

Based in information passed on by the client there exist a veneer of sand over top of some of the reefs. This is evident from the existence of sandwaves. Typically sandwaves exhibit a regular pattern in texture that can be identified in QTC SIDEVIEW. Only the “reef class” could, for example, be submitted to the statistical analysis and clustering to identify “subclasses” of reef with a veneer of sand. Given the data quality previously mentioned this advanced processing was not considered.

Recommendations

1. Given the environment it might be advisable to experiment with a fixed hull or pole-mounted towfish to maximize altitude (rule-of-thumb is altitude 10% to 15% of max. range). This should have the added advantage of reducing fish yaw.

2. If possible, refrain from having an echosounder at similar frequency running at the same time as the sidescan sonar data are being collected.

3. Having access to good quality bottom picks would have decreased the amount of time taken for automatic classification. We recommend an analysis of the reasons for the poor quality bottom picks in the data.

SELECTED READING

J. T. Anderson, R.S. Gregory, and W.T. Collins, Acoustic classifications of marine habitats in coastal Newfoundland, *ICES J of Marine Science* vol. 59, pp. 156-167, 2002.

J.M. Preston and A.C. Christney, Compensation of sonar image data primarily for seabed classification, US Patent Application serial number 427624, 2004.

N.G. Pace and H. Gao, Swathe Seabed Classification, *IEEE J. Oc. Eng.*, 13, pp. 83-90, 1988.

J.M. Preston, A.C. Christney, L.S. Beran and W.T Collins, Statistical seabed segmentation – from images and echoes to objective clustering. In *Proc. of the 7th. European Conference on Underwater Acoustics*, 813-818, Delft, Netherlands, 2004.

J.M. Preston, A.C. Christney, L.S. Beran and W.T Collins, R.A. McConnaughey, and S.E. Syrjala, Considerations in large-scale acoustic seabed characterization for mapping seabed habitats. *ICES Annual Science Conference*, CM 2004/T:13, Vigo, Spain, 2004.

R.M. Haralick, K. Shanmugam, and I. Dinstein, Textural features for image classification, *IEEE Trans. Syst. Man Cybern.* SMC-3, pp. 610-621, 1973.

APPENDIX A FORMAT OF SEABED FILE

The default position format is geographical decimal degrees. For this survey the data were converted to survey feet.

An example of a *.seabed file is given below:

20030406,170547453,-122.85029029,48.60624788,-25.22,18.86254692,-4.39753675,-99.68022919,99,
72,01,CLASS_01,MIDDLEBANK,20030406,114_1705,9,0

The above sample classification record is interpreted as follows:

Field Index	Field Value	Representation
A	20030406	the date-stamp (yyyymmdd) for that record
B	170547453	the time stamp (hhmmssms) for that record
C	-122.85029029	the longitude in decimal degrees
D	48.60624788	the latitude in decimal degrees
E	-25.22	the depth expressed in metres, displayed as a negative value
F	18.86254692	Q-Space value Q1
G	-4.39753675	Q-Space value Q2
H	-99.68022919	Q-Space value Q3
I	99	the class confidence in percent
J	72	the class probability in percent
K	01	the class ID
L	CLASS_01	the class name
M	MIDDLEBANK	the source vessel or survey name
N	20030406	the source date-stamp
O	114_1705	the source data set name
P	9	the source FFV file ID
Q	0	the source FFV file record index

General Reevaluation Report
and
Environmental Impact Statement

on

Hurricane Protection and Beach Erosion Control

WEST ONSLOW BEACH AND NEW RIVER INLET (TOPSAIL BEACH), NORTH CAROLINA

Appendix R - Nearshore Hardbottom Survey

Attachment 3 - High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC January / February 2007

High-Resolution 3D Bathymetric Assessment of Potential Hard Bottom Habitats: Topsail Island, Surf City and North Topsail Island, NC January / February 2007

Survey Report

Project No. DACW54-02-D-0006, Delivery Order 0035 Modification 01 Nearshore Hardbottom Sidescan Survey for Multibeam Data Collections Topsail Island, NC
G&O Project Number 146046.T35.6481.GEO

Submitted by:

GREENHORNE & O'MARA
CONSULTING ENGINEERS

With Subconsultant:

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

TABLE OF CONTENTS

Executive Summary

Geodynamics LLC was contracted by the USACE Wilmington District through Greenhorne & O'Mara Inc. on January 16th 2007 to perform a detailed bathymetric survey (phase 2) of zones identified as potential hard bottoms from the July 2006 side-scan sonar study performed by Geodynamics in July 2006 (phase 1). The January 26 – February 6th multibeam surveys employed a Simrad EM3002 shallow water multibeam sonar system to collect spatially dense bathymetric data across 0.85 square miles of seafloor for the development of an accurate surface model as described in the official Scope of Work (Appendix A). The system runs at 300 kHz and is compensated for motion and heading with an Applanix POS MV 320 v4 inertial navigation system. Sensor offsets have been surveyed to close within 1 millimeter by the National Geodetic Survey. The EM3002 produces a swath of sonar approximately 4 times the water depth and collects approximately 400 soundings per square meter. Sound velocity was calculated in real-time at the transducer head with an Applied Microsystems miniSV and profile data was collected with an Odom Digibar Pro.

Tidal corrections and positioning information were acquired using a site calibrated Trimble 5700 Real-Time Kinematic GPS (RTK-GPS) system integrated with the POS MV 320 through a Pacific Crest PDL radio modem. The RTK-GPS system uses a land-based station coupled with a 25-watt radio and a Maxrad 5 dB high-gain antenna to broadcast the computed real-time horizontal and vertical corrections at 10 Hz to the hydro survey platform. To compute centimeter-scale position and elevation information, determine the relationship between WGS-84 and local grid coordinates, and to evaluate the local geoid-spheroid separation, we first performed a detailed network adjustment and site calibration. Information on the site calibration can be found in the corresponding section of this final report and published accuracies on each of the systems can be found in Appendix C.

Survey Preparation

Survey Area

Topsail Island is located approximately 20 miles northeast of Wilmington and separates Lee Island to the south and Onslow Beach to the north. The Topsail Island nearshore survey was comprised of 18 planned survey lines (6 line per survey area) spaced 70' to 90' apart to obtain 100% seafloor coverage (Figure 1). The total area of the survey encompassed 0.85 square miles with a total of 57 line miles.

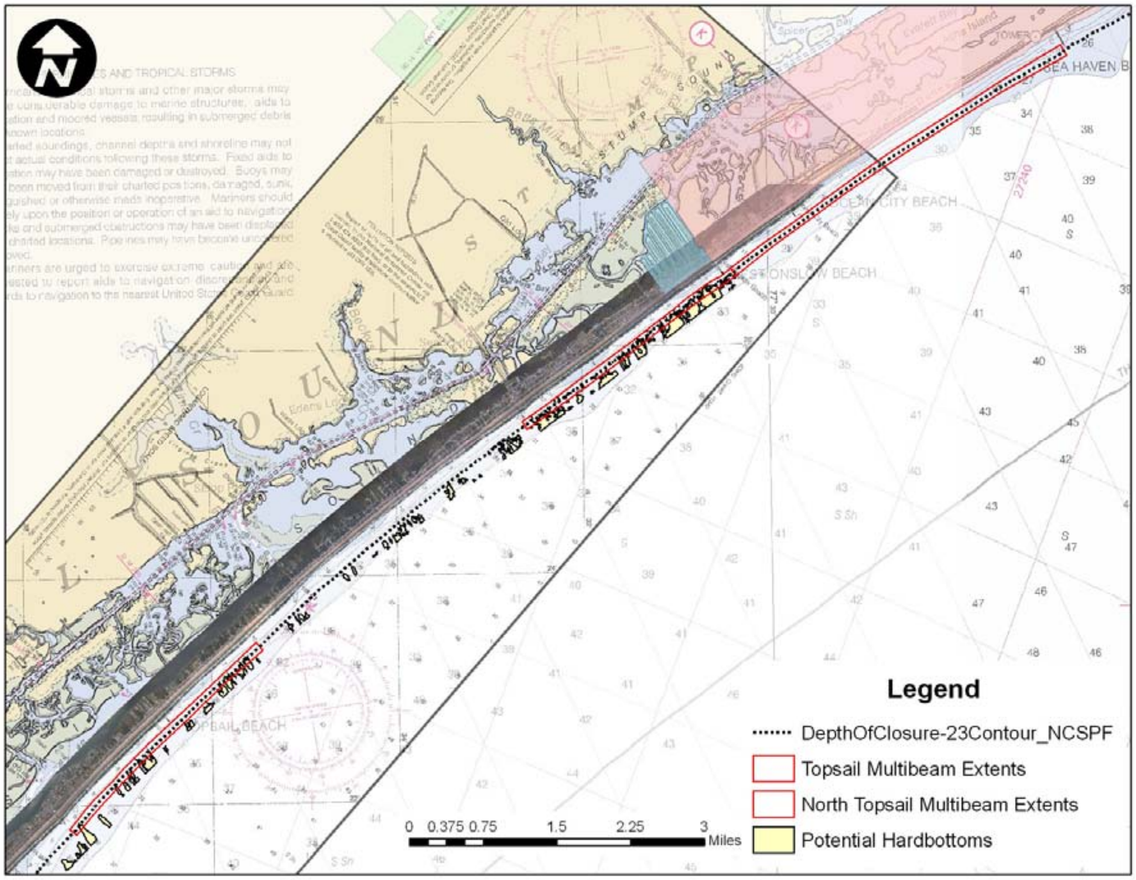

Figure 1. Map of Topsail, Surf City and North Topsail Island survey extents.

RTK-GPS Survey Control & Multibeam Calibration

Introduction & Purpose

The most common problem in accurately measuring the seafloor with any sonar-based system, especially in and around a tidal inlet, is the calculation of the tidal elevation offset. Commonly a tide staff or gauge is deployed in one location near the survey site and is used to calculate the tides for the entire survey area. However, it is widely understood that non-linear tidal phenomena, phase lags and tidal gradients can drastically influence the tidal elevation spatially across a tidal inlet and therefore the use of a single point measurement is often unreliable.

To avoid these potential tidal elevation errors which can translate into significant departures from the true bottom depth, we use geodetic Global Positioning Systems (GPS) with real-time kinematic (RTK) baseline processing that is integrated with the multibeam and inertial navigation instruments. The motion and Geoid 03 compensated positions and orthometric elevations of the RTK-GPS data stream are tagged with each sonar ping. In effect, the RTK-GPS mounted on the hydrographic survey vessel acts as a roving tide gauge collecting the most accurate tidal measurements throughout the survey area.

Multibeam swath sonar systems combine a complex array of instruments, consisting of the transducer, motion sensor, inertial navigation, and geodetic GPS systems. Standards developed by the International Hydrographic Organization (IHO), USACE Standards for Hydrographic Surveys, and the NOS Hydrographic Surveys Specifications and Deliverables for shallow water (<30 m) hydrography (IHO 1987; USACE 2003; NOS 2006) are used as the protocol for calibration. Proper alignment of these instruments with one another and with the vessel's reference frame is critical to achieve the high-accuracy required in the SOW. Calculation of the horizontal and vertical offsets between each of the instruments completed by the National Geodetic Survey is followed by a series of sea-based measurements known as the patch test.

The patch test is performed to calculate several residual biases influenced by the dynamics of the survey vessel and the alignment of the instruments. Results of the patch test, documented in the following sections, are used to calculate a pitch, roll and heading offset and positioning time delay or navigation latency. Additional calibration measures are performed in the field including comparison of nadir depths with a lead line and frequent sound velocity profiles. The results of these daily field checks can be found in the html metadata file accompanying the final soundings.

RTK-GPS Network Adjustment & Site Calibration

There are many environmental and operator-based influences that can affect the accuracy of RTK-GPS and the resultant baseline solutions (Bilker 2001; Trimble

Navigation Limited 1998; Magellan Corporation 2001). Although RTK-GPS is an emerging tool among hydrographers, little attention has been given to an accuracy standard for this methodology—especially in the field of coastal mapping and monitoring (Morton et al., 1993). In an effort to limit operator error and to quantify daily environmental error, we have developed an internal standards protocol for RTK error estimation based on thresholds developed by the California Department of Transportation and the US Army Corps of Engineers (USACE) Topographic Accuracy Standards (CALTRANS 2002; USACE 1994).

The first step in our protocol is to determine an appropriate land-based GPS station that will provide the most accurate corrections and range to the outer limits of the survey area. Phase one of the project we used a benchmark atop a circa 1940's rocket observation platform called "Tower 3". Our initial plan was to use this mark for phase 2 of the project; however, after approximately 3 weeks of trying to contact the owner for access to the site we were unable to reach the current owners of the property. We then chose to use "A230", which is approximately 0.5 miles south of "Tower 3".

The second step in our RTK-GPS protocol was to perform a detailed GPS site calibration on the new basestation prior to the collection of any hydrographic survey data. The site calibration is used to determine the basestation quality relative to the local network of NGS and NOS survey control and to analyze any potential spatial separations between the local geoid heights (GEOID 03) and ellipsoidal values (WGS-84) that may influence the resulting orthometric elevations. The calibration entails selecting the control to be used for the RTK-GPS basestation receiver and radio broadcast system and then checking at least three known geodetic benchmarks of exceptional horizontal and vertical quality within and even outside the survey boundaries. The benchmarks are occupied in "site calibration mode" over 300 epochs or approximately 3 to 5 minutes.

A detailed RTK-GPS site calibration for phase 2 of this project was performed on January 26, 2007 prior to the start of the multibeam data acquisition phase. Three benchmarks from various government and state agencies were used in the calibration and results can be found in Table 1. Results showed an average deviation of 4.8cm (0.157') in the Northing, 1.5cm (0.049') in the Easting and 3.0cm (0.098') in the Elevation.

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RTK-GPS Pre-Survey Site Calibration

General

Date	1/26/2007
Project	USACE Topsail Island Multibeam - phase 2
Surveyor(s)	Freeman / Bernstein
Equipment	Trimble 5700 Basestation, Trimmark III 25 watt RTK Radio, Maxrad 5dB gain Antenna, Zepher Geodetic base antenna, Trimble 5700 RTK rover, Zepher antenna
Weather	Sunny, Few Clouds, 45 F, NW Wind 15-25 kts, gust to 30 kts
Units	Meters
Notes	Access to Tower 3 basestaion used in phase 1 could not be obtained. A230 was then selected as the best possible RTK-GPS basestaion. Base was set on A230 and marks were checked to verify RTK quality throughout the survey extent.
Coordinate System	NC State Plane, NAD83 (horiz), NAVD88 (vert)

Basestation Information

Designation	A230
PID	EA0696
Agency	CGS
Horiz Order	1
Vert Order	2
N	71298.606
E	737877.413
Z	3.480

A230

A230 Benchmark

Benchmark Checks

Designation	CROCKER
PID	AI0831
Agency	NCGS
Horiz Order	1
Vert Order	3

	Recorded	Published	Difference
N	68542.047	68542.046	-0.001
E	735010.569	735010.571	0.002
Z	1.323	1.33	0.007

Notes: Benchmark is at intersection of Crocker and S. Anderson

Crocker Benchmark

Crocker BM Check

Benchmark Checks (cont.)

Designation	FIRTH		
PID	AI0904		
Agency	NGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	78267.399	78267.452	0.053
E	746327.217	746327.233	0.016
Z	1.246	1.20	-0.05
Notes	Benchmark is on NW side of W 9th St. North of Surf City.		

Firth Benchmark

Firth BM Check

Benchmark Checks (cont.)

Designation	DUNE AZ MK		
PID	AI0855		
Agency	NCGS		
Horiz Order	1		
Vert Order	3		
	Recorded	Published	Difference
N	82569.585	82569.674	0.089
E	752975.095	752975.121	0.026
Z	1.698	1.66	-0.038
Notes	see NGS datasheet for location description		

Dune AZ MK Benchmark

Dune AZ MK Benchmark Check

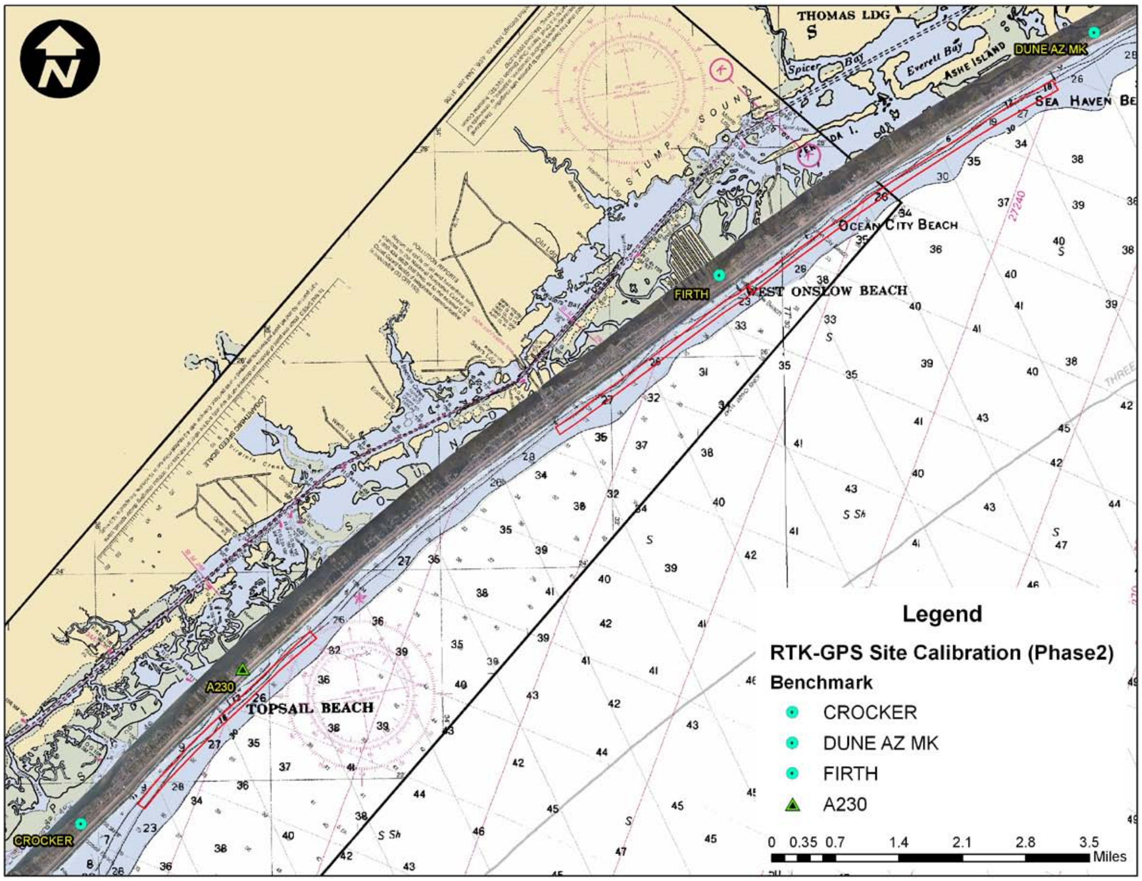


Figure 2. Map of new site calibration on A230 and the BM's checked.

Multibeam Echosounder Calibration Report

Calibration Date:	April 19, 2006
Ship	
Vessel	RV 4-Points
Echosounder System	EM3002
Positioning System	POS MV (tightly coupled)-RTK GPS
Attitude System	POS MV
Sound Velocity Probe	Odem Digibar Pro (profiler) / Valeport Mini SVS (at head)

Annual		
Installation	x	
System change	x	
Periodic/QC		
Other		

Calibration type: Multibeam Sonar

The following calibration report documents procedures used to measure and adjust sensor biases and offsets for multibeam echosounder systems. This report has been adopted and modified from NOAA. Calibration must be conducted A) prior to CY survey data acquisition B) after installation of echosounder, position and vessel attitude equipment C) after changes to equipment installation or acquisition systems D) whenever the Hydrographer suspects incorrect calibration results. The Hydrographer shall periodically demonstrate that calibration correctors are valid for appropriate vessels and that data quality meets survey requirements. In the event the Hydrographer determines these correctors are no longer valid, or any part of the echosounder system configuration is changed or damaged, the Hydrographer must conduct new system calibrations.

Multibeam echosounder calibrations must be designed carefully and individually in consideration of systems, vessel, location, environmental conditions and survey requirements. The calibration procedure should determine or verify system offsets and calibration correctors (residual system biases) for draft (static and dynamic), horizontal position control (DGPS), navigation timing error, heading, roll, and pitch. Standard calibration patch test procedures are described in *Field Procedures for the Calibration of Multibeam Echo-sounding Systems*, by André Godin (Documented in Chapter 17 of the Caris HIPS/SIPS 6.0 User Manual, 2006). Additional information is provided in *POS/MV Model 320 Ver 4 System Manual* (10/2003), Appendix F, Patch Test, and the NOAA Field Procedures Manual (FPM, 2003). The patch test method only corrects very basic alignment biases. These procedures are used to measure static navigation timing error, transducer pitch offset, transducer roll offset, and transducer azimuth offset (yaw). Dynamic and reference frame biases can be investigated using a reference surface.

Pre-calibration Survey Information

Reference Frame Survey

RV 4-Points was surveyed by the National Geodetic Survey on February 15, 2006 for precise centerline and instrument locations. Steve Breidenbach performed the survey with a Trimble 5603 total Station.

(IMU, Ref Pt., and XY of CG are all co-aligned and attitude and position is valid at the sensor. The values below are entered in POSview software.)

Reference to IMU Lever Arm

X(m)	Y (m)	Z (m)
0	0	0

Reference to Pri. GPS

X(m)	Y (m)	Z (m)
1.849	-1.061	-1.724

IMU frame w.r.t. Reference frame

X(deg)	Y (deg)	Z (deg)
0	0	0

Reference to Sensor Lever Arm

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

Reference to CG

X(m)	Y (m)	Z (m)
0	0	0.313

Figure 3. Photo of the centerline and instrument survey by NGS.

Reference to Vessel (Pt of validation for attitude and nav)

X(m)	Y (m)	Z (m)
-0.097	-2.130	0.849

__X__Measurements verified for this calibration.
___ __Drawing and table attached.
_____Drawing and table included with project report

POS MV Configuration File: 4_points_022806._*________________

Notes: _NGS vessel survey results were put in POSview and GAMS calibration was done on February 28, 2006___.

Calibration Area

Site Description

This patch survey was conducted in the Port of Morehead City's turning basin near Beaufort Inlet, North Carolina (N34 41 39.16 W076 40 07.53). This site was selected for its particular bottom features, such small scale ripple fields, sand waves (wavelength: ±5m, amplitude: ±0.15m), deep flat areas, and high slopes.

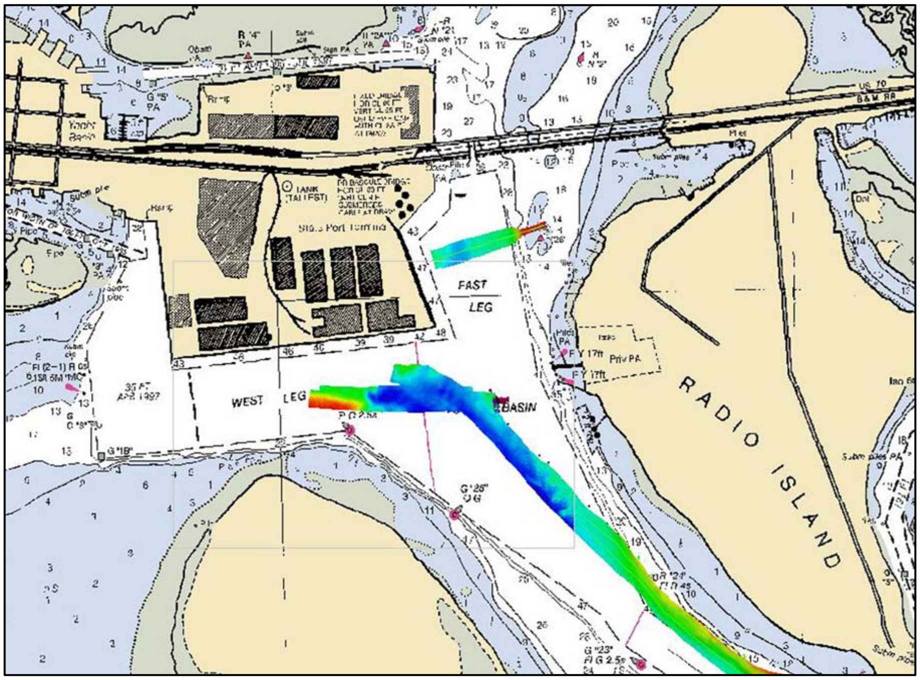


Figure 4. Map of the patch survey area within the Morehead City Turning Basin.

Survey Procedure

Vessel biases were determined through a patch test survey procedure. Data was acquired and analyzed in Kongsberg SIS package. The latency test was performed first by surveying the same survey line in the same direction at 2 different vessel speeds. The latency test was done twice to verify initial results. The pitch test was done second by surveying the same survey line in opposite directions at the same speed and evaluating the sloped portion of the survey line. The roll test was performed next by surveying the same survey line in opposite directions at the same speed and evaluating the deep flat portion of the survey line. The roll test was done twice to verify initial results. The yaw test was performed next by surveying 2 adjacent survey lines in the same direction, with similar speeds, with enough overlapping coverage such that the outer beams from each swath overlap (±40%).

Calibration Lines

Hypack Line	Line File	Az.	Spd	Correction			
				Pitch	Roll	Yaw	Latency
1	0000_20060301_163731_4points.all	57°	3.3kts				X
1	0001_20060301_164249_4points.all	57°	7.1kts				X
1	0002_20060301_165502_4points.all	237°	3.2kts				X
1	0003_20060301_165938_4points.all	237°	7.0kts				X
1	0002_20060301_155849_4points.all	237°	7.0kts	X			
1	0003_20060301_160222_4points.all	57°	7.0kts	X			
1	0000_20060301_172142_4points.all	57°	7.0kts		X		
1	0001_20060301_172427_4points.all	237°	7.0kts		X		
1	0000_20060301_183521_4points.all	237°	7.0kts		X		
1	0001_20060301_183741_4points.all	57°	7.0kts		X		
8	0001_20060301_191059_4points.all	280°	7.0kts			X	
7	0002_20060301_191957_4points.all	100°	7.0kts			X	

Sound Velocity Correction

Measure water sound velocity (SV) prior to survey operations in the immediate vicinity of the calibration site. Conduct SV observations as often as necessary to monitor changing conditions and acquire a SV observation at the conclusion of calibration proceedings. If SV measurements are measured at the transducer face, monitor surface SV for changes and record surface SV with profile measurements.

Sound Velocity Measurements

Time	Max Depth	Surface SV	Change Observed	Position	
				Latitude	Longitude
14:52:00	15.5m	1490.2		34 42.9705	76 41.6239
Continuous SV at head			<4 m/s throughout entire calibration		

Data Acquisition and Processing Guidelines

Initially, calibration measurement offsets should be set to zero in vessel configuration files. Static and dynamic draft offsets, inertial measurement unit (IMU) lever arm offsets, and vessel reference frame offsets must be entered in appropriate software applications prior to bias analysis. Perform minimal cleaning to eliminate gross flyers from sounding data.

Navigation Timing Error (NTE)

Measure NTE correction through examination of a profile of the center beams from lines run in the same direction at maximum and minimum vessel speeds. NTE is best observed in shallow water.

Transducer Pitch Offset (TPO)

Apply NTE correction. Measure TPO correction through examination of a profile of the center beams from lines run up and down a bounded slope or across a conspicuous feature. Acquire data on lines oriented in opposite directions, at the same vessel speed. TPO is best observed in deep water.

Transducer Roll Offset (TRO)

Apply NTE and TPO corrections. Measure the TRO correction through examination of roll on the outer beams across parallel overlapping lines. TRO is best observed over flat terrain in deep water. An additional check for TRO adjustment can be performed by running two lines parallel to a sloped surface.

Transducer Azimuth Offset (TAO or yaw)

Apply NTE, TPO and TRO corrections. Measure TAO correction through examination of a conspicuous topographic feature observed on the outer beams of lines run in opposite directions.

Patch Test Results and Correctors

Evaluator	NTE (sec)	TPO (deg)	TAO (deg)	TRO (deg)
Bernstein/Hohing	0.00	0.00	0.00	-0.65
Final Values	0.00	0.00	0.00	-0.65

Corrections Calculated in:	
Caris	
ISIS (BathyPro)	
Other	SIS

NOTE: TRO bias of -0.65 was put in SIS software.

Evaluator: Dave Bernstein
Reviewed by: Chris Freeman
Accepted by: Dave Bernstein
Date accepted: April 21, 2006

Graphical Examples of Calibration Acceptance

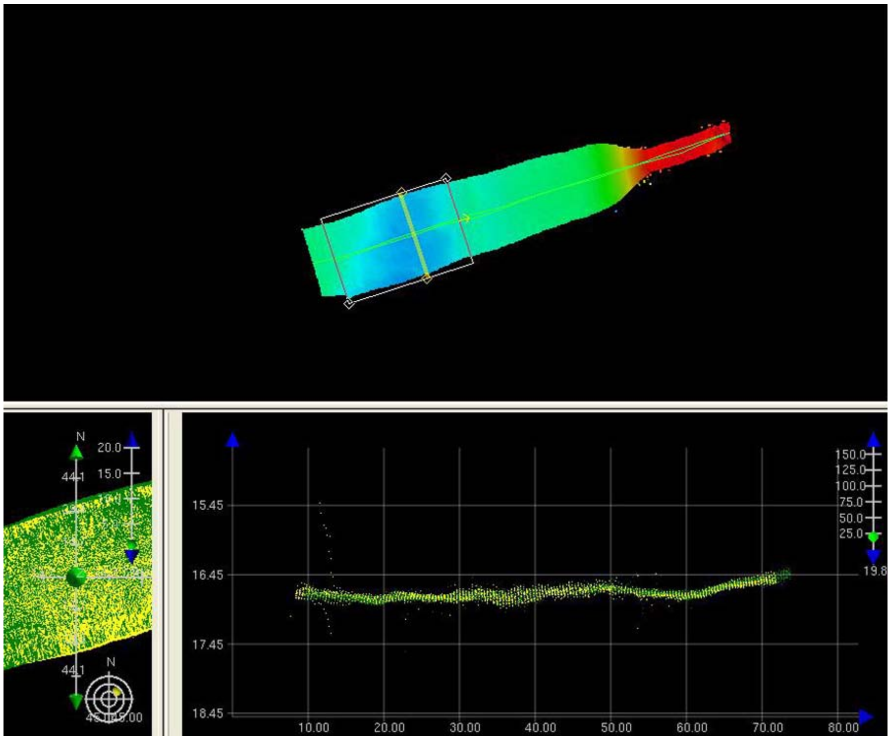


Figure 5. Caris screen grab illustrating acceptance of roll calibration.

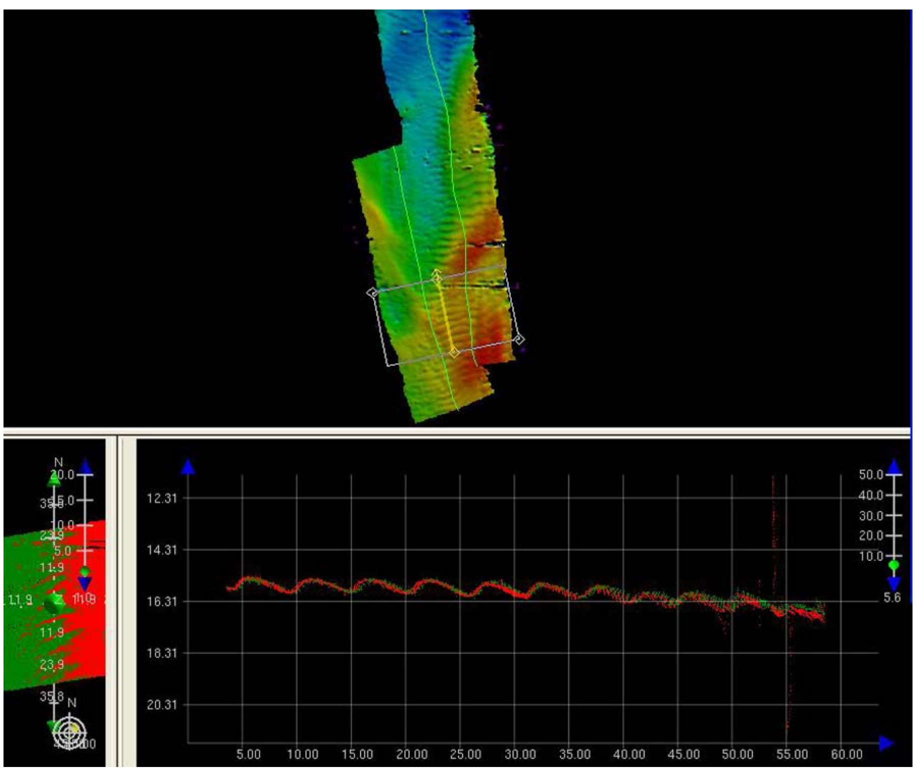


Figure 6. Caris screen grab illustrating acceptance of yaw calibration.

Data Processing Routines & QA/QC Information

Introduction

Processing high-density multibeam bathymetry and backscatter data requires a multitude of processing routines and data quality analyses. The following section will detail all aspects of data post-processing for the Topsail Island multibeam surveys. Also presented in this section is detailed QA/QC information and analysis generated throughout the various processing procedures.

Bathymetry Processing

The multibeam collects swath widths approximately 4 times the water depth. The portions of swath, mainly in the outer beams, that exhibit areas of inconsistent data are clipped and not included in the final digital file. Sounding track lines are generally parallel to each other and parallel to the seafloor contour. Sinuous lines and data acquired during turns are not included in the final processed data. To meet the accuracy and resolution standards for measured depths specified in the USACE Hydrographic Surveying Manual and the NOS Hydrographic Surveys, Specifications and Deliverables Manual, measured echosounder depths were corrected for all departures from true depths attributable to the method of sounding or to faults in the measuring apparatus. These corrections are subdivided into four categories, and are listed below in the sequence in which they were applied to the data.

1. Instrument error corrections: included to account for the sources of error related to the sounding equipment itself.

2. Vessel offsets: added to the observed soundings to account for the depth of the echosounder below the water surface, positioning of the motion reference unit, and GPS antenna.

3. Velocity of sound correctors: applied to the soundings to compensate for the fact that echosounders may only display depths based on an assumed sound velocity profile while the true velocity may vary in time and space.

4. Heave, pitch, roll, heading and navigation latency corrections: applied to the multibeam soundings to correct for the effect of vessel motion caused by waves and swells, the error in the vessel's heading, and the time delay from the moment the position is measured until the data is received by the GPS receiver.

Multibeam Data Processing Steps in CARIS HIPS software:

The EM3002 sonar system has a unique arrangement of data flow. Most settings that influence the data are put in before and during a survey and therefore are not a factor in data processing (these include vessel offsets, lever arms, vessel biases, timing biases, and survey sound velocity). Vessel attitude is also processed real-time during a survey.

Post-processing of multibeam data consist of attitude and navigation editing, merging, swath editing, area-based editing, and exporting of final data.

1. Attitude & Navigation Editing: Errors or gaps in attitude and navigation information causing errors in soundings are edited.

2. Merging: Computing and integrating the GPS tide in the sounding data. Additional sound velocity corrections are made if needed in this phase.

3. Total Propagated Error (TPE) is calculated

4. Swath- and beam-based filters and TPE (IHO standards) filters are applied.

5. Swath Editing: Swaths are edited for erroneous data if needed

6. Base or CUBE Surface is created for area- and CUBE-based editing.

7. Area-based editing using the subset editor to edit/check erroneous data only within the desired subset.

8. CUBE filtering and editing

9. Recompute TPE

10. Recompute CUBE and/or base surfaces

11. Final export of base surface to XYZ decimated soundings.

TPE (Total Propagated Error)

Although tidal corrections are perhaps the largest source of error, the combination of multiple sensors, vessel geometry and sound velocity variations also contribute to uncertainty in shallow water hydrographic surveying (Allen, 2005). Precise calculations of these uncertainty values are fundamental to the field of hydrographic surveying. To accurately estimate uncertainty we analyze each individual error source and calculate a total propagated error (TPE) for the Topsail Island survey using CARIS HIPS Pro v 6.1. The TPE function with the Combined Uncertainty and Bathymetry Estimator (CUBE) filters data for soundings with uncertainty values that fall outside the limits set by the International Hydrographic Organization (IHO, 1998) and USACE standards (USACE, 2003). The average vertical TPE value for the Topsail Island survey is 0.43 ft (13 cm) and the average horizontal TPE value is 0.39 ft (12cm), allowing us to achieve a vertical and horizontal accuracy that exceeds IHO special order and the highest USACE for Navigation and Dredging Support Surveys for individual soundings (not swath coverage).

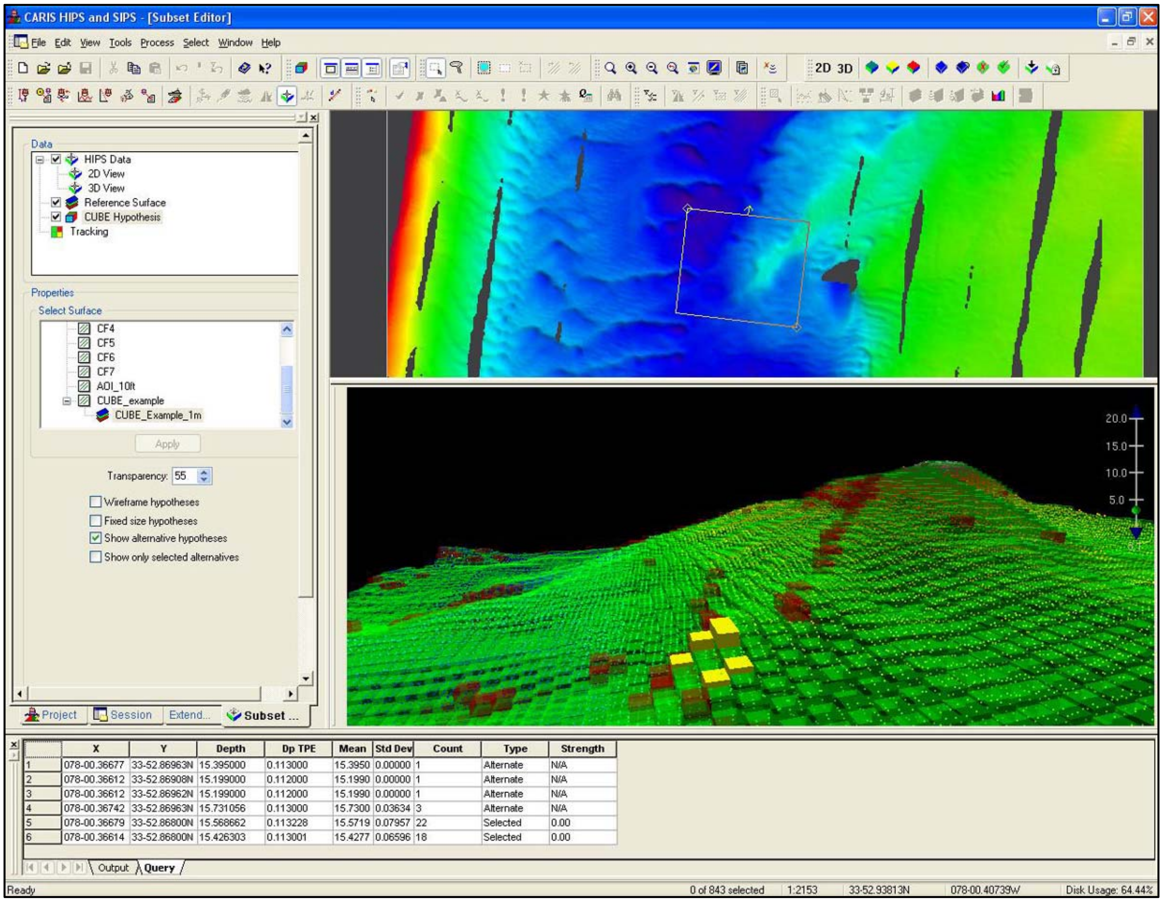
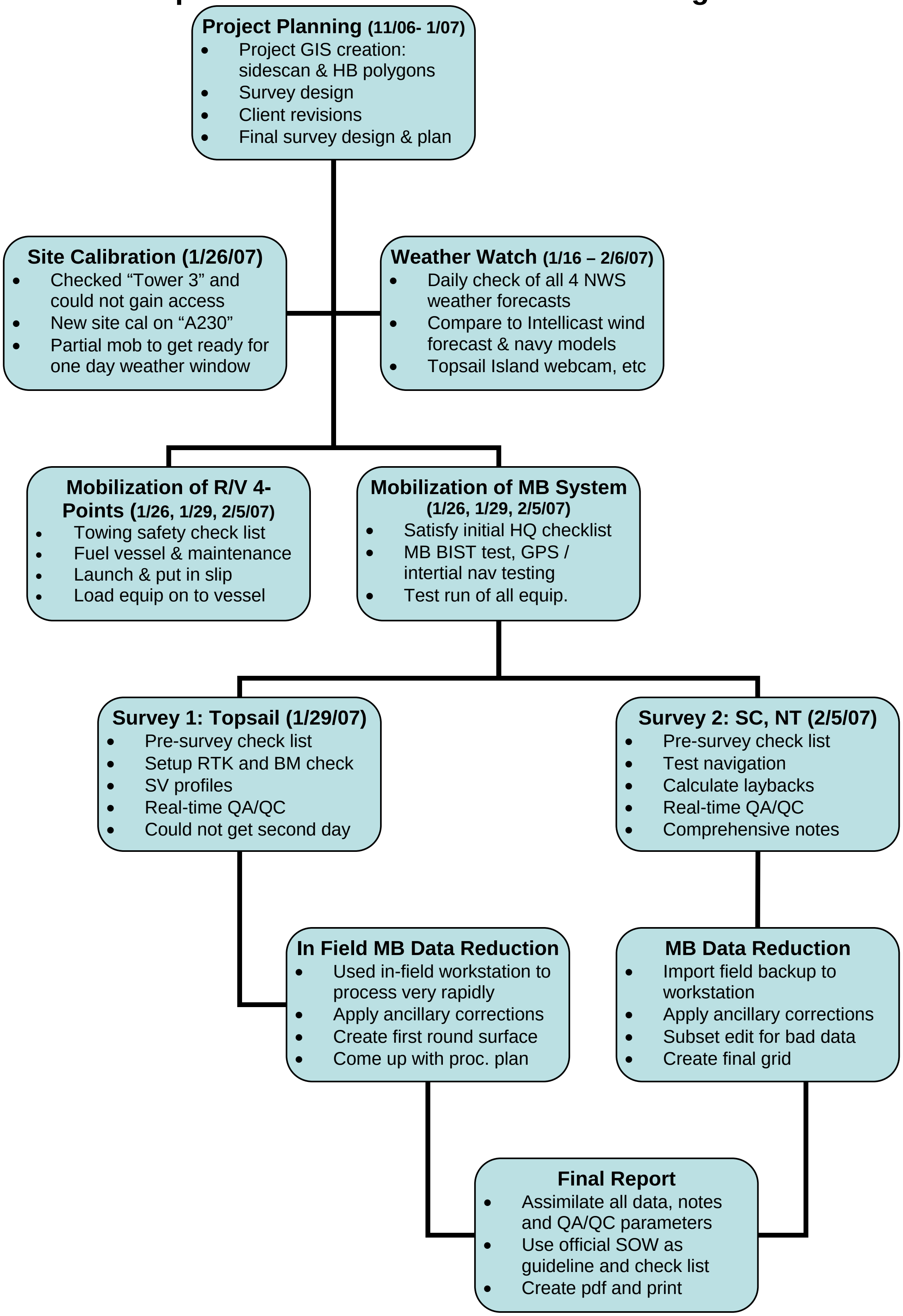
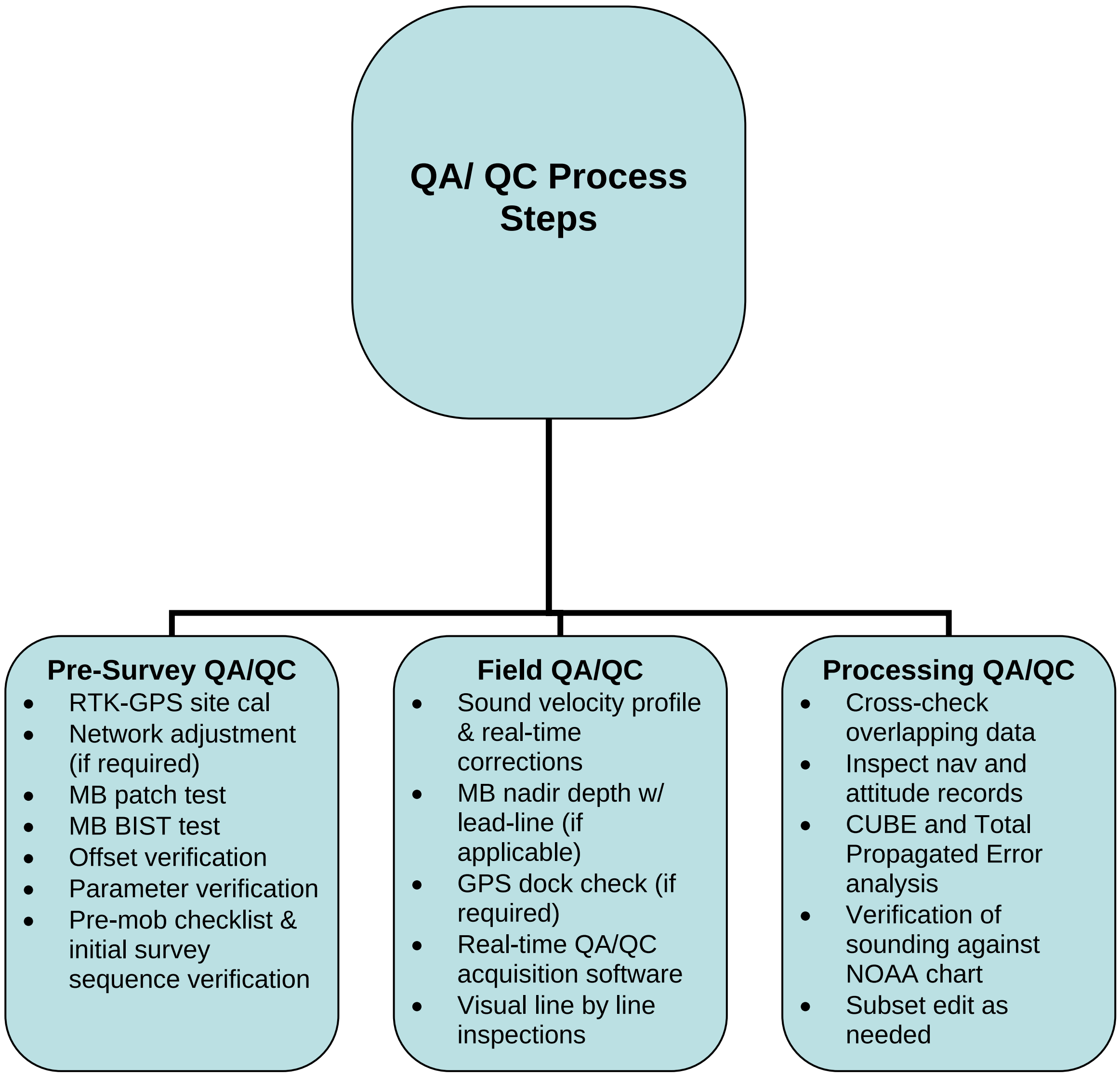


Figure 7. Screen capture showing an example of the CUBE editing process.

Topsail Island Multibeam Workflow Diagram



Topsail Island Multibeam QA/QC Workflow Diagram



Graphical Summary of Deliverables

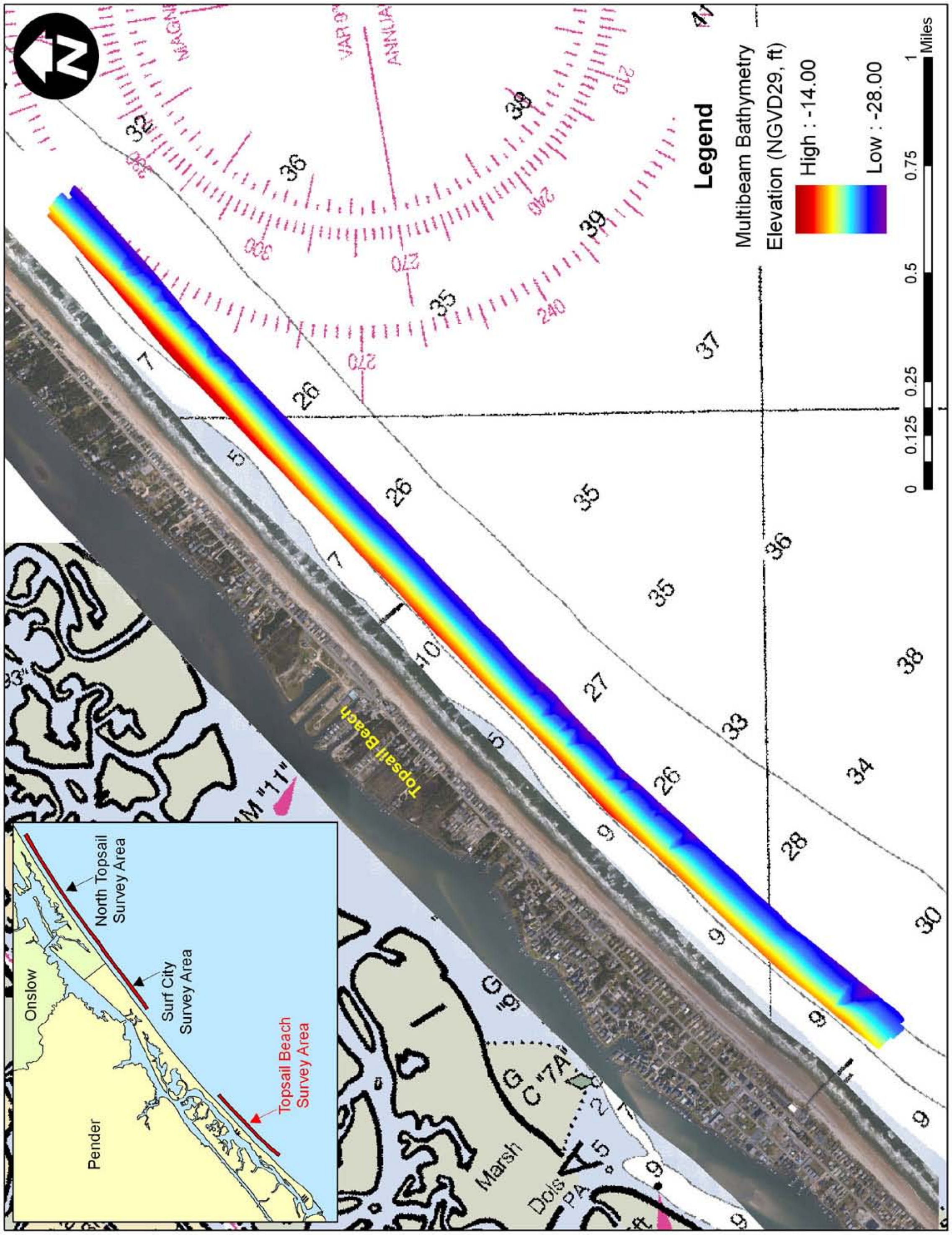


Figure 8. Plan view bathymetric map showing the "southern" survey reach.

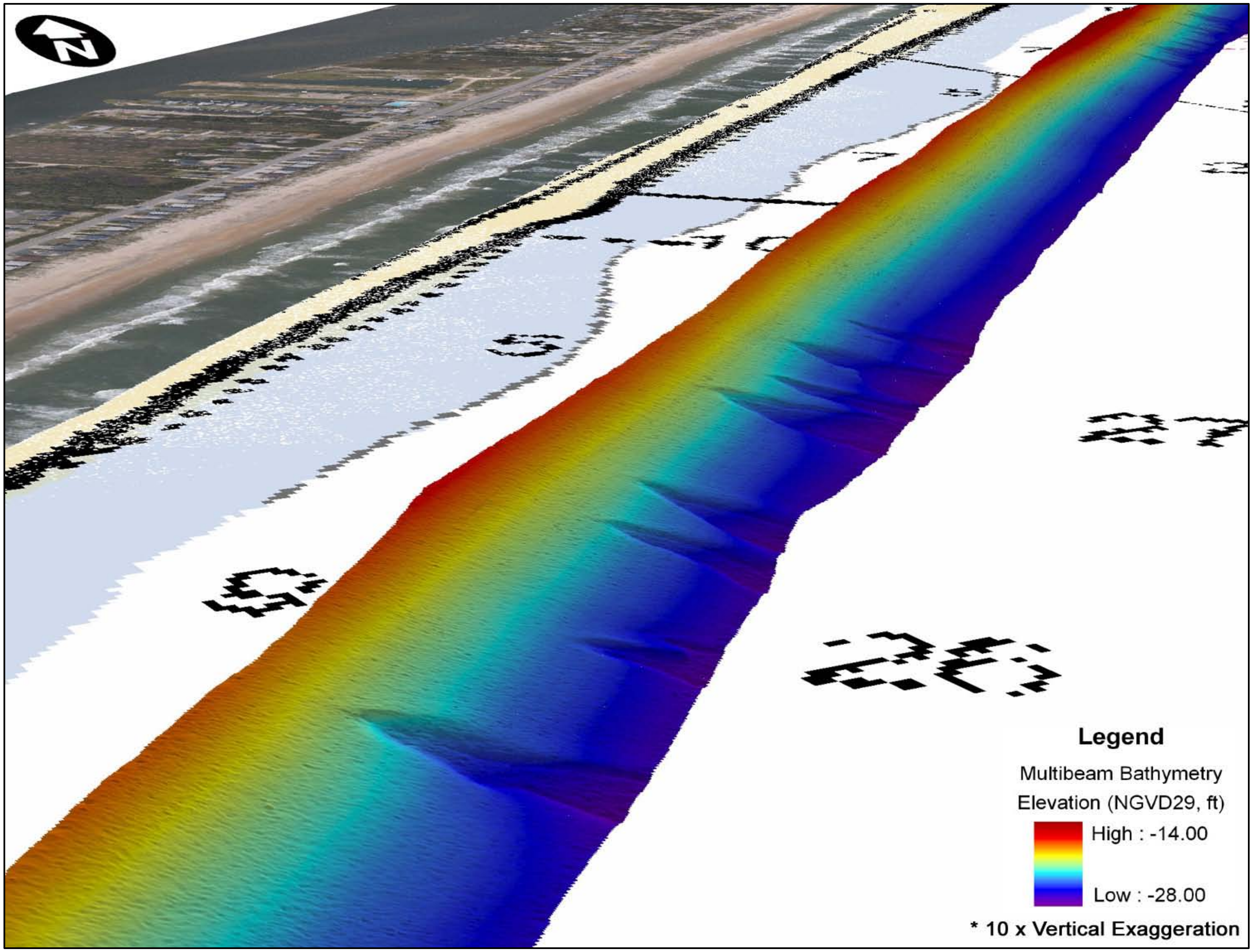


Figure 9. 3D perspective view of Topsail Island inner shoreface. Inshore signature or scour depressions that likely extend offshore.

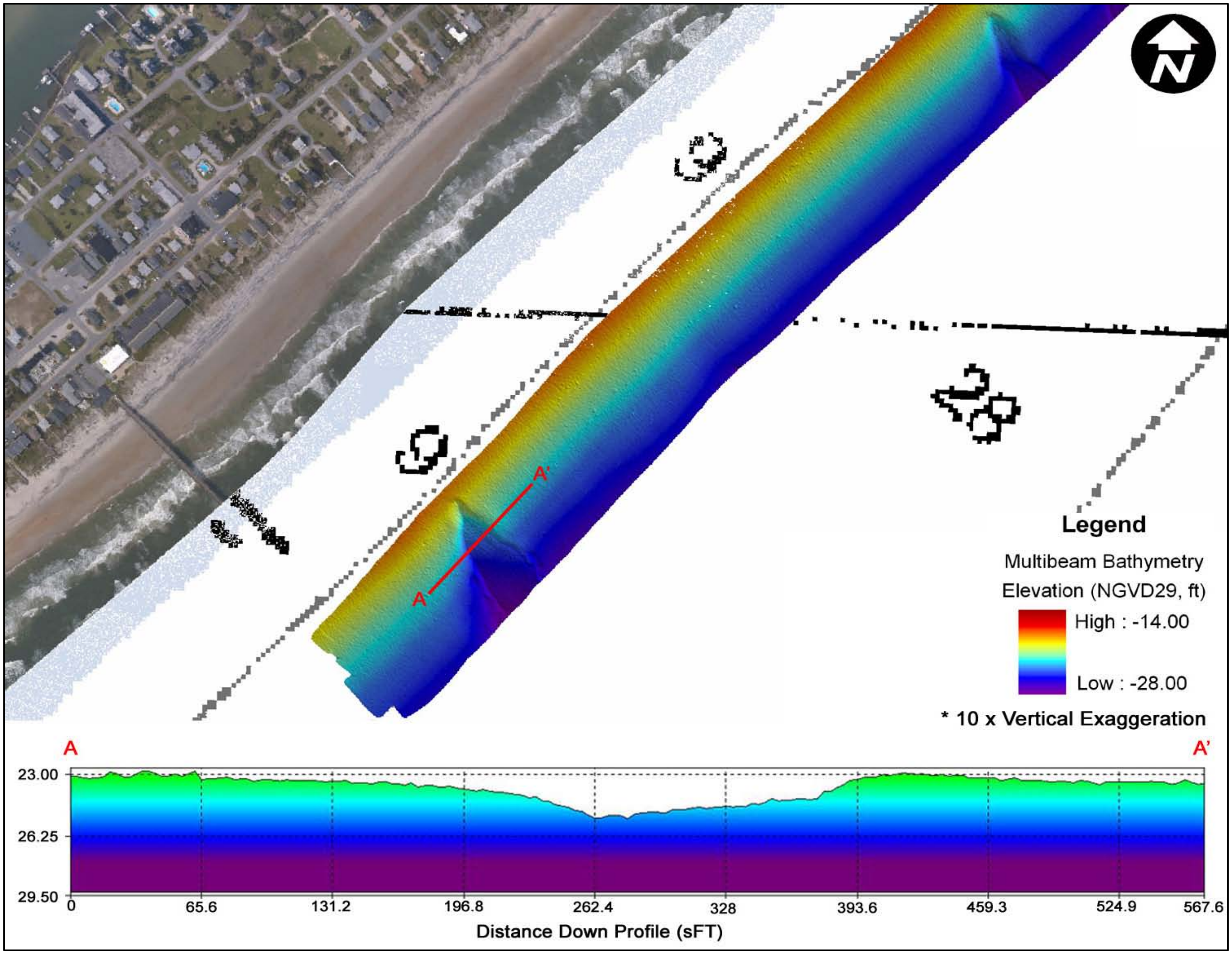


Figure 10. Zoom in on scour depression area for Topsail Island with profile cross section.

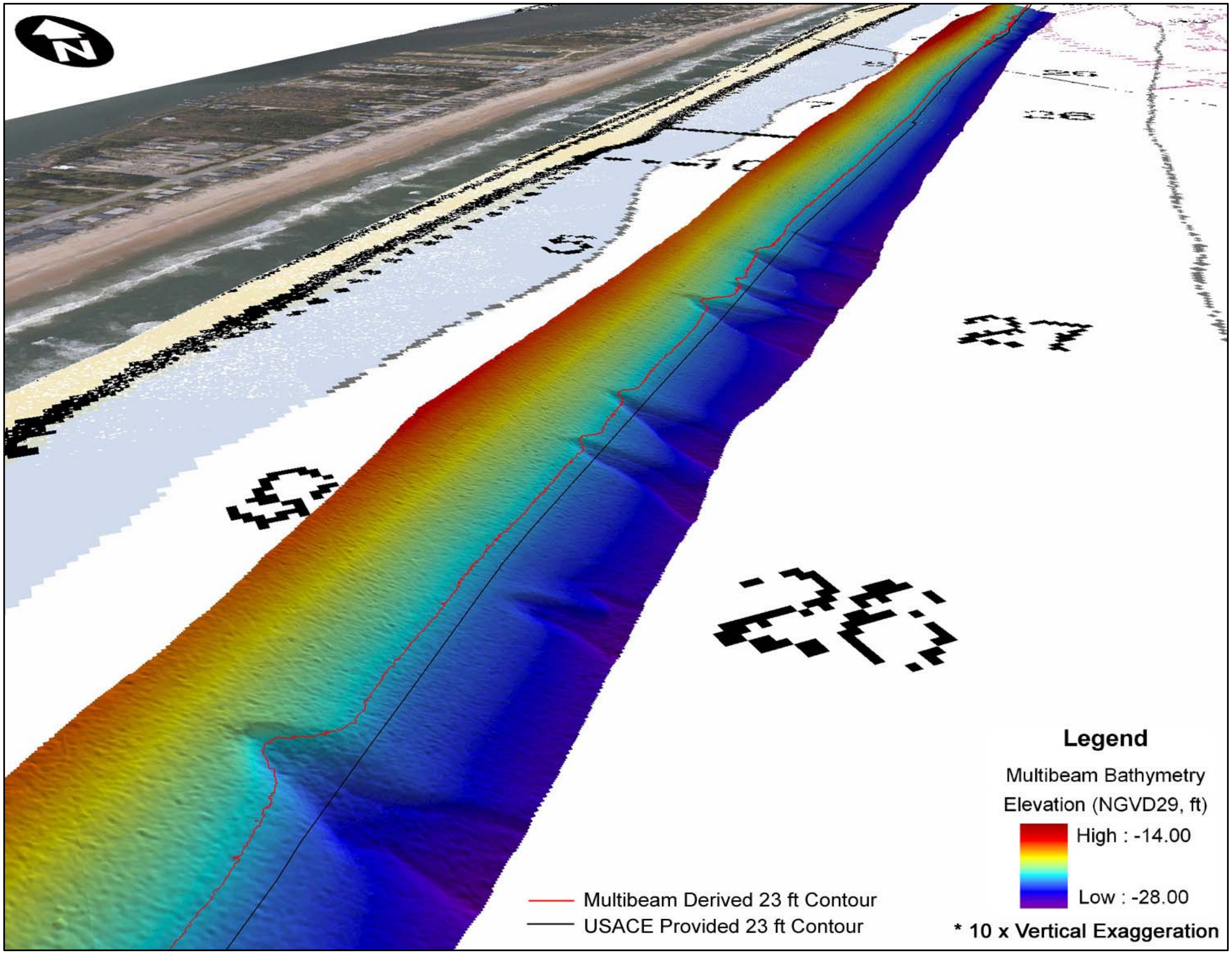


Figure 11. 23' multibeam and 23' USACE contours draped on 3D perspective view of the Topsail Beach inner shoreface.

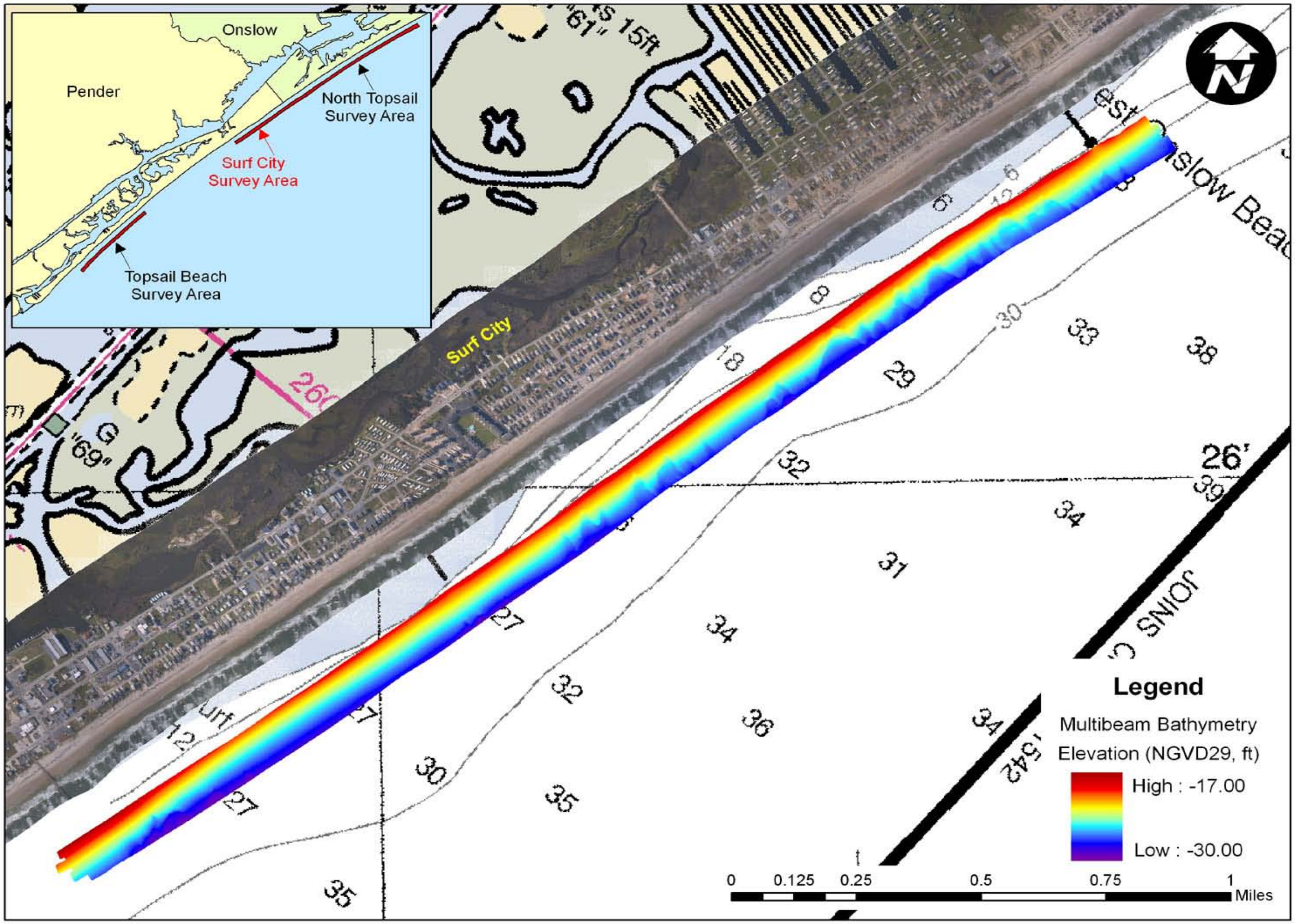


Figure 12. Plan view bathymetric map of the Surf City or “middle” survey area.

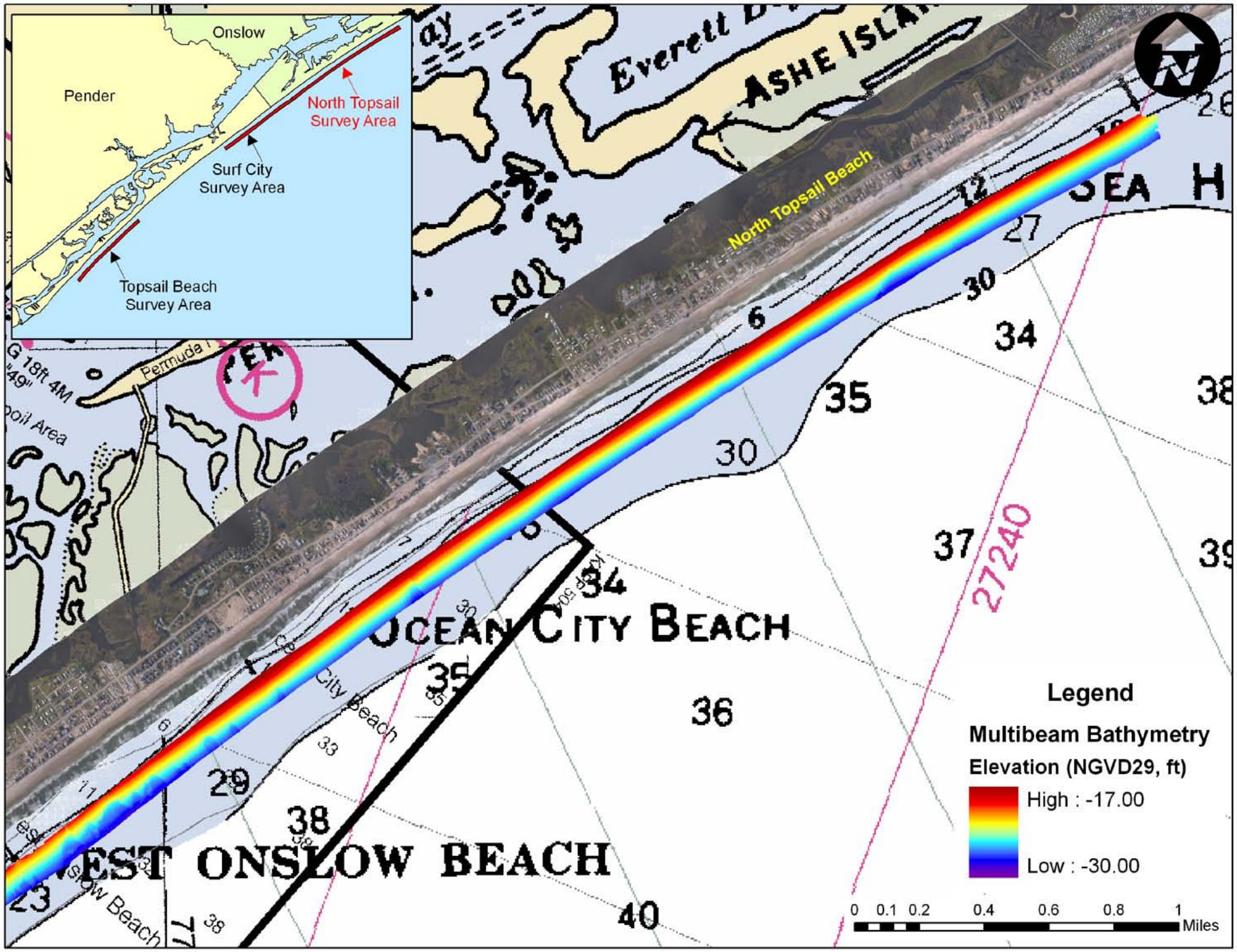


Figure 13. Plan view bathymetric map of the North Topsail or “northern” survey area.

Appendix A – Official USACE Scope of Work
(Scanned G&O Copy)

CONTRACT DACW54-02-D-0006, TASK ORDER 00-5, MOD. 01

MODIFICATION
TO
SCOPE OF WORK
NEARSHORE HARD BOTTOM SIDESCAN SURVEY
FOR MULTIBEAM DATA COLLECTION
TOPSAIL ISLAND, NORTH CAROLINA

1. Location of Work. The tasks to be performed under this scope of work pertain to the geographic area of Topsail Island, North Carolina as indicated on figure 1.

2. General Requirements. The Contractor shall supply all necessary labor, materials, equipment, rentals, and travel expense to conduct and document the work as described herein.

3. Detailed Requirements. The Contractor shall acquire full coverage multibeam sonar data within zones identified to contain potential hardbottom regions as identified in Phase 1 of the project as well as those areas previously identified as potential hard bottom in North Topsail by CPE Inc.

The Contractor shall provide all necessary services, equipment, labor, and materials to perform a multibeam survey within the survey limits as indicated on figure 1, and the post processing of the collected field data into the required formats and deliverables as indicated. The following survey datums are required:

Horizontal – North Carolina State Plan, NAD83, US Survey, Feet
Vertical – NGVD 1929, Feet

A. Hydrographic Data. Hydrographic survey coverage for the area depicted on the attached map shall be provided. The Contractor shall conduct the multibeam surveys as to ensure 100% coverage to the extent practical of the survey area shown on the attached map. Survey lines should be taken at sufficient intervals to ensure this coverage. Coordinates shown on the attached map are in feet and reference the North Carolina State Plane Coordinate System, NAD83. All data shall meet the recommended minimum performance standards established in EM 1110-2-1003 (Table 3-1) for the "Other General Surveys and Studies" project classification.

B. System Calibration and Check. The Contractor shall calibrate and check the multibeam system in accordance with the procedures outlined in EM 1110-2-1003. A log (either written or digital) containing the results of all calibrations and checks shall be kept by the Contractor.

C. Data Editing. All hydrographic survey data shall be fully edited and corrected. The data shall undergo a gridded depth reduction using 5-foot cells or less, where the depth saved shall be the depth closest to the center of the cell.

Note: USACE documents can be downloaded from the following web site: http://www.usace.army.mil/inet/usace-docs/eng-manuals/em.htm

4. Survey Control. Phase 2 multibeam surveys will use US Coast and Geodetic Survey benchmark Tower Three 1947 for RTK-GPS corrections. A complete site calibration has been performed on this mark during Phase 1; however, prior to the start of surveying in Phase 2 Contractor shall check at least one mark within the control network to verify correct basestation setup.

5. Clearances. The Contractor shall acquire all Clearances necessary to obtain the required data. All discussions for access to private or public property or restricted waters or airspace must be included in the required weekly status report with name of person, address, and telephone number.

6. Required Deliverables. The Contractor is required to deliver Shapefiles, Raster Data Sets, Metadata Records, a Weekly Status Reports, and a Final Written Report.

6.1 GIS-Compatible Data The Contractor shall deliver data in a format compatible with ESRI ArcView/ArcInfo Version 9.x.

6.1.1 Multibeam Data. The Contractor shall deliver an ArcGrid of each Multibeam Survey area specified in the attached project design map. The ArcGrid shall represent the final data with all appropriate corrections (motion, tides, CUBE, TPE, etc) applied.

6.1.2 Point Shapefiles. The Contractor shall deliver any ancillary data that could possibly be imported into a geodatabase in shape file format.

6.2 Metadata Record. An FGDC compliant metadata record for each spatial data deliverable shall be created using ESRI ArcView/ArcInfo ArcCatalog version 9.0. Appropriate information shall be entered in all required fields. The Contractor shall attach the appropriate metadata record to each spatial data file using ArcCatalog so that no importing or formatting of the metadata record is required by the Government.

7. Weekly Status Report. **The Contractor is required to submit a Weekly Status Report each week, beginning on the Task Order Award Date, until all deliverables are received and accepted by the Government.** The Weekly Status Report shall be delivered via e-mail no later than 8:00 AM each Monday and shall document the Contractor's progress from the previous Monday through the previous Sunday. The status report shall itemize each scope item with percent of work complete and an estimated date of completion. The report shall also include the number and type of field crews working, a description of any problems and/or delays encountered, and any

photographs of the site and/or significant site features (such as outlet structures, retaining walls, escarpments, etc.) and/or specialized data collection activities.

8. Final Written Report. A written report summarizing all data collection activities shall be submitted as a Portable Document File (PDF) and in bound hardcopy. The following items shall be included in the survey report:

- Written description of workflow to complete task order (start to finish) including flowchart diagram and detailed description of QA/QC process
- Dates and times of each data collection activity
- Atmospheric Conditions for each day of data collection activity
- All Horizontal and Vertical Control used including monument name, establishing agency, date established, description, and published horizontal and vertical values
- TBM descriptions with vertical values (N/A)
- Copy of all field notes
- Complete and detailed list of all survey equipment used including copy of last factory calibration report
- Metadata Records as described in 4.4 above
- Photographs of the site and any significant features or data collection techniques used

9. Quality Control. If work is found to be in error, incomplete, illegible or unsatisfactory after assignment is completed, the Contractor shall be liable for all cost in connection with correcting such errors. Corrective work may be performed by Government personnel or Contractor personnel at the discretion of the Contracting Officer. In any event, the Contractor shall be responsible for all costs incurred for correction of such errors, including salaries, automotive expenses, equipment rental, supervision, and any other costs in connection therewith. All data and deliverables shall be reviewed for the following:

- Required coverage of the project limits
- Capture of all required features
- Required accuracies
- Required horizontal and vertical datum
- Adherence to the delivery order requirements

10. Technical POC. All technical questions concerning work under this task order shall be directed to Jim Jacaruso at (910) 251-4064.

11. Schedule & Completion Date. A completed product for the Topsail Beach portion of this modification shall be delivered in its entirety no later than 31 January 2007. Upon award of this modification, fieldwork for the Phase 2 multibeam survey project should proceed such that the final deliverables are completed and delivered no later than 21 days from the modification date, weather conditions permitting. Safety of field

personnel is the priority, followed by timeliness of schedule. The Contractor is to use judgment on the exact days of data collection for both safety and data quality concerns. Scheduling of surveys should be coordinated with the POC in advance and weekly updates of progress to obtain field data will be provided. Data analysis, documentation, and computer files should be delivered by early February pending the ultimate schedule for data acquisition. This schedule is subject to adjustment by the Contracting Officer.

12. Deliver To. All work shall be delivered to:

U. S. Army Corps of Engineers
Wilmington District
Attn: Jim Jacaruso, TS-EE
69 Darlington Avenue
PO Box 1890
Wilmington, NC 28402-1890

Appendix B – Field Notes

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.

Total Daylight: 10-11hrs

DATE: 1/26/07

TIME	TASK	NOTES
6:30am	mobilization of 4-Points and trailer check, fuel vessel, travel to Topsail, put vessel in the water and moor	There was a change in the survey plan by the Corps to get on site and mobilize to try and get one of these one day windows we are having. So we can get the data before the 31st deadline
11:30am	New site calibration	Could not gain access to Tower 3. Could not reach owners of property for ~3 weeks now. Even found a possible number for them in Jacksonville but no answering machines on either line. After putting vessel in we started hunting for A230
12:00pm	Bench mark and range check.	Found A230 and were able to put radio antenna out on the beach with the 100' GPS cable. First step was to get all the way to the northern survey extents and check marks. Thing checked out w/in 3cm. Then we worked our way south checking various marks.
5:30pm	Wrap up site cal and break down GPS equipment. Get boat safe in slip.	Weather forecast changed once again. In fact wind was already SW at about 15 ~4pm and the marine forecast is still calling it NW? Looks like tomorrow is a wash. Will leave boat in slip for the next couple days
6:00pm - 7:30	Drive back to PKS	After getting boat secure we headed back to HQ. Get GPS equipment on charge and semi unpacked

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/27/07

TIME	TASK	NOTES
		SW wind. No survey

SURF CITY TO CAPE FEAR NC OUT 20 NM-

559 AM EST SAT JAN 27 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM 1 PM EST THIS AFTERNOON THROUGH LATE TONIGHT

TODAY

W TO SW WINDS 15 TO 20 KT...BECOMING SW 20 TO 25 KT. SEAS BUILDING TO 5 TO 6 FT. SEAS 2 TO 3 FT NEAR SHORE.

TONIGHT

SW WINDS 20 TO 25 KT...BECOMING W 15 TO 20 KT AFTER MIDNIGHT. SEAS 5 TO 7 FT...EXCEPT AROUND 3 FT NEAR SHORE. A SLIGHT CHANCE OF SHOWERS AFTER MIDNIGHT.

SUN

W WINDS 10 TO 15 KT WITH GUSTS UP TO 25 KT. SEAS 2 TO 4 FT. A CHANCE OF SHOWERS IN THE MORNING.

SUN NIGHT

W WINDS 15 TO 20 KT...BECOMING NW 25 TO 30 KT AFTER MIDNIGHT. SEAS 5 TO 7 FT.

MON

NW WINDS 20 TO 25 KT...DIMINISHING TO 15 TO 20 KT IN THE AFTERNOON. SEAS 4 TO 6 FT.

AFTERNOON. SEAS 4 TO 6 FT.

MON NIGHT

NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS
AROUND 3 FT.

TUE

W WINDS 10 TO 15 KT. SEAS 2 TO 3 FT.

WED

N WINDS 10 TO 15 KT. SEAS 2 TO 3 FT.
SURF CITY TO CAPE FEAR NC OUT 20 NM-

320 PM EST SAT JAN 27 2007

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes	
Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07	
US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/28/07

TIME	TASK	NOTES
		Gustsy winds. No survey

859 AM EST SUN JAN 28 2007

GALE WARNING REMAINS IN EFFECT FROM 4 PM EST THIS AFTERNOON THROUGH MONDAY MORNING

TODAY

NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 35 KT LATE THIS MORNING AND AFTERNOON. SEAS 4 TO 5 FT. SEAS AROUND 2 FT NEAR SHORE. RAIN EARLY THIS MORNING...THEN A SLIGHT CHANCE OF RAIN LATE THIS MORNING.

TONIGHT

W WINDS 20 TO 25 KT WITH GUSTS UP TO 30 KT...BECOMING NW 30 TO 35 KT WITH GUSTS UP TO 40 KT. SEAS 6 TO 8 FT...EXCEPT UP TO 3 FT NEAR SHORE. A SLIGHT CHANCE OF RAIN IN THE EVENING.

MON

NW WINDS AROUND 25 KT WITH GUSTS UP TO 35 KT... DIMINISHING TO 15 TO 20 KT IN THE AFTERNOON. SEAS 6 TO 7 FT... SUBSIDING TO 3 TO 5 FT IN THE AFTERNOON.

MON NIGHT

W WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT AFTER MIDNIGHT. SEAS BUILDING TO 3 TO 5 FT.

TUE

TUE
W WINDS 15 TO 20 KT WITH GUSTS UP TO 25 KT. SEAS 4 TO 5 FT.

TUE NIGHT
NW WINDS 15 TO 20 KT...BECOMING N AFTER MIDNIGHT. SEAS
3 TO 5 FT.

WED
N WINDS 10 TO 15 KT...BECOMING NE. SEAS 2 TO 4 FT.

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)

15 January 2006 Eastern Standard Time

Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.

Total Daylight: 10-11hrs

DATE: 1/29/07

TIME	TASK	NOTES
6:30am	Check weather and verified a go. Packed GPS equipment	Drove down ~ 7am
9:00am	Setup base and check mark	Set the base up and checked BM Crocker
9:45am	Prepare boat	Had to wait for the winds to die down a bit. Was blowing up to 30knts in the am and then died to ~20knts mid day. Unclear if surface conditions will allow good data at this stage
11:45am	Begin transit to site	on the transit to site we marked some of the nav aids for safe return home.
12:30pm	On site and start survey	Started survey in southern section. Was able to get both the southern and middle sections. This is the data that is needed by the 31st. Looks like we'll make the deadline but still have to process. Got the base surface generated on the way home! Thank goodness for new mobile workstation
5:30pm	Dock	Got to the dock just before dark. Moored and prepared for tomorrow. Forecast still looking decent for tomorrow am but they have the winds increasing out of the west. Will check updated intellicast at hotel
6:30pm - 9:30pm	In-field data processing	Was able to get some level of processing completed this evening. Data is looking very clean. Hopefully we can make some headway offshore tomorrow

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/30/07

TIME	TASK	NOTES
5:30am to 1:30pm	Tried to survey but got blow out, pulled boat out of water, packed gps gear, head back and get gps gear on charge	1/2 acqusition day. The south forcast had winds W at 15-20 for today but it was blowing light SW at prior to first light. By 9am it was blowing 15 plus out of the SW. They finally changed the forecast to reflect this at at the 10am forecast

SURF CITY TO CAPE FEAR NC OUT 20 NM-

307 PM EST TUE JAN 30 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM 8 PM EST THIS EVENING THROUGH WEDNESDAY MORNING

THROUGH 6 PM

SW WINDS 15 TO 20 KT. SEAS AROUND 3 FT. SEAS AROUND 2 FT NEAR SHORE.

TONIGHT

W WINDS 15 TO 20 KT...INCREASING TO 20 TO 25 KT LATE THIS EVENING AND EARLY MORNING...THEN BECOMING NW LATE. SEAS 4 TO 5 FT. SEAS AROUND 3 FT NEAR SHORE.

WED

NW WINDS 20 TO 25 KT...BECOMING N 10 TO 15 KT IN THE AFTERNOON. SEAS 3 TO 5 FT...SUBSIDING TO 2 TO 3 FT IN THE AFTERNOON.

WED NIGHT

N WINDS AROUND 10 KT...BECOMING E AFTER MIDNIGHT. SEAS 2 TO 3 FT.

THU

SE WINDS AROUND 10 KT...BECOMING SW WITH GUSTS UP TO 20 KT IN THE AFTERNOON. SEAS 2 TO 4 FT...BUILDING TO 4 TO 6 FT IN THE

THE AFTERNOON. SEAS 2 TO 4 FT...BUILDING TO 4 TO 6 FT IN THE AFTERNOON. A SLIGHT CHANCE OF RAIN IN THE MORNING...THEN SHOWERS LIKELY IN THE AFTERNOON.

THU NIGHT

SW WINDS 15 TO 20 KT...INCREASING TO 20 TO 25 KT WITH GUSTS UP TO 30 KT AFTER MIDNIGHT. SEAS 6 TO 9 FT. SHOWERS IN THE EVENING...THEN RAIN AFTER MIDNIGHT.

FRI

W WINDS 20 TO 25 KT...DIMINISHING TO 15 TO 20 KT IN THE AFTERNOON. SEAS 6 TO 9 FT. NEAR SHORE...SEAS 4 TO 6 FT... SUBSIDING TO 2 TO 4 FT IN THE AFTERNOON. A CHANCE OF RAIN IN THE MORNING.

FRI NIGHT

W WINDS 20 TO 25 KT...BECOMING NW 15 TO 20 KT AFTER MIDNIGHT. SEAS 4 TO 6 FT...EXCEPT UP TO 3 FT NEAR SHORE.

SAT

N WINDS 10 TO 15 KT. SEAS 2 TO 4 FT.

SUN

N WINDS 10 TO 15 KT. SEAS 3 TO 5 FT.

S OF CAPE LOOKOUT TO N OF SURF CITY NC OUT 20 NM

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 1/31/07

TIME	TASK	NOTES
		N winds in forecast. No survey

S OF CAPE LOOKOUT TO N OF SURF CITY NC OUT 20 NM-

409 PM EST TUE JAN 30 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT THROUGH WEDNESDAY AFTERNOON

TONIGHT

W WINDS 20 TO 25 KT. SEAS 3 TO 5 FT...BUILDING TO 5 TO 7 FT AFTER MIDNIGHT.

WED

NW WINDS 20 TO 25 KT...BECOMING N 15 TO 20 KT IN THE AFTERNOON. SEAS 4 TO 6 FT.

WED NIGHT

N WINDS AROUND 5 KT...BECOMING E AFTER MIDNIGHT. SEAS AROUND 2 FT.

THU

S WINDS 5 TO 10 KT...INCREASING TO 20 TO 25 KT IN THE AFTERNOON. SEAS 3 TO 5 FT BUILDING TO 4 TO 6 FT. SHOWERS LIKELY.

THU NIGHT

S WINDS 20 TO 25 KT. SEAS 6 TO 8 FT. A CHANCE OF SHOWERS.

FRI

FRI

SW WINDS 20 TO 25 KT...BECOMING W 15 TO 20 KT IN THE AFTERNOON. SEAS 6 TO 8 FT...SUBSIDING TO 5 TO 7 FT IN THE AFTERNOON.

FRI NIGHT

W WINDS 15 TO 20 KT. SEAS 4 TO 6 FT.

SAT

NW WINDS 10 TO 15 KT...BECOMING N 15 TO 20 KT. SEAS 3 TO 5 FT.

SUN

N WINDS 15 TO 20 KT. SEAS 3 TO 5 FT.

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR		
Project Timeline & General Field Notes		
Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07		
US Navy Astronomical Data		
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)		
15 January 2006 Eastern Standard Time		
Begin civil twilight 6:49 a.m.		
Sunrise 7:16 a.m.		
Sun transit 12:20 p.m.		
Sunset 5:23 p.m.		
End civil twilight 5:50 p.m.		
Total Daylight: 10-11hrs		
DATE: 2/1/07		
TIME	**TASK**	**NOTES**
		Stong NE winds in forecast. No survey

SURF CITY TO CAPE FEAR NC OUT 20 NM-

317 PM EST THU FEB 1 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT THROUGH FRIDAY EVENING

THROUGH 6 PM

NE WINDS 15 TO 20 KT. SEAS 4 TO 6 FT. SEAS AROUND 2 FT NEAR SHORE. LIGHT RAIN WITH AREAS OF DRIZZLE.

TONIGHT

NE WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...BECOMING N WITH GUSTS UP TO 20 KT LATE. SEAS AROUND 7 FT. SEAS AROUND 3 FT NEAR SHORE. RAIN LIKELY WITH AREAS OF DRIZZLE THIS EVENING...THEN RAIN LIKELY AFTER MIDNIGHT.

FRI

NW WINDS 10 TO 15 KT...BECOMING W IN THE AFTERNOON. GUSTS UP TO 25 KT. SEAS 6 TO 9 FT...EXCEPT UP TO 6 FT NEAR SHORE. A CHANCE OF RAIN IN THE MORNING.

FRI NIGHT

W WINDS 20 TO 25 KT. SEAS 4 TO 7 FT... SUBSIDING TO 3 TO 5 FT AFTER MIDNIGHT. NEAR SHORE...SEAS 2 TO 4 FT.

SAT

NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 3 TO 5 FT.

NW WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 3 TO 5 FT.

SAT NIGHT

W WINDS 10 TO 15 KT...INCREASING TO 20 TO 25 KT AFTER MIDNIGHT. SEAS 2 TO 4 FT.

SUN

NW WINDS 15 TO 20 KT WITH GUSTS UP TO 25 KT. SEAS 2 TO 4 FT.

SUN NIGHT

NW WINDS 10 TO 15 KT. SEAS 2 TO 3 FT.

MON

NW WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT. SEAS 2 TO 4 FT.

TUE

N WINDS 20 TO 25 KT...DIMINISHING TO 15 TO 20 KT. SEAS 3 TO 5 FT.

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: **10-11hrs**	

DATE: 2/2/07

TIME	TASK	NOTES
		Gusty winds. No survey

SURF CITY TO CAPE FEAR NC OUT 20 NM-

616 PM EST SAT FEB 3 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM SUNDAY EVENING THROUGH MONDAY MORNING

TONIGHT

W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS AROUND 3 FT. SEAS 2 FT OR LESS NEAR SHORE.

SUN

W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 25 KT IN THE AFTERNOON. SEAS 3 TO 5 FT...EXCEPT 2 TO 3 FT NEAR SHORE.

SUN NIGHT

W WINDS 20 TO 25 KT...BECOMING NW. SEAS 4 TO 6 FT.

MON AND MON NIGHT

NW WINDS 20 TO 25 KT WITH GUSTS UP TO 30 KT. SEAS 4 TO 6 FT.

TUE AND TUE NIGHT

NW TO W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 2 TO 4 FT.

WED

N WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT. SEAS BUILDING TO 3 TO 5 FT.

THU

N WINDS 15 TO 20 KT...BECOMING NW 10 TO 15 KT. SEAS 3 TO 5 FT.

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data	
Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 2/3/07

TIME	TASK	NOTES
		Gusy winds in forecast. No survey.

SURF CITY TO CAPE FEAR NC OUT 20 NM-

616 PM EST SAT FEB 3 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM SUNDAY EVENING THROUGH MONDAY MORNING

TONIGHT

W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS AROUND 3 FT. SEAS 2 FT OR LESS NEAR SHORE.

SUN

W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT...INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 25 KT IN THE AFTERNOON. SEAS 3 TO 5 FT...EXCEPT 2 TO 3 FT NEAR SHORE.

SUN NIGHT

W WINDS 20 TO 25 KT...BECOMING NW. SEAS 4 TO 6 FT.

MON AND MON NIGHT

NW WINDS 20 TO 25 KT WITH GUSTS UP TO 30 KT. SEAS 4 TO 6 FT.

TUE AND TUE NIGHT

NW TO W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT. SEAS 2 TO 4 FT.

WED

N WINDS 10 TO 15 KT...INCREASING TO 15 TO 20 KT. SEAS BUILDING TO 3 TO 5 FT.

THU

N WINDS 15 TO 20 KT...BECOMING NW 10 TO 15 KT. SEAS 3 TO 5 FT.

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)

15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.

Total Daylight: 10-11hrs

DATE: 2/4/07

TIME	TASK	NOTES
		SW winds in forecast. No survey. They have offshore winds for tomorrow but pretty strong. Might have a chance if they change it tonight to be a lttle lighter. Anything can happen with how the forecasts have been lately.

640 AM EST SUN FEB 4 2007

SMALL CRAFT ADVISORY REMAINS IN EFFECT FROM 6 PM EST THIS EVENING THROUGH MONDAY MORNING

TODAY

W WINDS 10 TO 15 KT WITH GUSTS UP TO 20 KT... INCREASING TO 15 TO 20 KT WITH GUSTS UP TO 25 KT LATE THIS MORNING AND EARLY AFTERNOON...THEN BECOMING SW 20 TO 25 KT WITH GUSTS UP TO 30 KT LATE. SEAS BUILDING TO 4 TO 5 FT. SEAS 2 TO 3 FT NEAR SHORE.

TONIGHT

W WINDS 20 TO 25 KT...BECOMING NW AFTER MIDNIGHT. GUSTS UP TO 35 KT. SEAS 4 TO 7 FT...EXCEPT UP TO 4 FT NEAR SHORE.

MON

NW WINDS 20 TO 25 KT WITH GUSTS UP TO 35 KT. SEAS 4 TO 7 FT.

MON NIGHT

NW WINDS 15 TO 20 KT WITH GUSTS UP TO 30 KT. SEAS 4 TO 6 FT.

TUE

NW WINDS 15 TO 20 KT...BECOMING W 10 TO 15 KT IN THE AFTERNOON. SEAS 2 TO 4 FT.

TUE NIGHT

W WINDS 15 TO 20 KT...BECOMING SW 20 TO 25 KT AFTER MIDNIGHT. SEAS 3 TO 5 FT.

WED

W WINDS 15 TO 20 KT...BECOMING N. SEAS 3 TO 5 FT.

THU

N WINDS 15 TO 20 KT...BECOMING NW 10 TO 15 KT. SEAS 3 TO 5 FT...SUBSIDING TO 2 TO 3 FT.

Project Timeline & General Field Notes

Project: Topsail Island Phase 2 Multibeam 1/26-2/5/07

US Navy Astronomical Data

Sunday: Surf City, Pender County, North Carolina (longitude W77.5, latitude N34.4)	
15 January 2006	Eastern Standard Time
Begin civil twilight	6:49 a.m.
Sunrise	7:16 a.m.
Sun transit	12:20 p.m.
Sunset	5:23 p.m.
End civil twilight	5:50 p.m.
Total Daylight: 10-11hrs	

DATE: 2/5/07

TIME	TASK	NOTES
6:00am	Check forecast and verified a go for today. Packed GPS gear and drove down	Got all the gear ready and headed out the door by 7:45am. At this point not sure it will be favoritable but at least it is offshore. Might die like it did last week.
9:30am	Setup base and prepared boat for survey	Got the base going and checked a mark. Winds are still strong but the surface conditions are flat. Going to give it a go
10:45am	Transit to northern survey site	still having hydraulic steering problems but we were able to transit at 27knts
11:25am	Start survey	Had a brief sonar glitch that kept us in suspense. Was able to get it to lock in. Thinking it was just cold.
5:15pm	Dock and final demob	Got back to the dock and started the demob process. Got boat out of water and broke the base down.
6:45pm - 8pm	Head back to HQ	Check trailer for brake wear

geodynamics COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Dock-side GPS Check	X	See Metadata for BM Check		
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			
Survey Operations		**Latitude (Northing)**	**Longitude (Easting)**	**Value**
Input Initial SV cast in SIS Runtime		34 21.7451	077 37.3611	1492.2
SV Cast #1		34 21.7451	077 37.3611	1492.2
SV Cast #2		34 25.2728	077 32.5627	1492.7
SV Cast #3				
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes	
Project	USACE Topsail MB 2
Survey Area	Multibeam Southern Area & Middle area
Sea State	2' SSE swell, wind chop on top
Wind	NW 15 gust to 25-30kts
Air Temperature	34 F at start
Sea Temperature	51.7 F at start
Tides	L:11:40 am H: 4:50 pm EST
Survey Features & Navigational Aids	N/A
Comments	Had to wait 1/2 day for winds to calm a bit.

Topsail Phase II Multibeam
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Line Name	MS/CL	Direction	Notes
0	MS	NE	HP 2 Start 12:24 pm EST
1	MS	NE	HP 2 cont due to PPS off E 12:51
2	MS	SW	HP 3
3	MS	NE	HP 4
4	MS	SW	HP 5
5	MS	NE	HP 6
6	MS	SW	HP 1 - end S section E 2:41
7	MS	NE	HP 2 - S 2:59 E 3:20
8	MS	SW	HP 3
9	MS	NE	HP 4
10	MS	SW	HP 5
11	MS	NE	HP 6
End Survey Day			

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Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	Complete	Notes		
		Latitude (Northing)	Longitude (Easting)	Elev.
Perform Dock-side GPS Check	X	See Metadata for BM Check		
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			

Survey Operations		Latitude (Northing)	Longitude (Easting)	Value
Input Initial SV cast in SIS Runtime				
SV Cast #1				
SV Cast #2				
SV Cast #3				
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes

Project	USACE Topsail MB 2
Survey Area	Multibeam Northern Area
Sea State	2' SSE swell, decent S wind chop on top
Wind	SSW 10-15kts at 7:00am
Air Temperature	31 F at start
Sea Temperature	51.7 F at start
Tides	L:12:35 pm H: 5:48 pm EST
Survey Features & Navigational Aids	N/A
Comments	SSW winds picking up seas building to 2-4 quickly. Survey terminated

Line Name	MS/CL	Direction	Notes
0	MS	NE	
1	MS		
2	MS		
3	MS		
4	MS		
5	MS		
6	MS		
7	MS		
8	MS		
9	MS		
10	MS		
11	MS		

geodynamics
COMPLEX COASTAL CHANGE MADE CLEAR

Multibeam Daily Operation Proceedures & Checklist

Pre-Survey Operations	**Complete**	**Notes**		
		Latitude (Northing)	**Longitude (Easting)**	**Elev.**
Perform Dock-side GPS Check	X	See Metadata for BM Check		
Power up POS MV	X			
Power up UPS	X			
Power up EM3002 PU	X			
Power up Acquisition PC	X			
Power up Navigation PC	X			
Power up Trimble GPS	X			
Perform BIST (head in water)	X			

Survey Operations		**Latitude (Northing)**	**Longitude (Easting)**	**Value**
Input Initial SV cast in SIS Runtime		34 26.5378	077 30.3729	1488.9
SV Cast #1		34 26.5378	077 30.3729	1488.9
SV Cast #2		34 28.0899	077 27.8448	1487.2
SV Cast #3				
SV Cast #4				
SV Cast #5				
SV Cast #6				
SV Cast #7				
SV Cast #8				
Vessel Draft Check (waterline to ducer)				0.53m

General Survey Notes

Project	USACE Topsail MB 2
Survey Area	Multibeam Northern Area
Sea State	1-2' SSW swell, decent S wind chop on top
Wind	SSW 10-15kts at 7:00am
Air Temperature	31 F at start
Sea Temperature	49.8 F at start
Tides	H: 9:30 L: 4:26 pm EST
Survey Features & Navigational Aids	N/A
Comments	Initial BIST on Head =7 TX error, cleared on re-test out of water

Line Name	MS/CL	Direction	Notes
0	MS	NE	HP 1 S 11:10am EST
1	MS	NE	HP 1
2	MS	NE	HP 1 S 11:26am EST E 11:58am Est
3	MS	SW	HP 2 S 12:01pm EST
4	MS	SW	HP 2 S 12:01pm EST
5	MS	NE	HP 3
6	MS	NE	HP 3
7	MS	SW	HP 4
8	MS	SW	HP 4
9	MS	NE	HP 5
10	MS	NE	HP 5
11	MS	SW	HP 2
12	MS	SW	HP 2
13	MS	NE	HP 1 Redo
14	MS	NE	HP 1 Redo
End Survey			

Appendix C – Equipment & Instrument Accuracies

R/V 4-POINTS

Hydrographic Survey

The research vessel *4-Points* is a custom fiberglass survey boat designed specifically for shallow water sonar and acoustical operations. The vessel is 25' long with a 10' beam; the bottom tapers from a deep "Carolina" style Vee to a relatively flat-bottomed stern that provides a shallow draft of approximately 1.2'. Twin 140 four-stroke engines, hung on a stainless steel bracket, power the vessel. All electronics and generators are grounded to the sea via a bottom mounted bonding plate to eliminate all electrical noise. Side-scan instrumentation is deployed, towed and retrieved from custom davit on starboard side.

Instrumentation:

- **Simrad EM 3002 multibeam sonar**
  - Multi-Frequency: in 300 kHz band
  - Max ping rate: 40 Hz
  - No. of beams/ping: 254 Roll and Pitch stabilized
  - Beam width: 1.5° x 1.5°
  - Beam spacing: 0.9°
  - Depth range from sonar head:1 to 150 m
  - Depth resolution: 1 cm
  - Depth accuracy: 5 cm RMS
  - Range sampling rate: 15 kHz
  - Bottom detection by phase or amplitude. Seabed imaging & classification with backscatter (sidescan-like) output.
  - Full swath width accuracy to the latest IHO standard

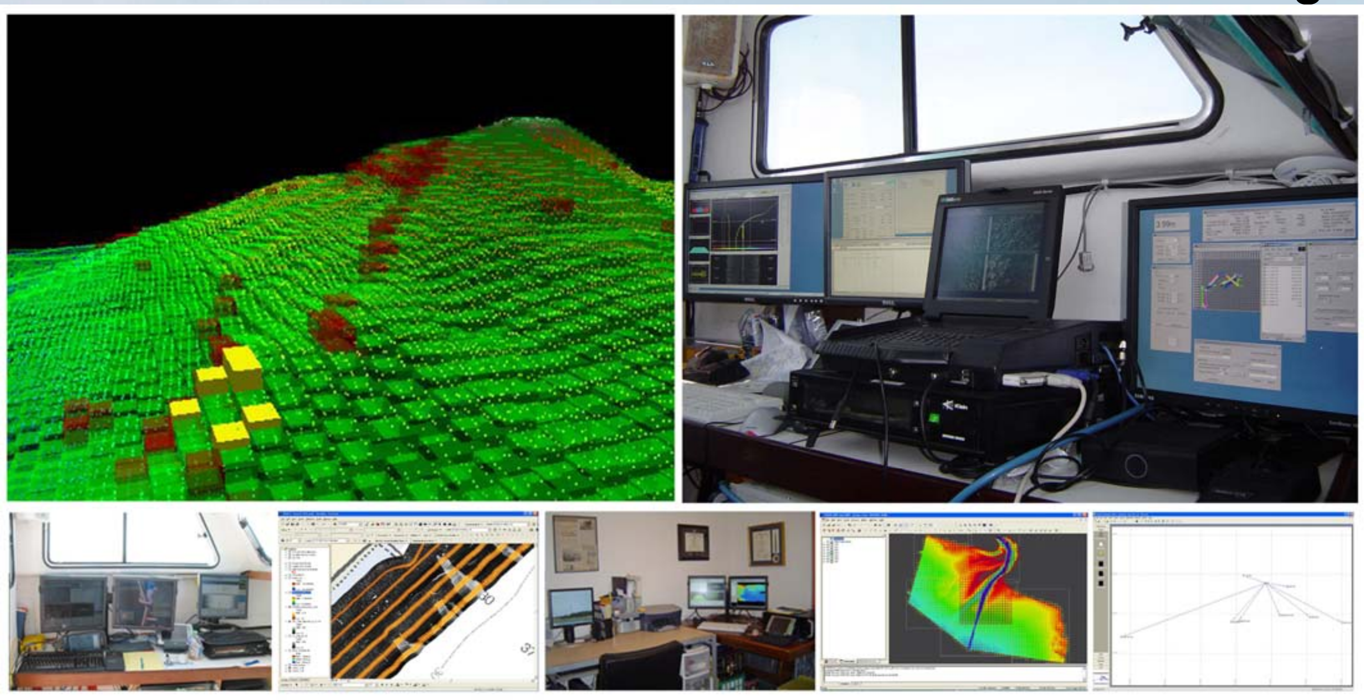
- **POS MV 320 v4 (with RTK Corrections)**
  - Roll, Pitch accuracy: 0.02° (1 sigma with GPS or DGPS)
  - 0.01° (1 sigma with RTK)
  - Heave Accuracy: 5 cm or 5% (whichever is greater)
  - Heading Accuracy: 0.02° (1 sigma) with 2 m antenna baseline
  - Position Accuracy: 0.02 - 0.10 m (RTK) with input

- **Trimble 5700 dual frequency GPS system & RTK-Basestation**
  - Instrument used for topo/bathy positioning and tidal corrections
  - High precision L1 and L2 measurements
  - 24 channels L1 C/A code, L1/L2 full cycle carrier
  - Extremely low latency (20 milliseconds)
  - Published horizontal accuracy: 10 mm + 1ppm RMS
  - Published vertical accuracy: 20 mm + 1ppm RMS

- **Odom Hydrographics Digibar Pro sound velocity probe**
  - Sampling rate: 10 Hz
  - Depth accuracy: > 31 cm
  - Velocity accuracy: +/- 0.3 m/sec

- **Applied Microsystems MicroSV sound velocity sensor**
  - SV: time of flight
  - Sampling rate: 10 Hz or continuous programmable
  - Velocity accuracy: 0.05 m/sec
  - Sampling rate: 10 Hz
  - AC or DC power

Processing



Geodynamics maintains a cluster of high-end computer workstations and file/backup servers for the most demanding geospatial data acquisition, processing and analysis. At geodynamics we specialize in high-end spatial data processing and analysis through geographic information science and 3D visualization.
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Instrumentation:

Hardware

- **Field**
  - Custom rack mounted multibeam acquisition PC
  - 3.6 GHz Intel Pentium 4 processors with 800 MHz system bus
  - 2 GB of RAM
  - 512 Dual DVI graphics card
  - (2) 500 GB SATA hard drives
  - Simrad SIS & Applanix POS View acquisition software
  - CARIS HIPS/SIPS
  - (3) Fujitsu pentop navigation PC
  - (3) Maxtor external backup hard drives ~ 850 GB of storage

- **Office**
  - (4) high-end Dell GIS processing workstations
  - (2) Dell workstation laptops
  - (2) 1 TB RAID network attached storage devices
  - (4) Maxtor / Seagate external backup drives ~ 1.2 TB of storage

Software

- **Multibeam / Side Scan**
  - Caris HIPS / SIPS 6 sp2
  - Triton Imaging ISIS
  - Triton Imaging BathyPro & DelphMap

- **Singlebeam**
  - **Hypack Max v. 6.2 sp1**
  - Caris HIPS / SIPS 6 sp2

- **Topographic**
  - Trimble Geomatics Office
  - Caris HIPS / SIPS 6 sp2 (Lidar)

- **GIS**
  - ArcView 3.3a (Spatial, 3D & Image Analyst)
  - ArcGIS 9.1 (Spatial, ArcScene, 3D, Survey & Geostatistical Analyst)
  - Surfer 8.0
  - ArcIMS