Feasibility Report
and
Final Environmental Impact Statement

on

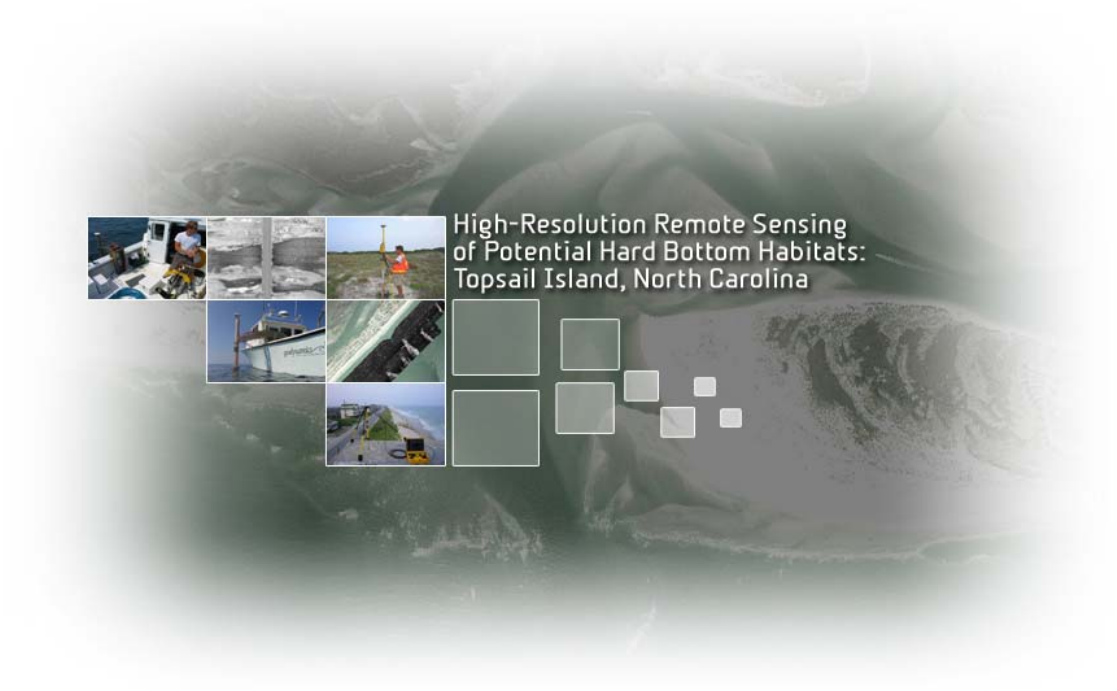
Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 2

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

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
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TABLE OF CONTENTS

TABLE OF CONTENTS ii

Executive Summary 1

Survey Preparation 1

Survey Area 1

RTK-GPS Survey Control & Multibeam Calibration 2

RTK-GPS Network Adjustment & Site Calibration 3

Multibeam Echosounder Calibration Report 8

Data Processing Routines & QA/QC Information 14

Introduction 14

Bathymetry Processing 14

Side-Scan Processing 15

Typical Side-Scan Artifacts 16

Potential Hardbottom Identification 20

Topsail Island Remote Sensing Workflow Diagram 22

Topsail Island Remote Sensing QA/QC Workflow Diagram 22

Graphical Summary of Deliverables 23

Appendix A – Official USACE Scope of Work 30

Appendix B - Benchmark Descriptions 34

Appendix C– Field Notes, Daily GPS Quality & Copy of Field Book 41

Appendix D - *R/V 4-Points* Setup & Instrument Accuracies 47

Appendix E – QTC Report 53

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

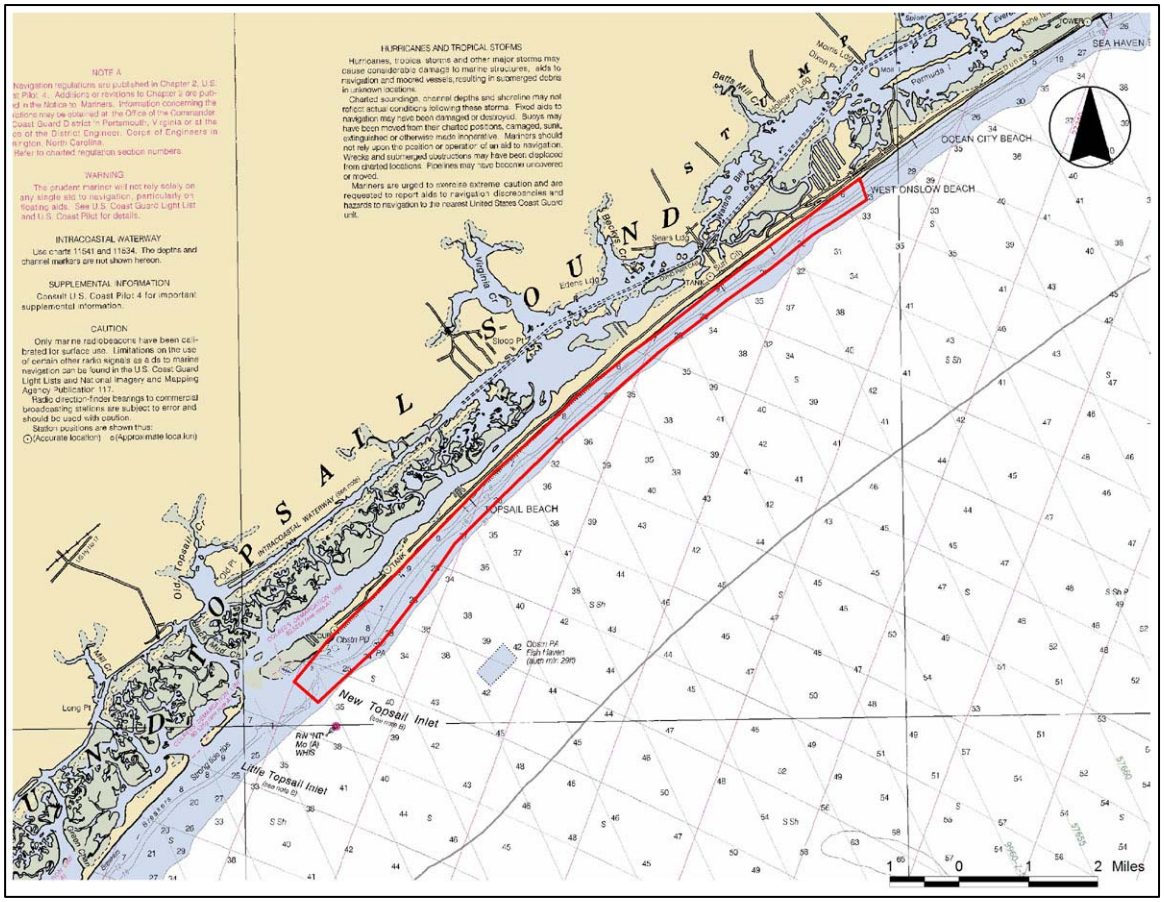

Figure 1. Topsail Island side-scan survey planning map illustrating the proposed survey extents.

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.

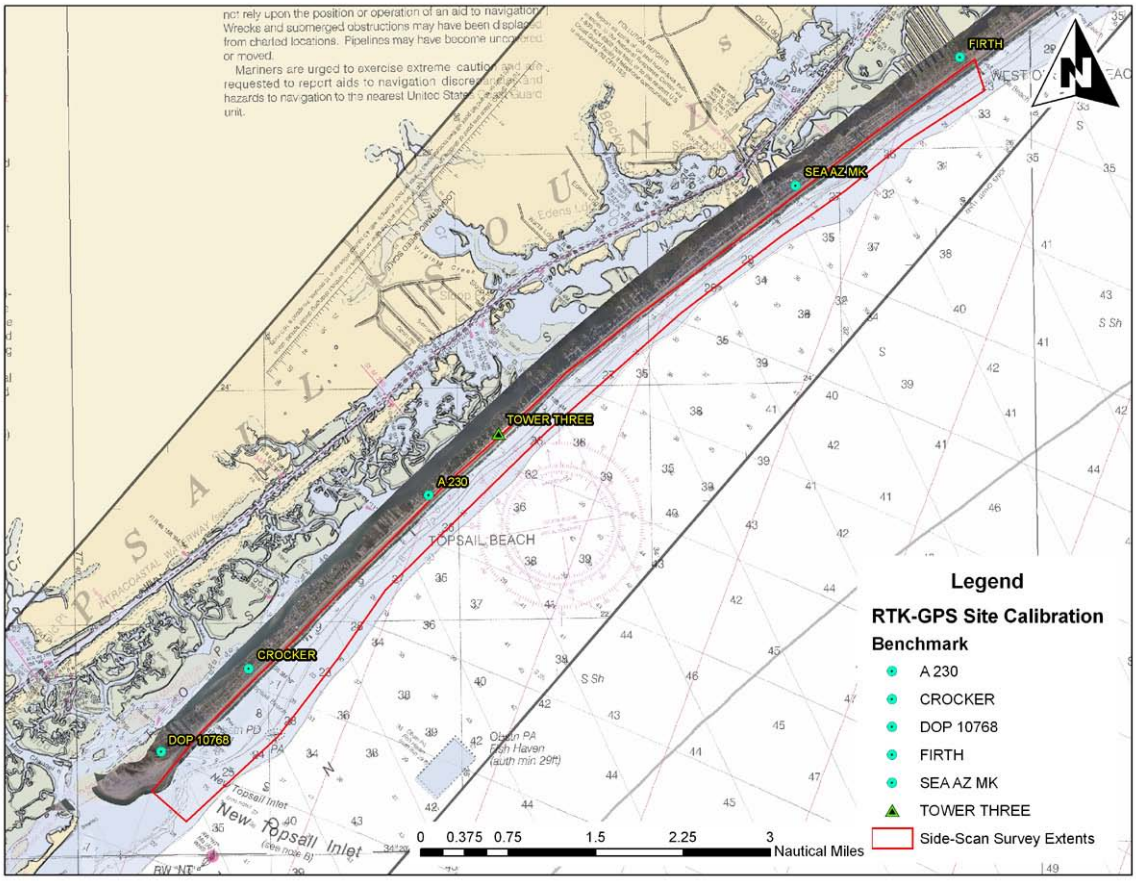

Figure 2. Topsail Island RTK-GPS site calibration map.

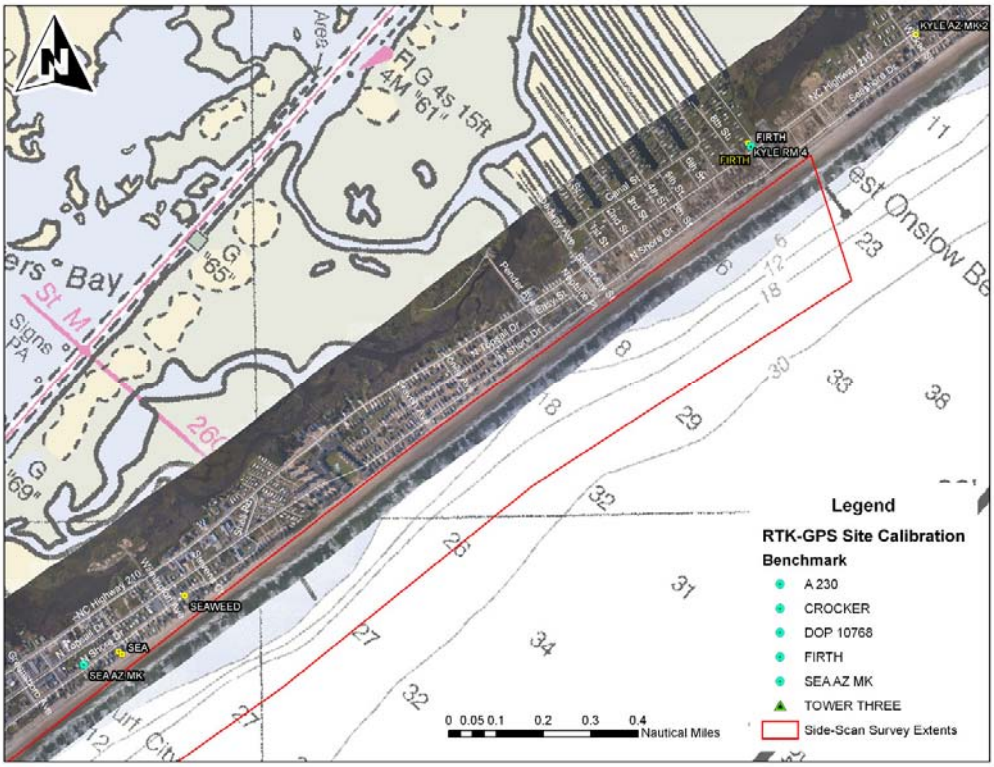

Figure 3. Topsail Island site calibration planning and control search map of the Surf City area.

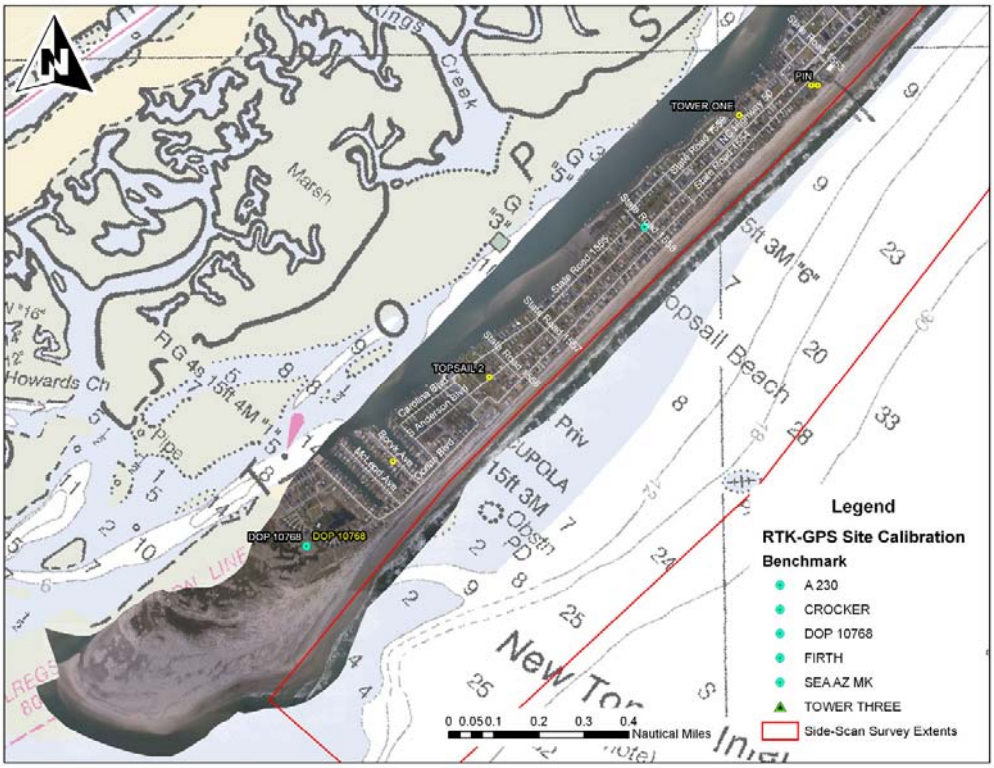

Figure 4. Topsail Island site calibration planning and control search map of the New Topsail Inlet area.

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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
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 Benchmark

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.

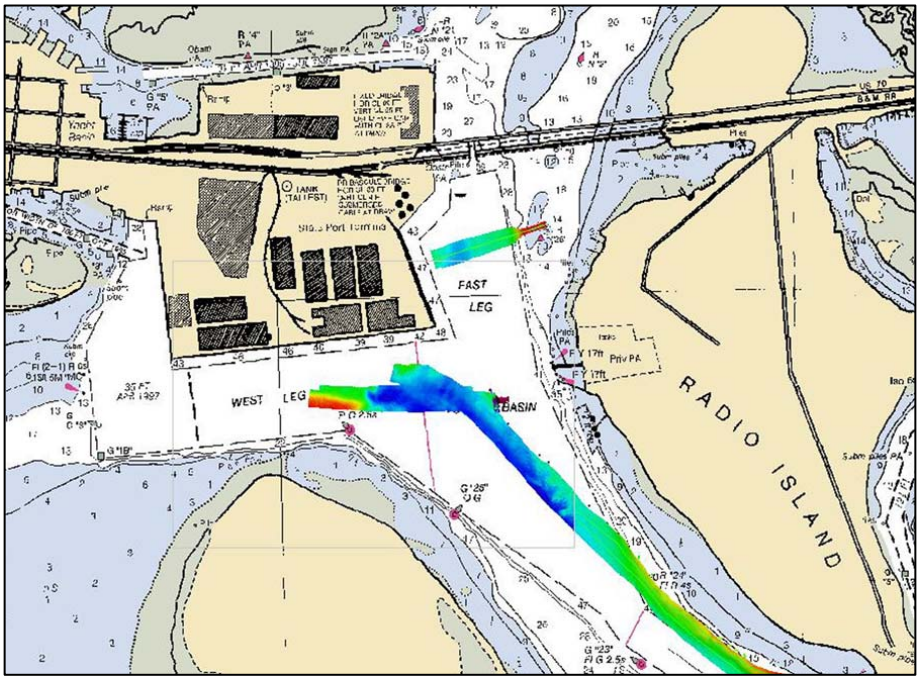


Figure 6. Map of the patch survey area within the Morehead City Turning Basin.

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

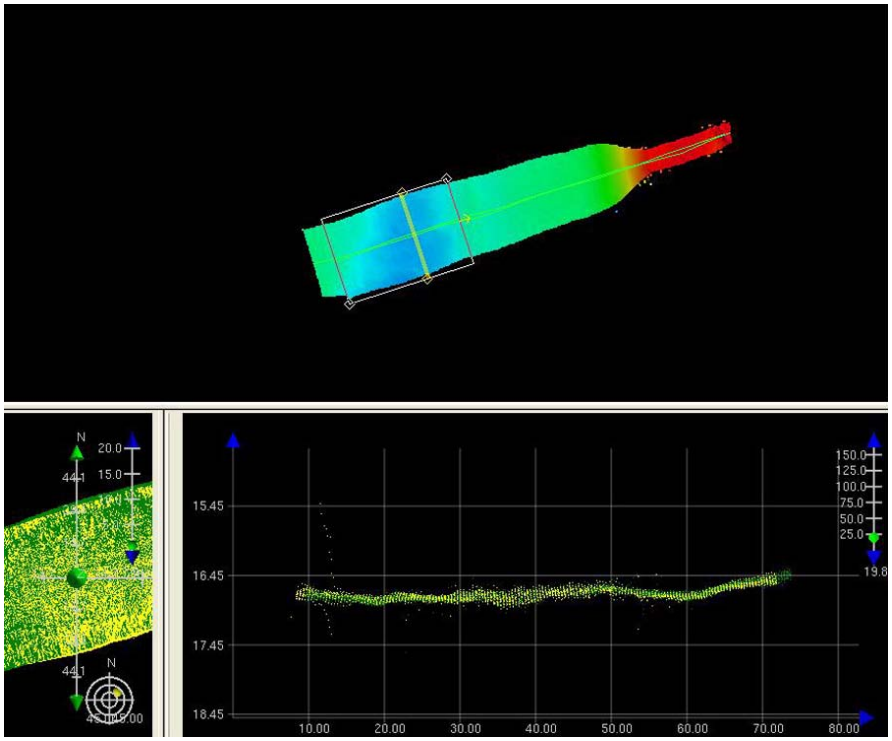


Figure 7. Caris screen grab illustrating acceptance of roll calibration.

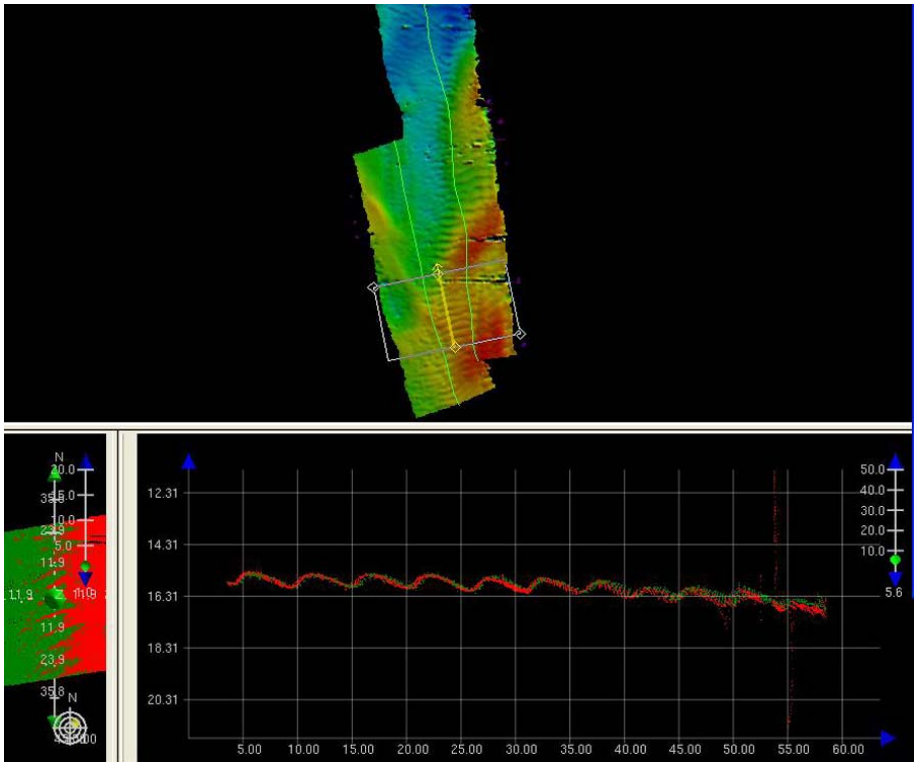


Figure 8. Caris screen grab illustrating acceptance of yaw calibration.

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

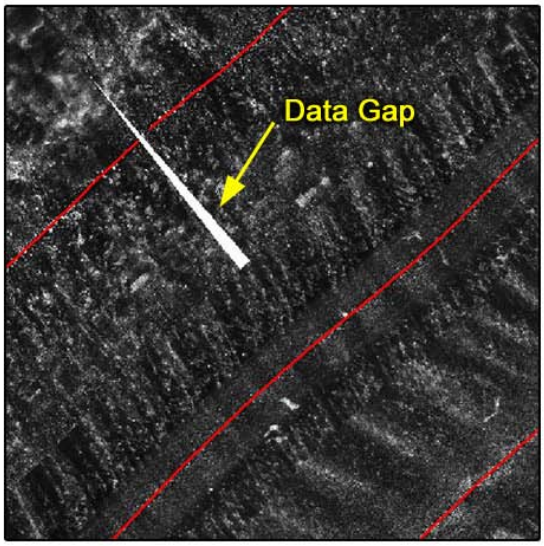


Figure 9a. Data Gap in side-scan record.

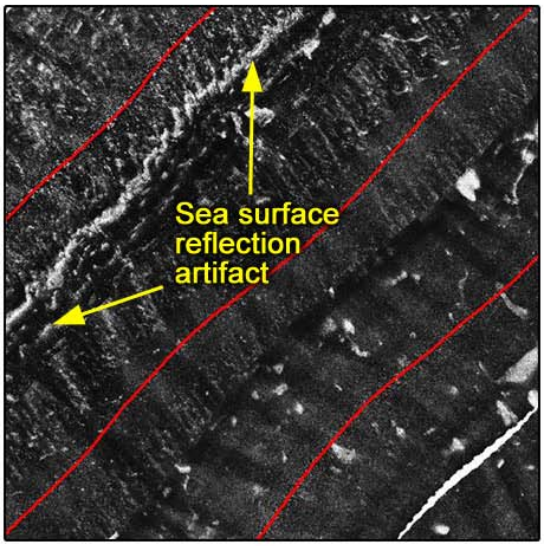


Figure 9b. Sea surface reflection artifact.

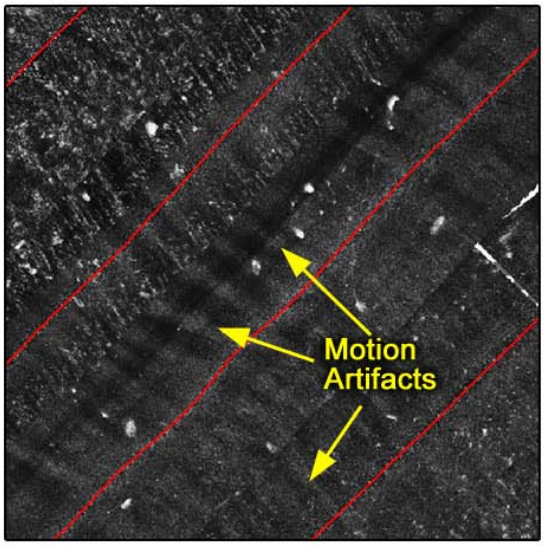


Figure 9c. Artifacts produced by vessel-towfish motion.

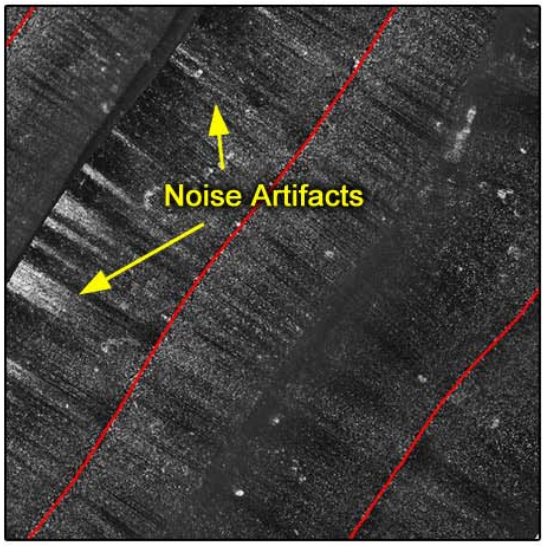


Figure 9d. Noise artifacts.

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.

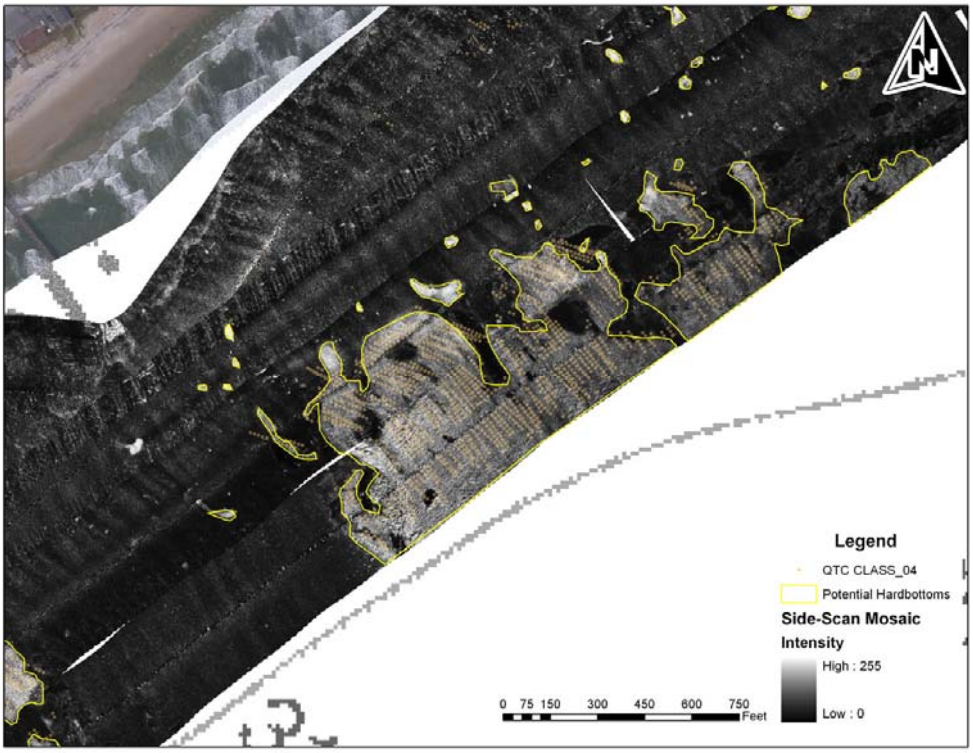


Figure 10. Map illustrating potential hardbottom areas.

Topsail Island Remote Sensing Workflow Diagram

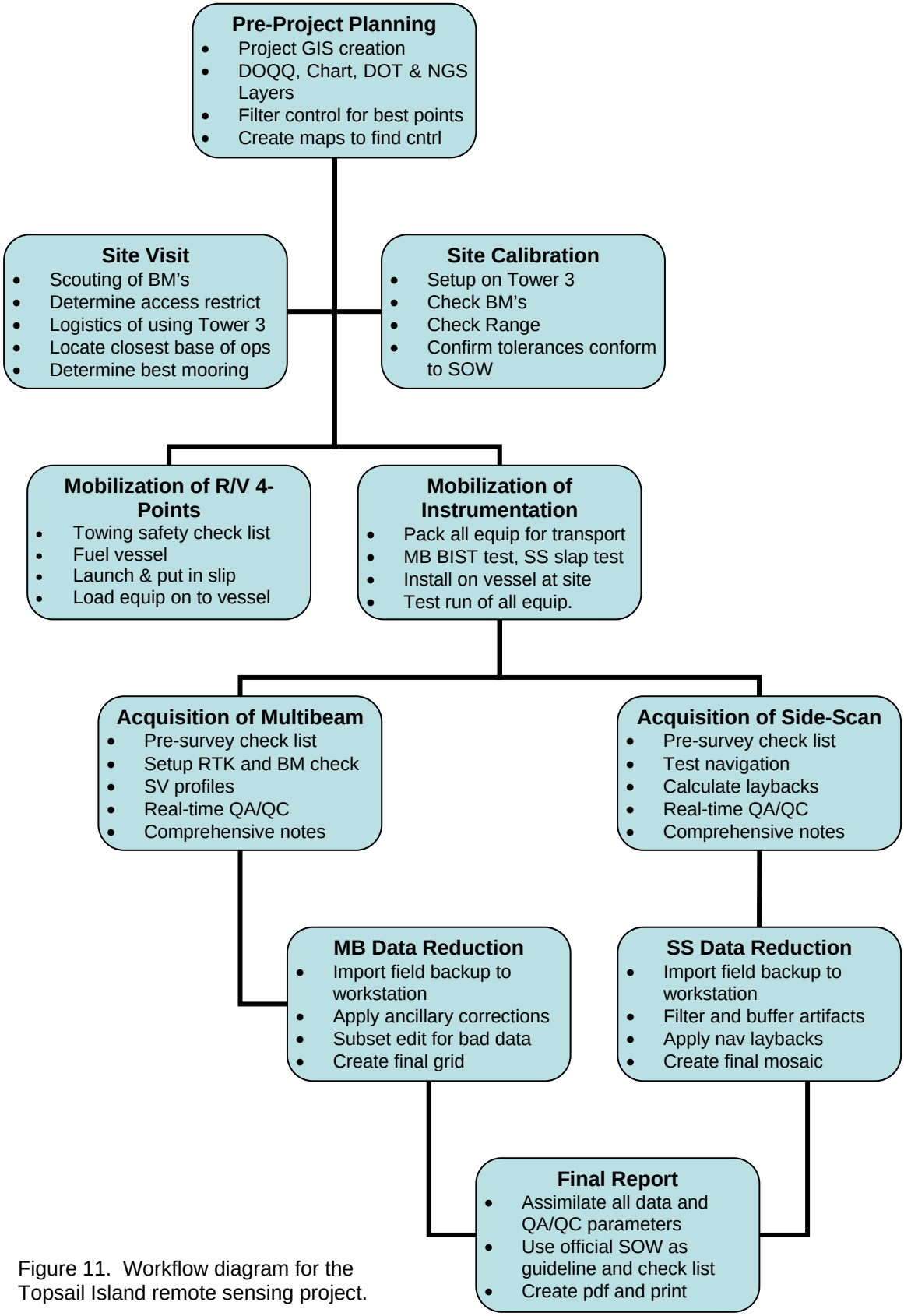


Figure 11. Workflow diagram for the Topsail Island remote sensing project.

Topsail Island Remote Sensing QA/QC Workflow Diagram

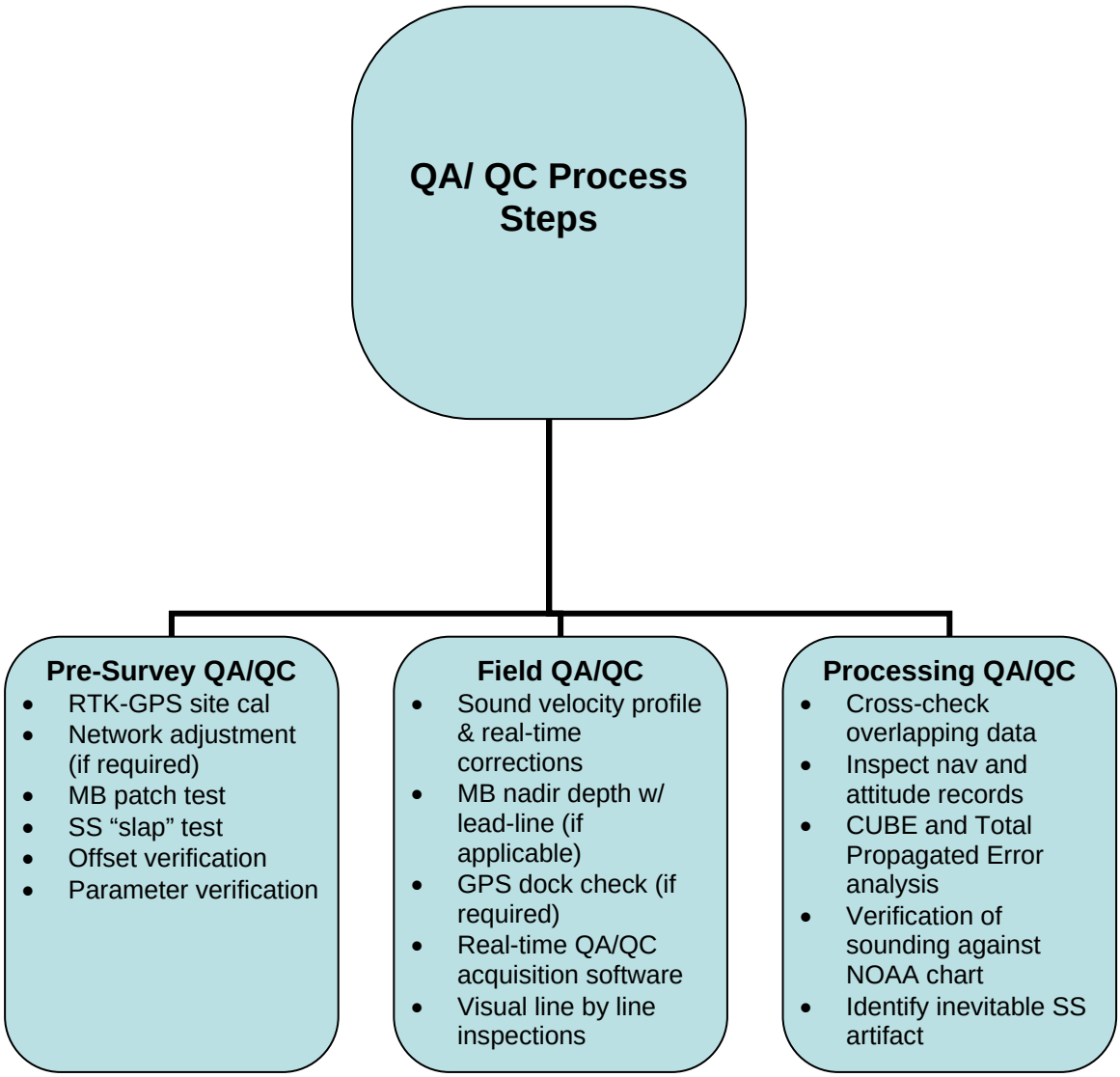


Figure 12. QA/QA Workflow diagram for the Topsail Island remote sensing project.

Graphical Summary of Deliverables

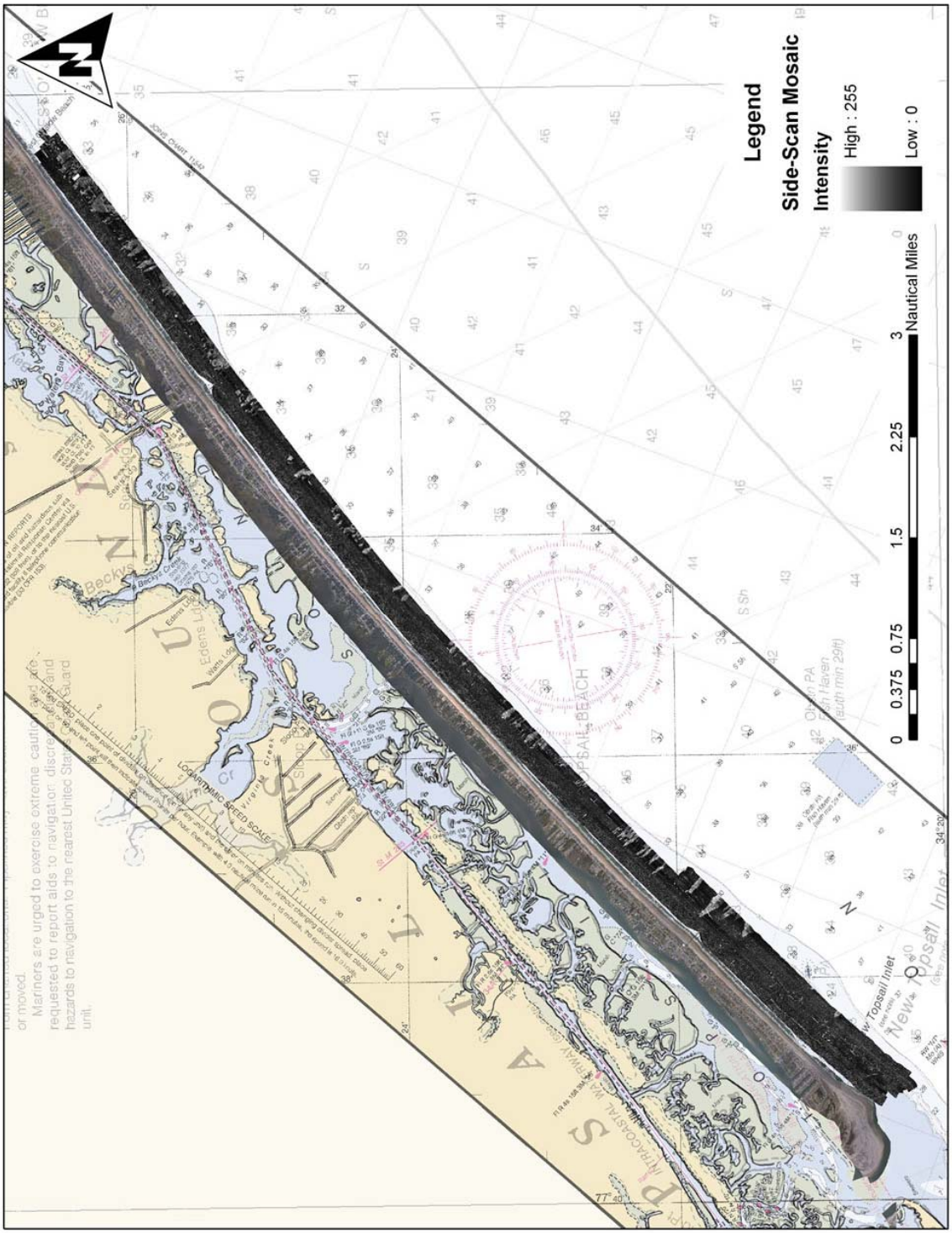


Figure 13. Side-scan sonar mosaic.

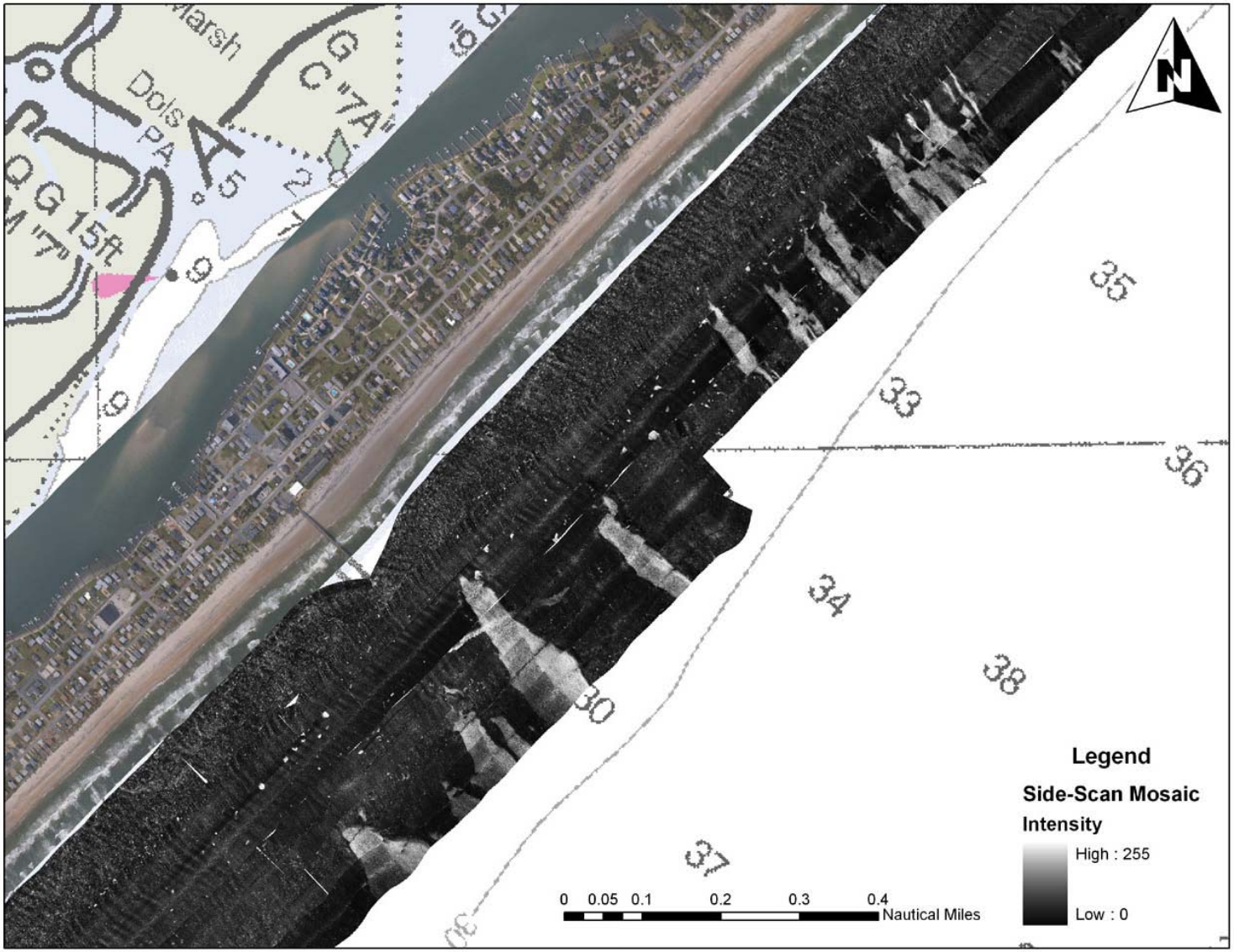


Figure 14. Close-up view of the side-scan sonar mosaic in the south portion of the survey area.

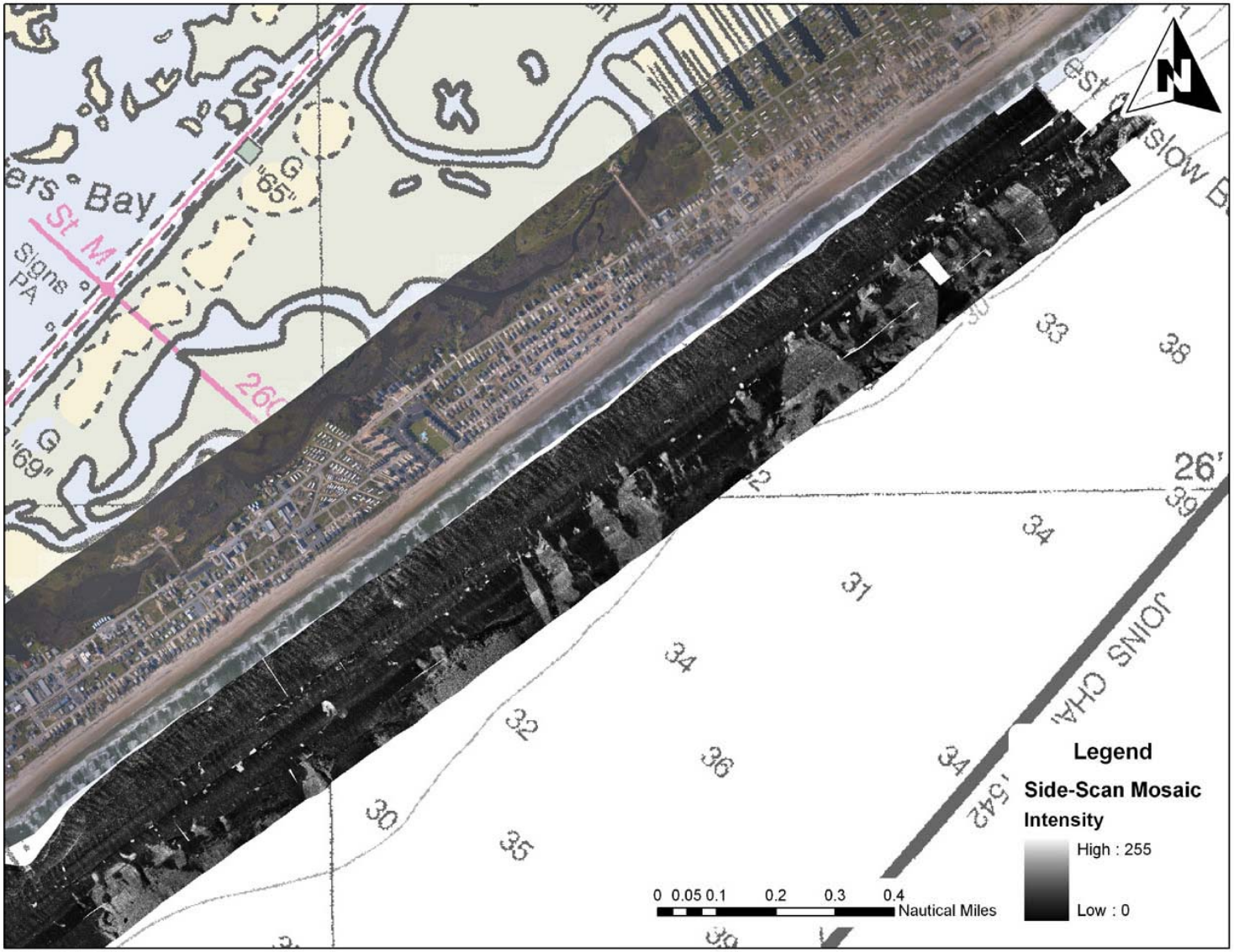


Figure 15. Close-up view of the side-scan sonar mosaic in the north portion of the survey area.

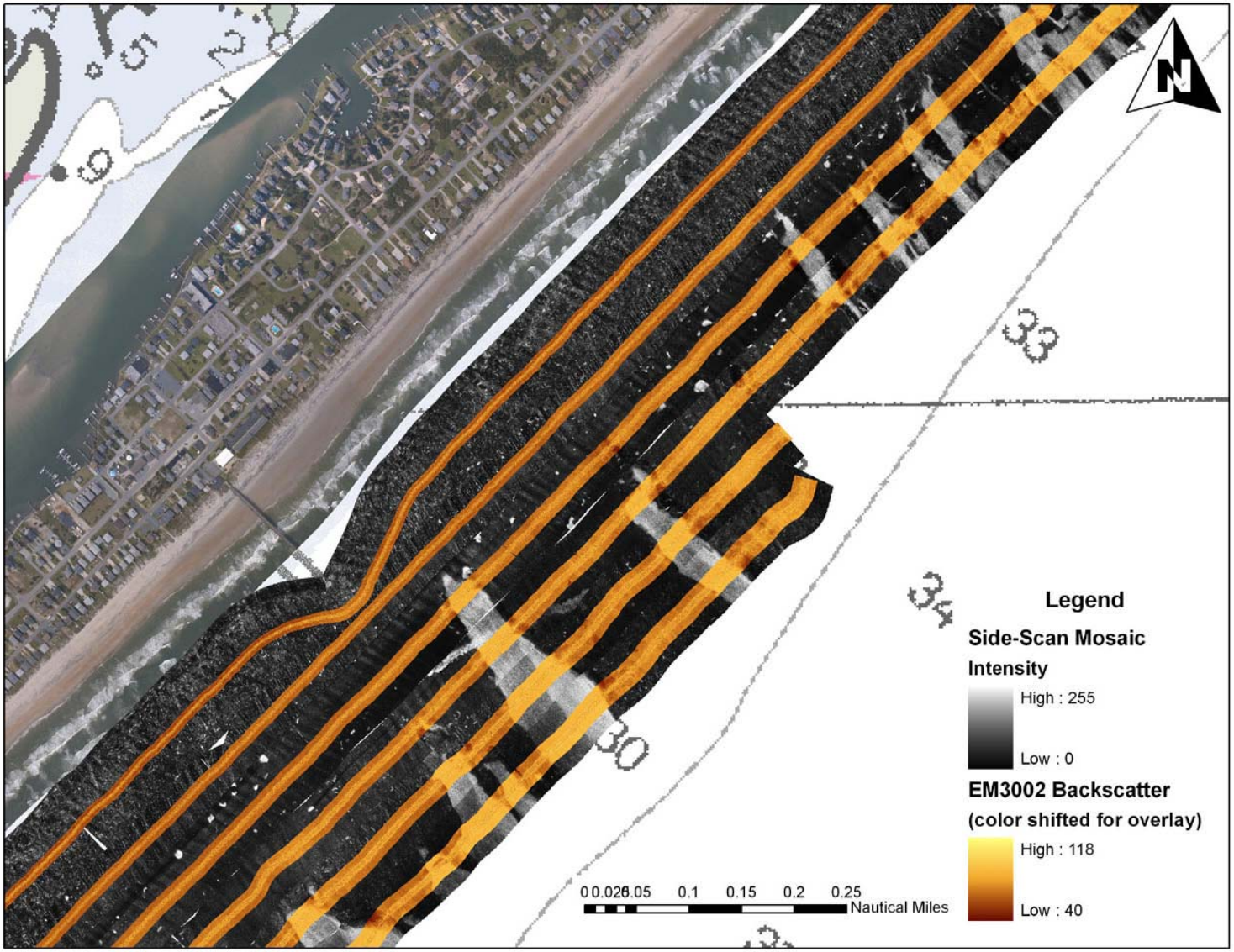


Figure 16. Side-scan sonar mosaic overlaid with EM3002 backscatter data. Alignment of features between datasets illustrates excellent positioning calculation for the side-scan mosaic.

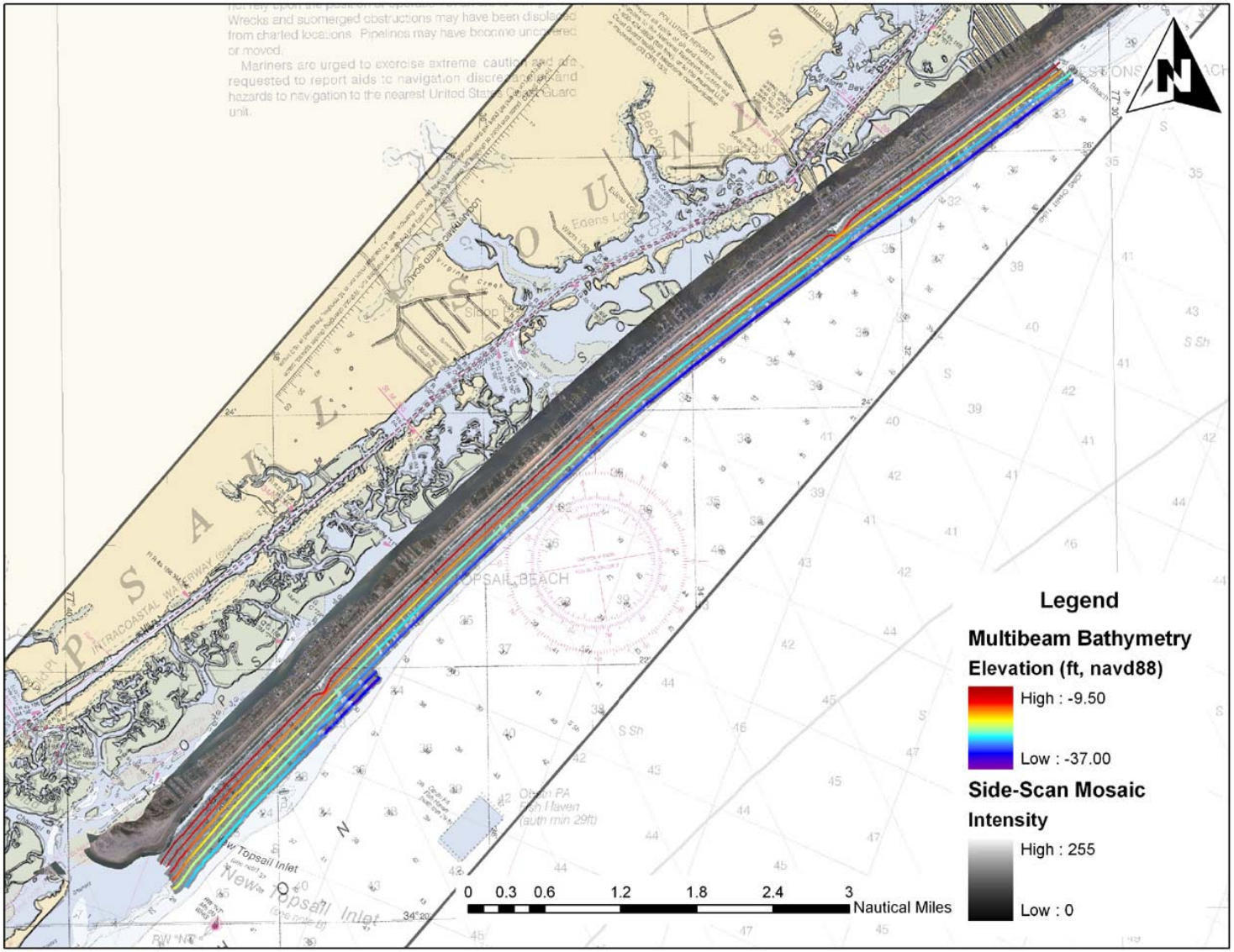


Figure 17. EM3002 Multibeam bathymetry.

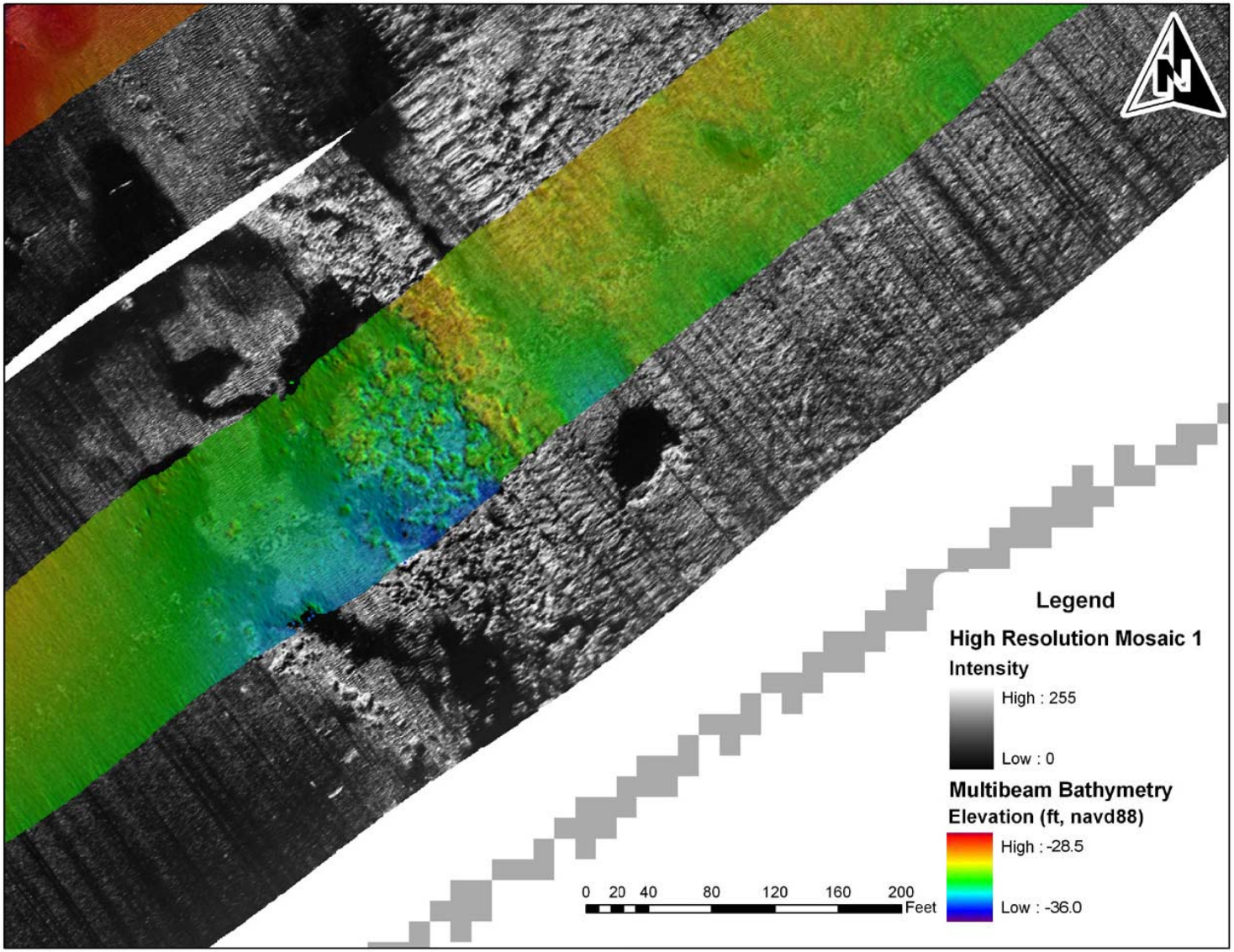


Figure 18. Rendered bathymetry overlaid on high-resolution side-scan sonar imagery. Map illustrates a low-relief hardbottom and sediment interface.

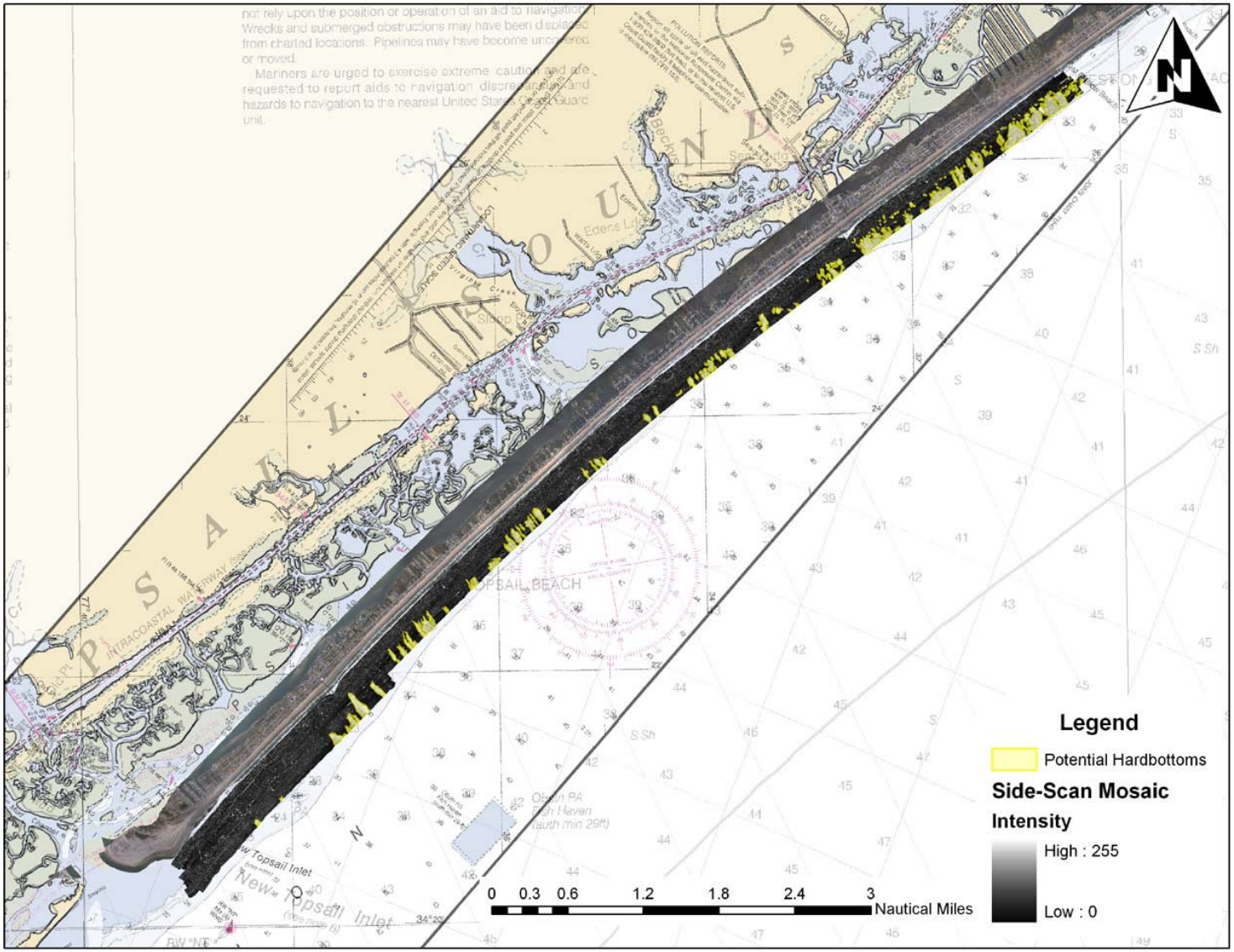


Figure 19. Side-scan sonar mosaic overlaid with polygon shapefile of potential hardbottom areas.

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

POB

CROCKER (1,3)

68542.046	68542.204
735010.571	735010.538
1.33	1.351

pib.

A230

71298.606	71298.~~768~~ 722 TOPO
737877.413	737877.~~388~~ 390
3.480	3.452
	3.460 CNTRL

1.21 T

1.95 →

~~POINTS~~

3/63

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
2.570 | 2.605
pub | rec

AI 0866
1,3 | NCGS

USACE Topsail Side Scan

July 17, 2006

mobilization

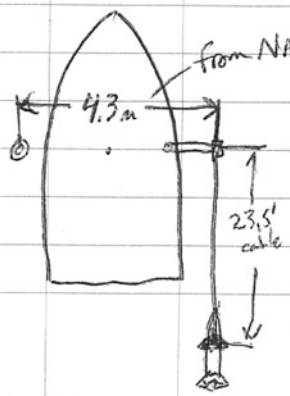
- left PKS ~ 12:15pm after USACE estimate
- Got boat in water + slip ~ 2:00pm
- Set up base on Tower 3
  - checked mark ~ 1.3cm!

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

July 18, 2006

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

Side Scan Measurements



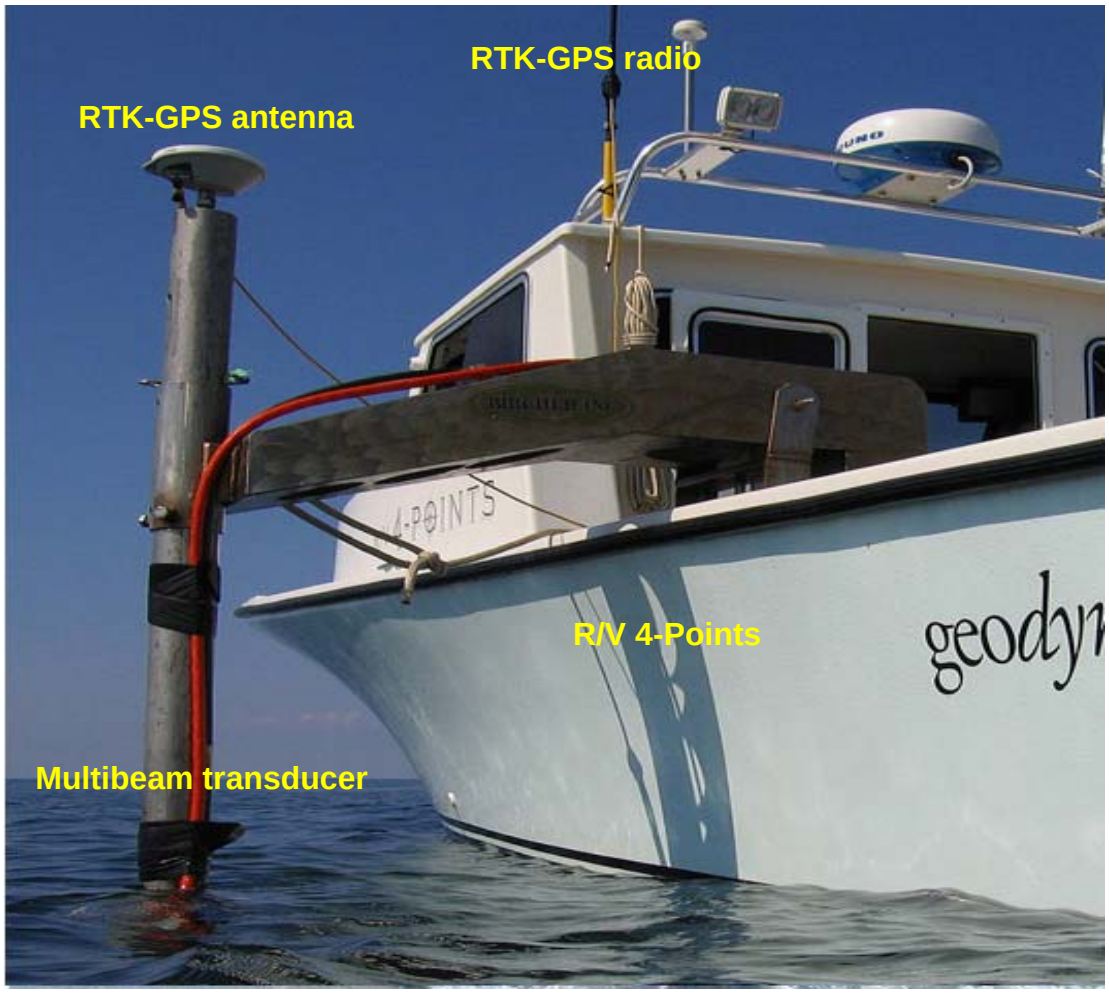
Cable out from block to fish = approx. 23.5'

Logbook calc would come to: 12.5 m roughly

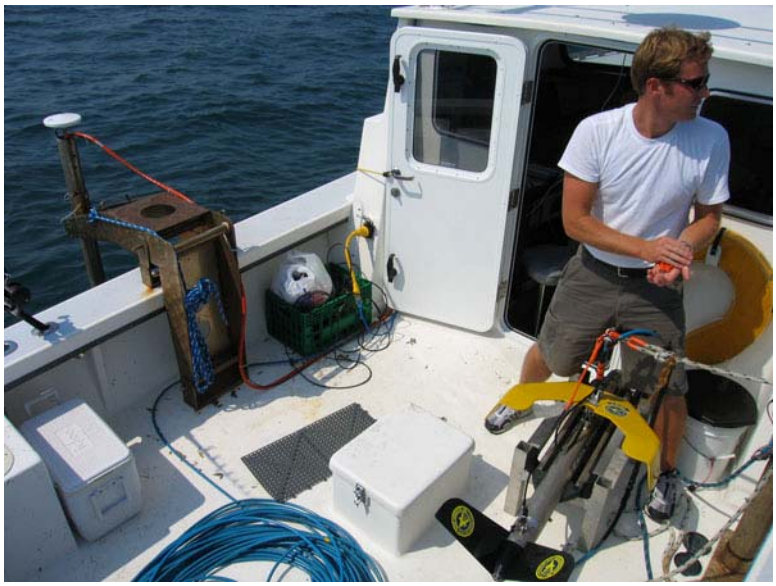
Seems more like 6 in depth

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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Table of Contents

Executive Summary 3

Introduction 4

Processing the Data 5

Sidescan Data Quality 8

Classification Results 13

Discussion and Recommendations 17

Selected Reading 18

APPENDIX A Format of Seabed File 19

List of Figures

Figure 1: Towfish heading and yaw rate in a line of Topsail data set 10

Figure 2: Towfish pitch and roll in a line of the Topsail data set 10

Figure 3. : Backscatter Mosaic of "Topsail" survey area. (source: Geodynamics Group) 13

Figure 4: Acoustic Classes Overlaid on Bathymetry 14

Figure 5 Interpolated classified point data set. 14

Figure 6: The results of automatic classification showing only Class 5 which is interpreted as reef. 15

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. 16

List of Tables

Table 1: Cleaning tools. 5

Table 2. Survey lines in Topsail data set 11

Table 3: Cleaning parameters. 12

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.

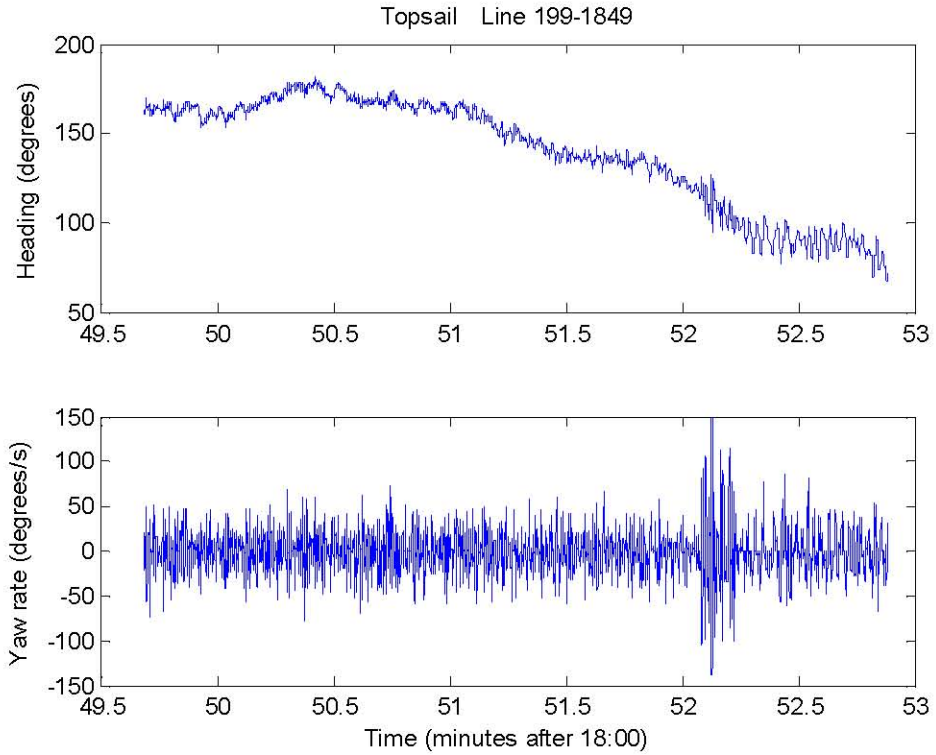

Figure 1: Towfish heading and yaw rate in a line of Topsail data set

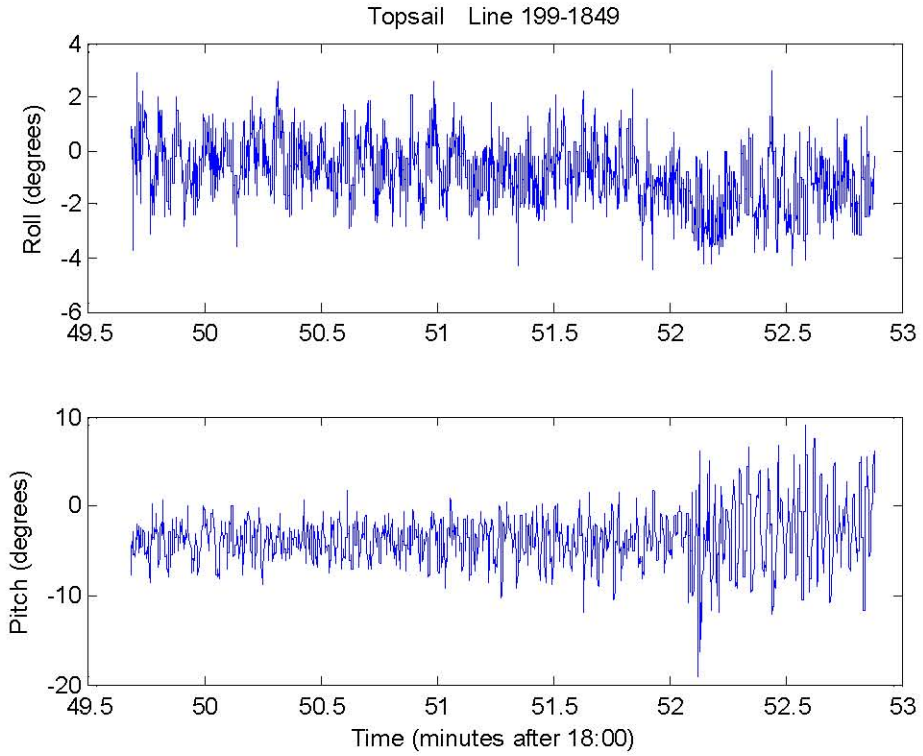

Figure 2: Towfish pitch and roll in a line of the Topsail data set

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.

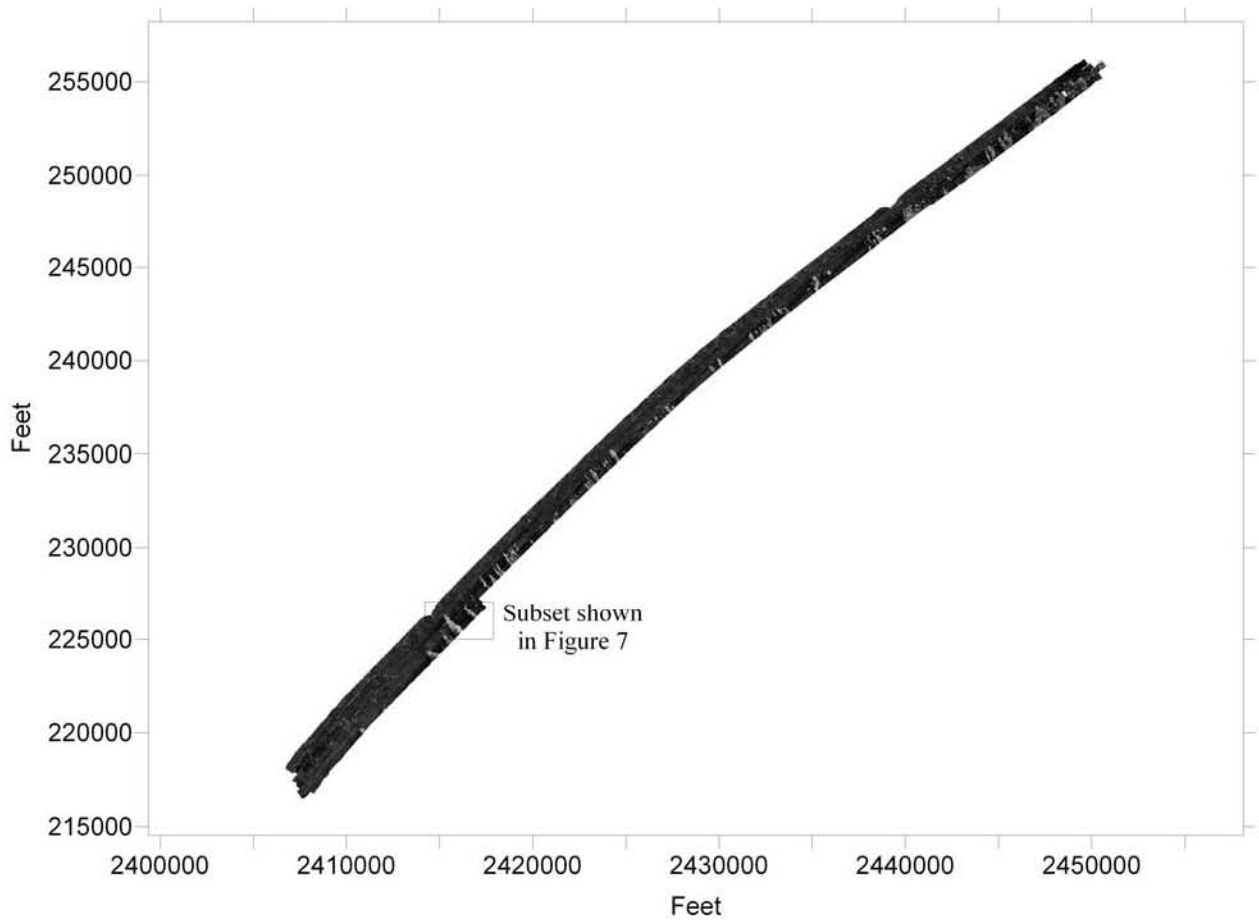

Figure 3. : Backscatter Mosaic of "Topsail" survey area. (source: Geodynamics Group)

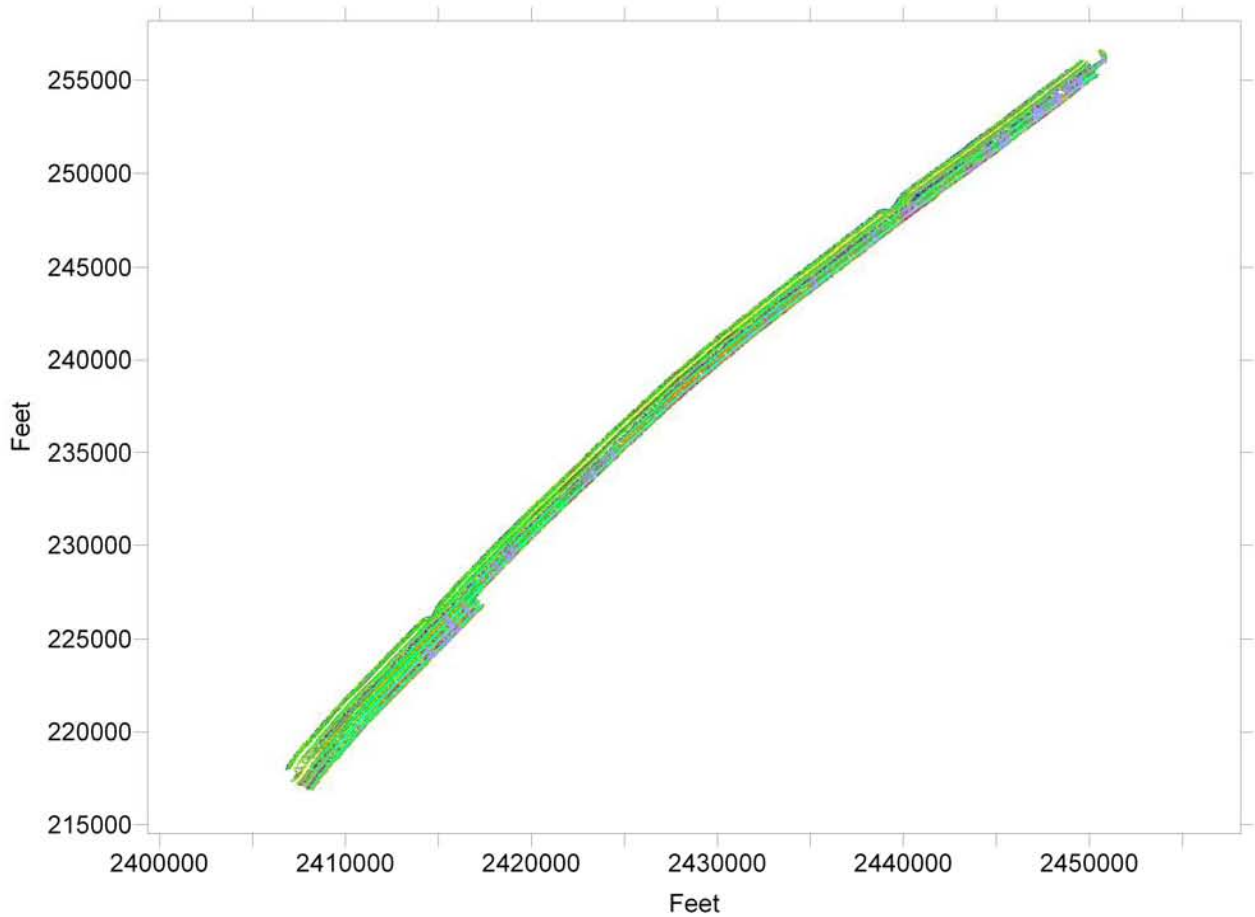

Figure 4: Acoustic Classes Overlaid on Bathymetry

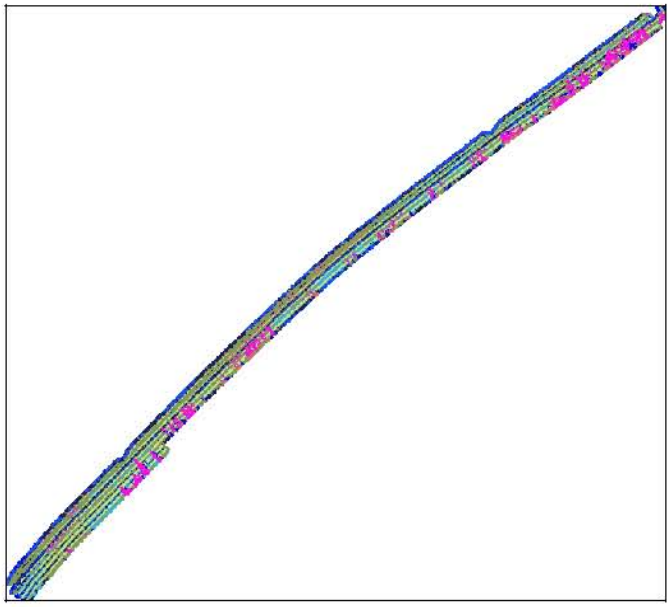

Figure 5 Interpolated classified point data set.

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.

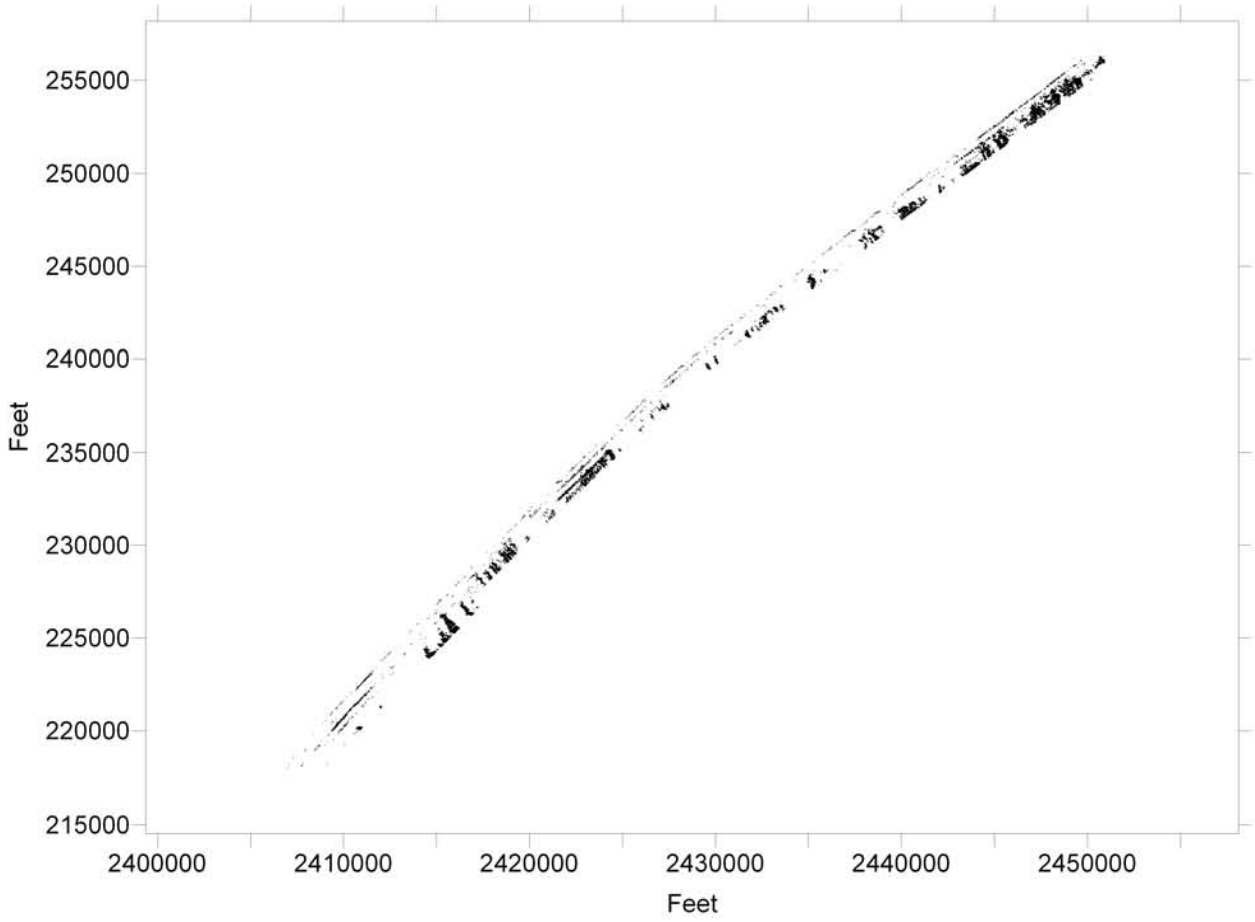

Figure 6: The results of automatic classification showing only Class 5 which is interpreted as reef.

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.

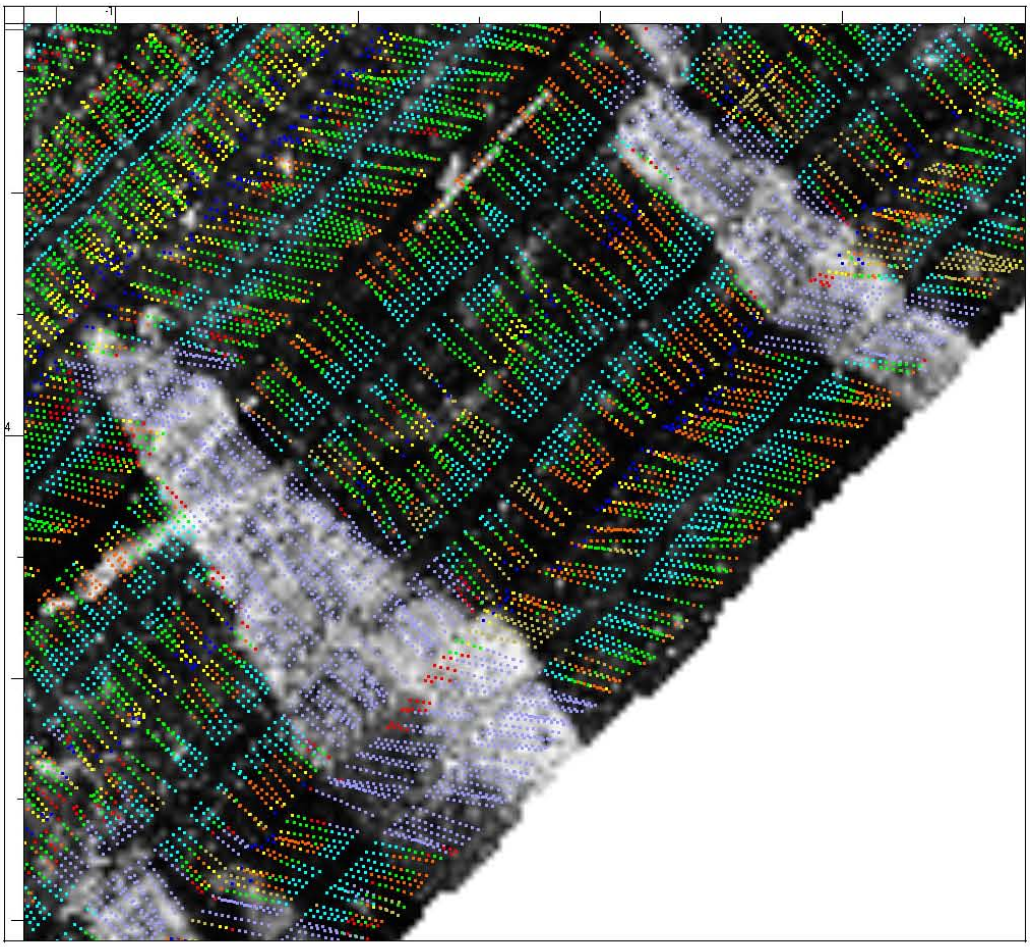

Figure 7: Class 5 interpreted as reef only. The purple class (Class 5) correlates with the reef class seen on the sidescan sonar mosaic. Please see Figure 3 for location of this area.

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.

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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

Feasibility Report
and
Final Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 3

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

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

TABLE OF CONTENTS ..... **ii**

Executive Summary **1**

Survey Preparation *1*

Survey Area *1*

RTK-GPS Survey Control & Multibeam Calibration **3**

Introduction & Purpose *3*

RTK-GPS Network Adjustment & Site Calibration *3*

Multibeam Echosounder Calibration Report *8*

Data Processing Routines & QA/QC Information **14**

Introduction *14*

Bathymetry Processing *14*

TPE (Total Propagated Error) *15*

Topsail Island Multibeam Workflow Diagram **17**

Topsail Island Multibeam QA/QC Workflow Diagram **18**

Graphical Summary of Deliverables **19**

Appendix B – Field Notes **30**

Appendix C – Equipment & Instrument Accuracies **56**

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.

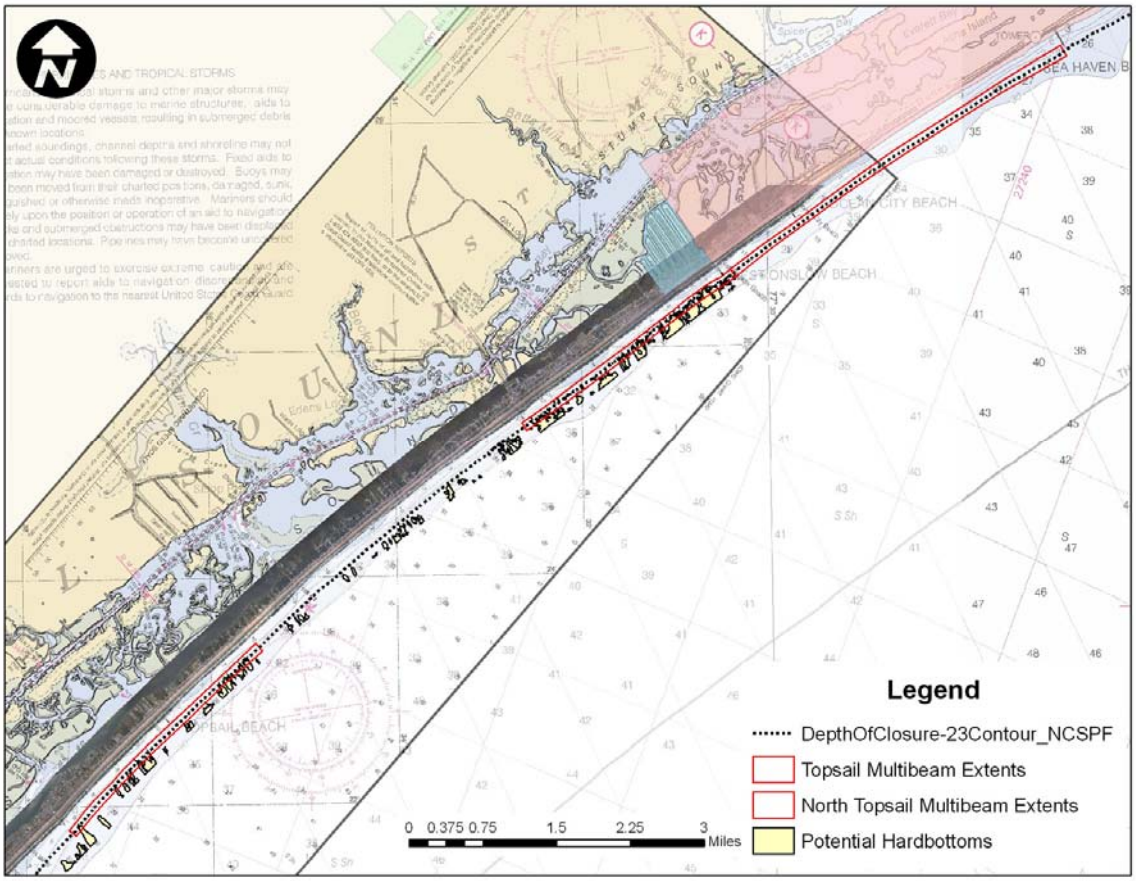

Figure 1. Map of Topsail, Surf City and North Topsail Island survey extents.

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

Crocker Benchmark

Crocker BM Check

Notes	Benchmark is at intersection of Crocker and S. Anderson

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

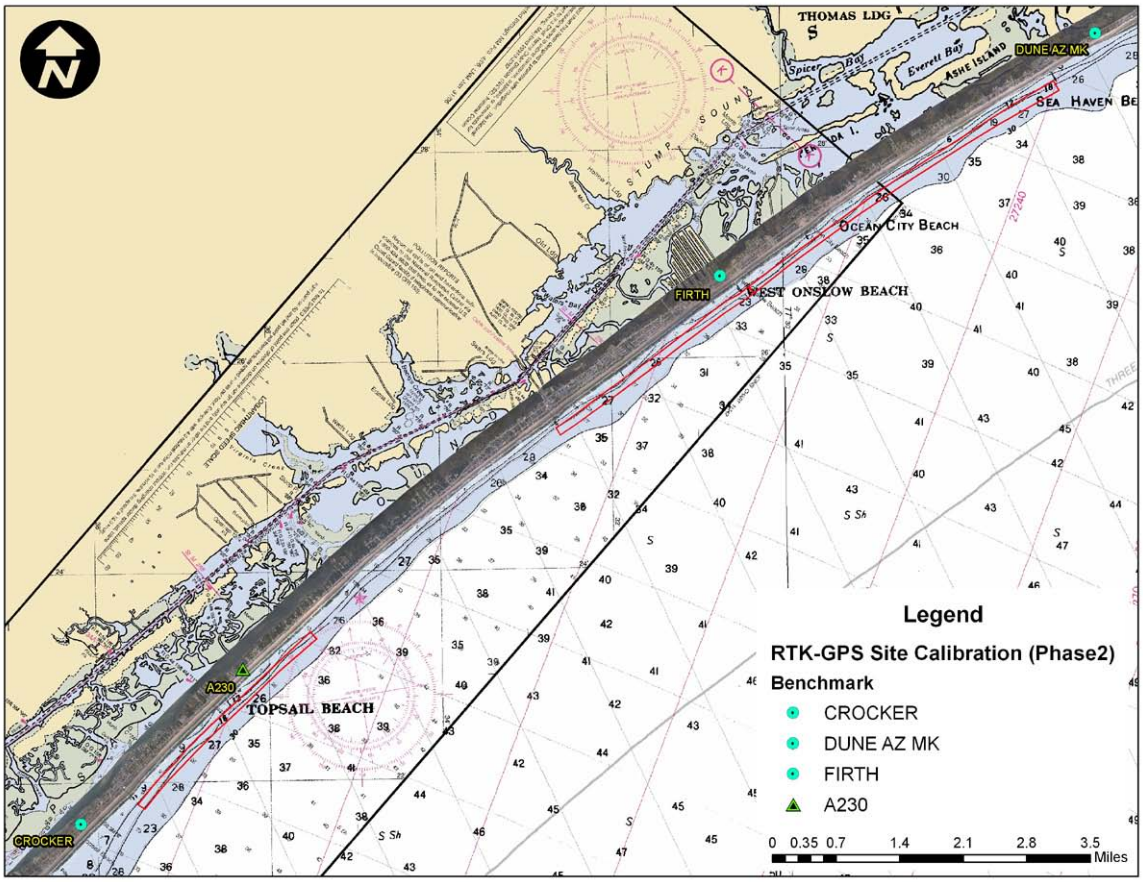


Figure 2. Map of new site calibration on A230 and the BM's checked.

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.

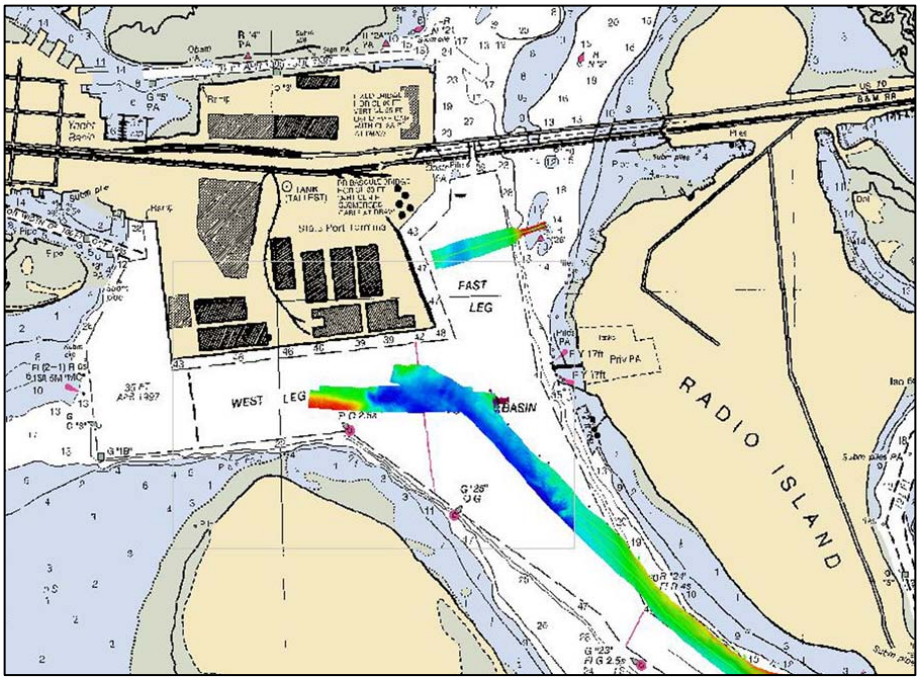


Figure 4. Map of the patch survey area within the Morehead City Turning Basin.

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

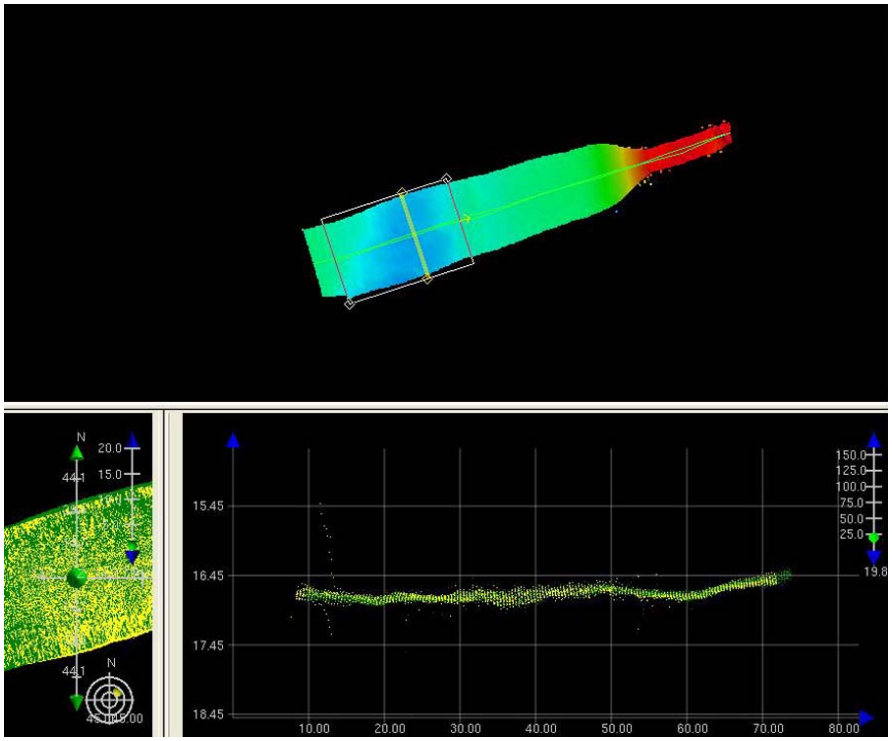


Figure 5. Caris screen grab illustrating acceptance of roll calibration.

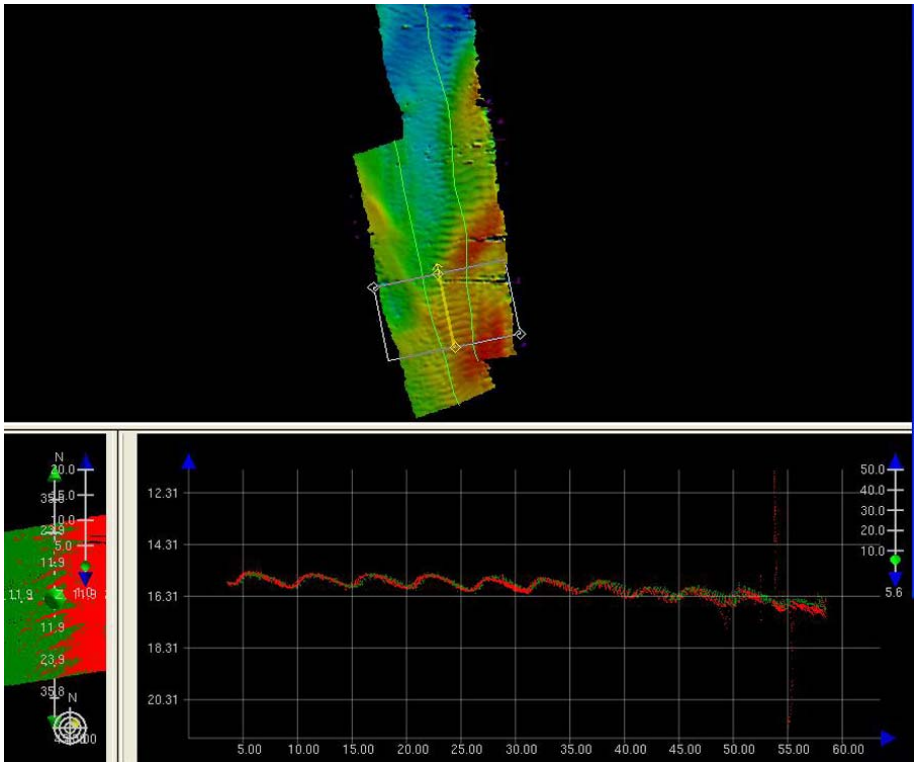


Figure 6. Caris screen grab illustrating acceptance of yaw calibration.

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).

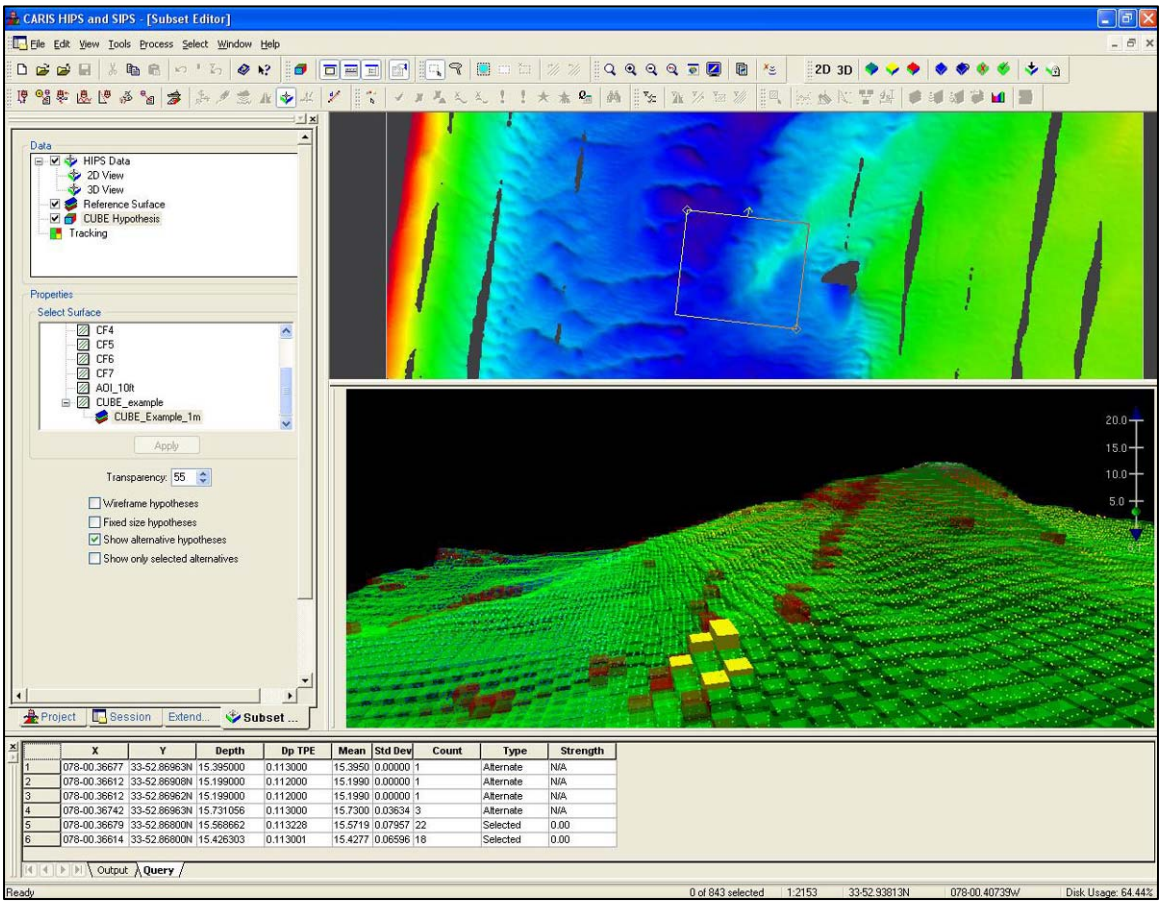
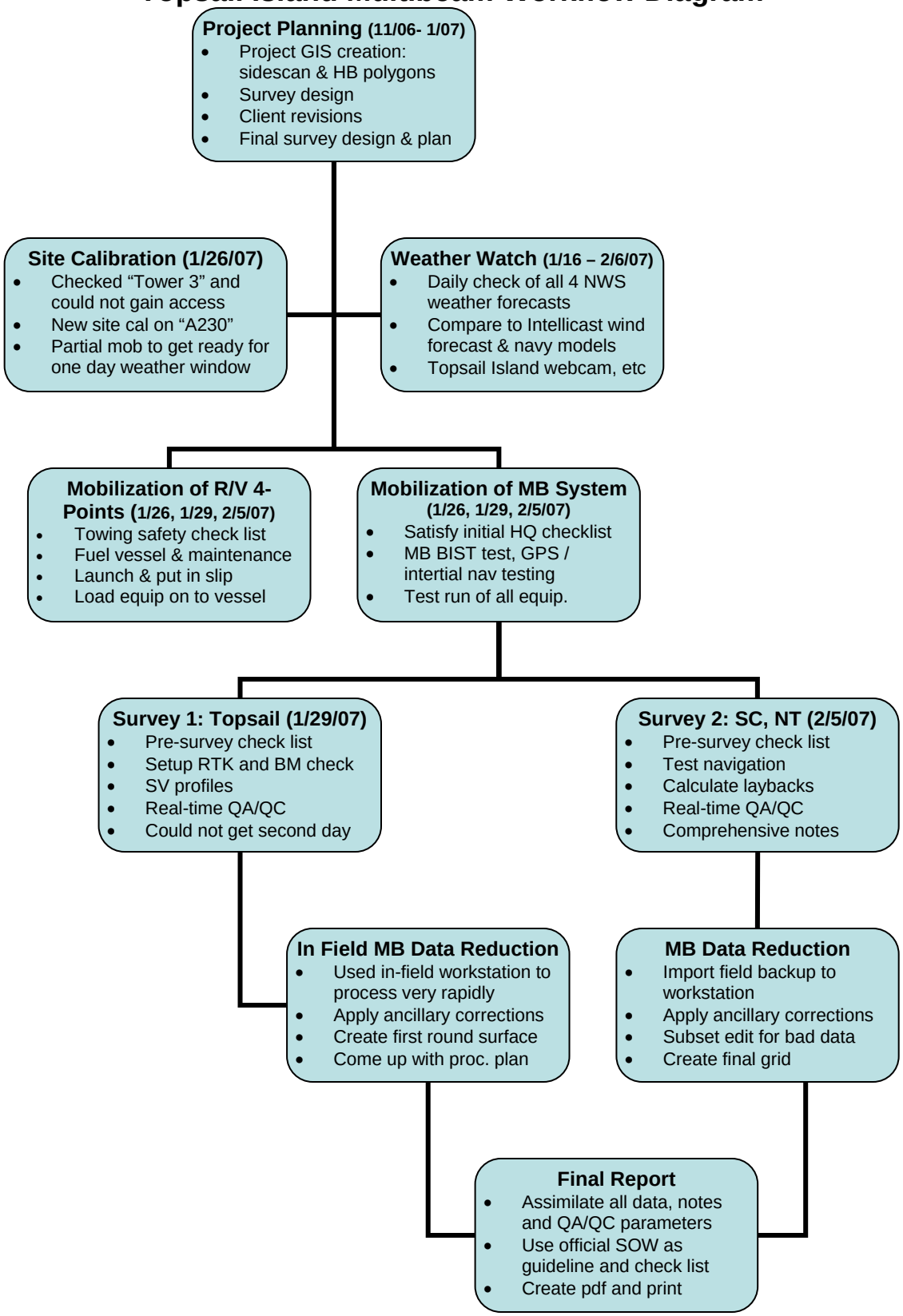
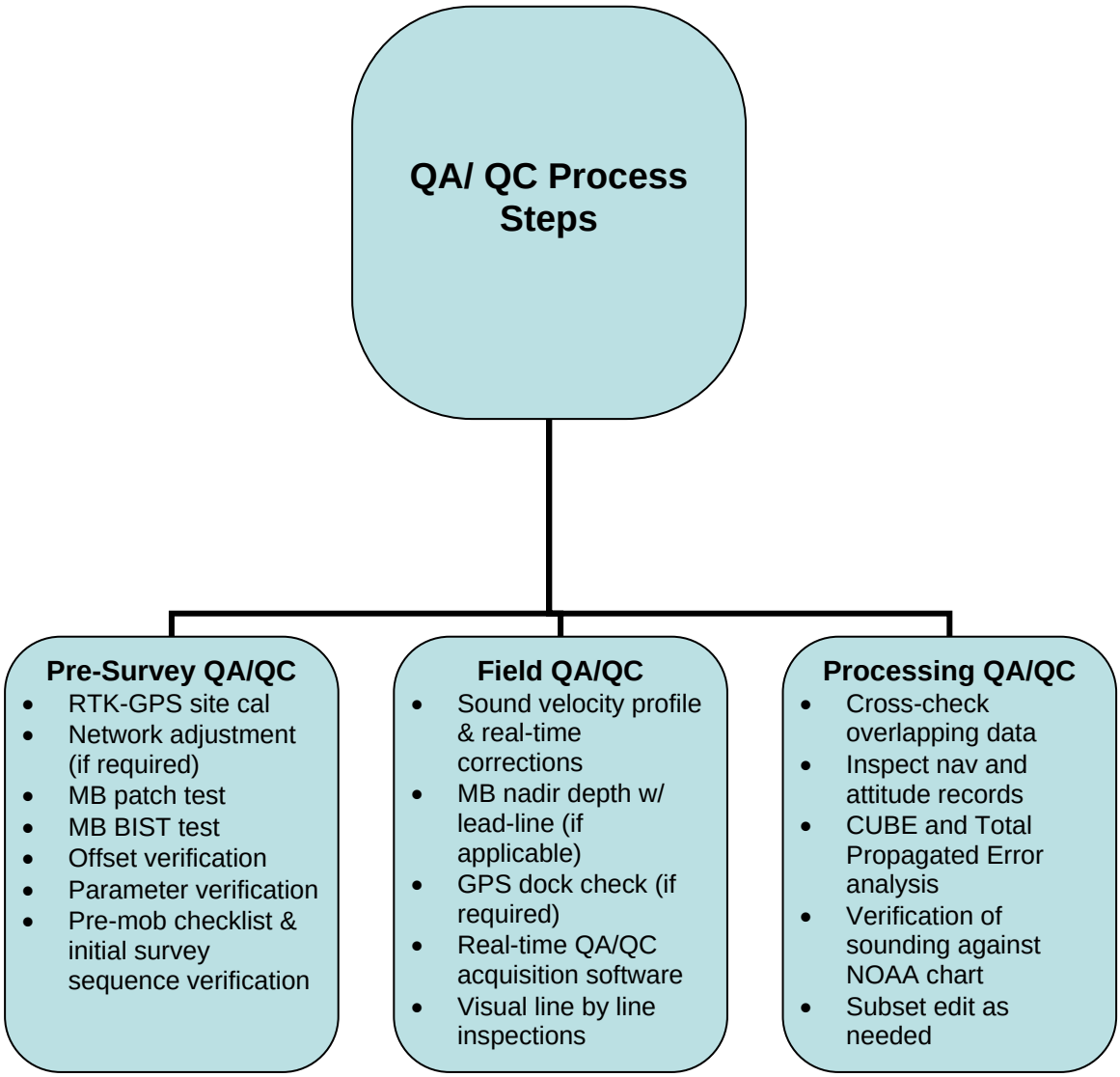


Figure 7. Screen capture showing an example of the CUBE editing process.

Topsail Island Multibeam Workflow Diagram



Topsail Island Multibeam QA/QC Workflow Diagram



Graphical Summary of Deliverables

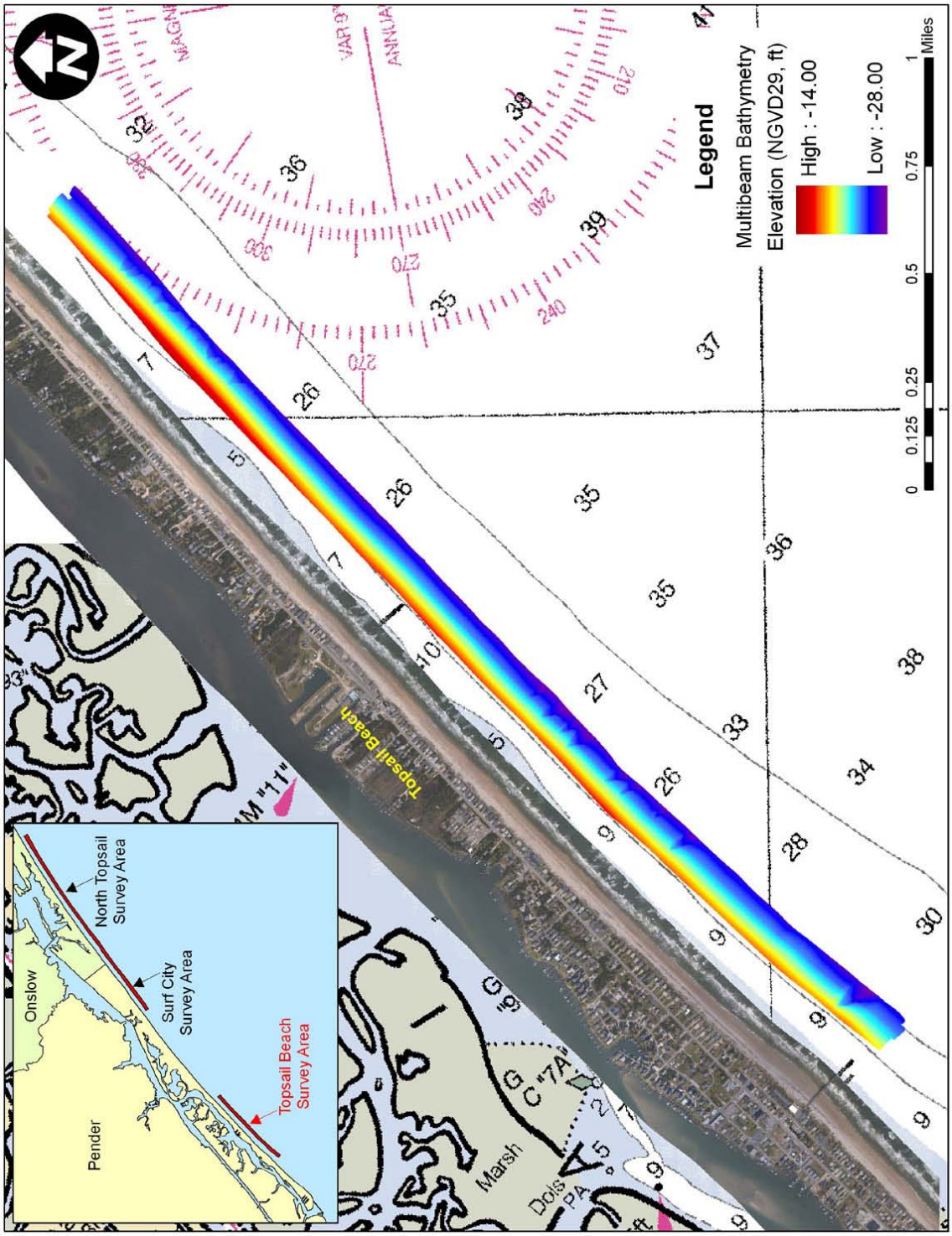


Figure 8. Plan view bathymetric map showing the "southern" survey reach.

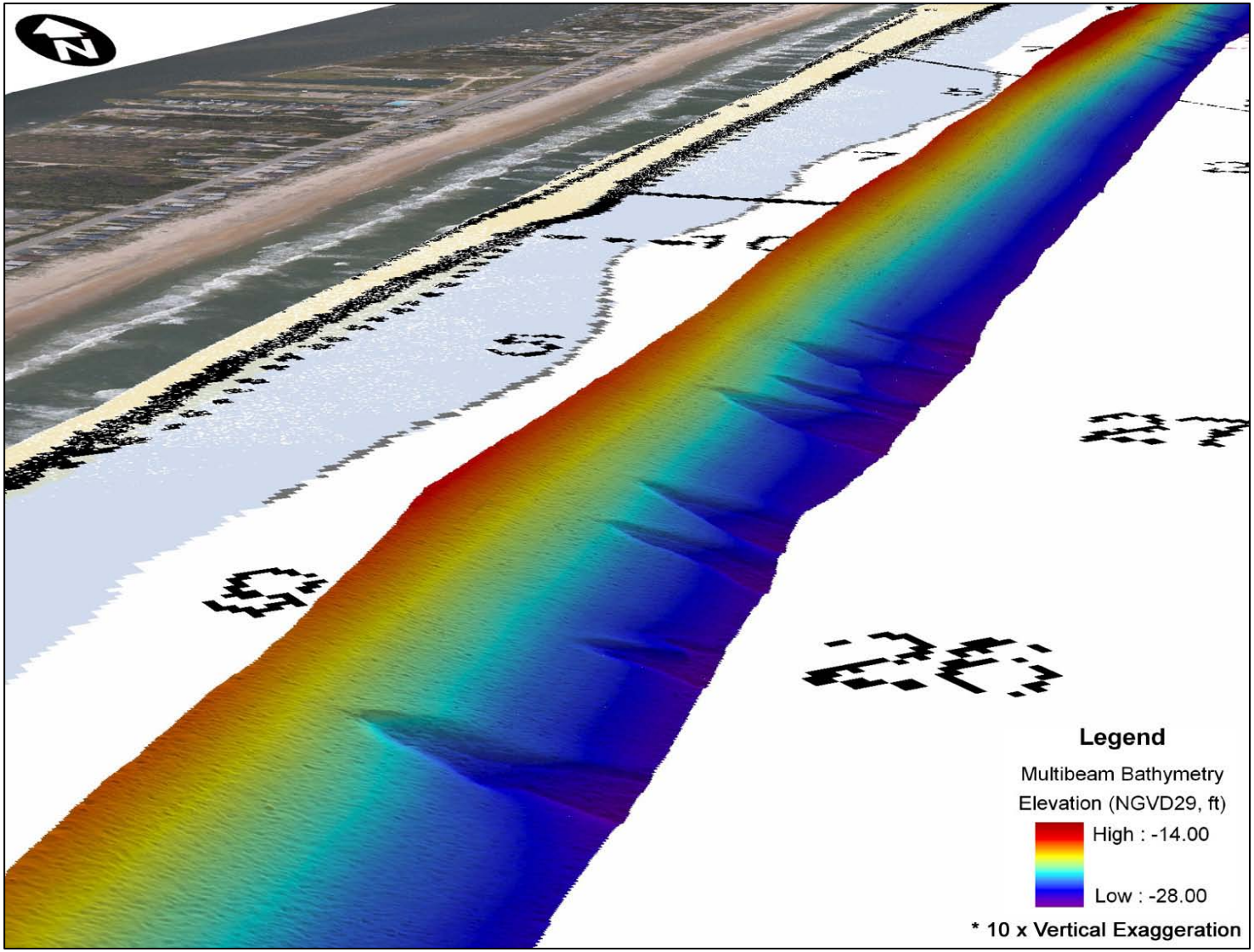


Figure 9. 3D perspective view of Topsail Island inner shoreface. Inshore signature or scour depressions that likely extend offshore.

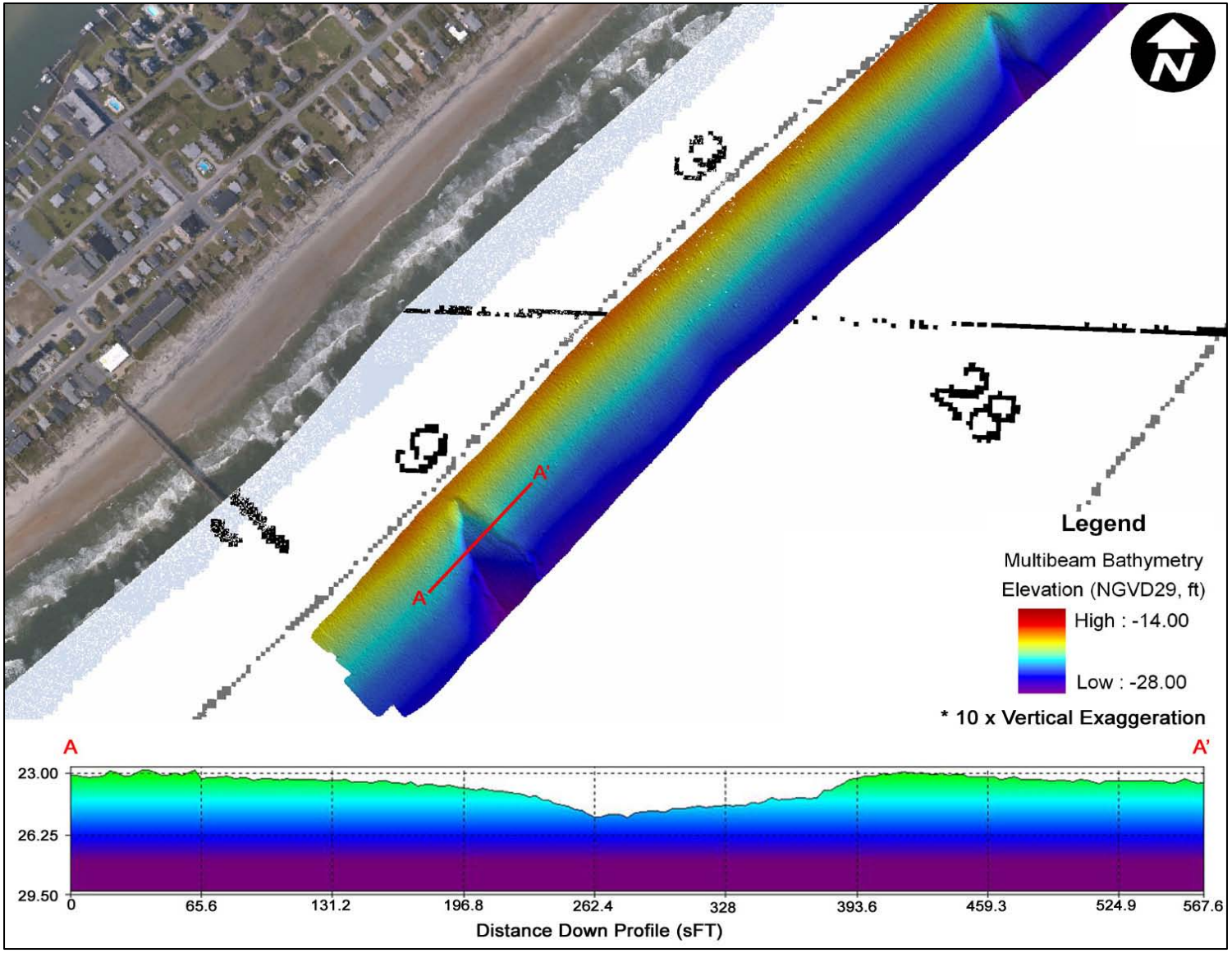


Figure 10. Zoom in on scour depression area for Topsail Island with profile cross section.

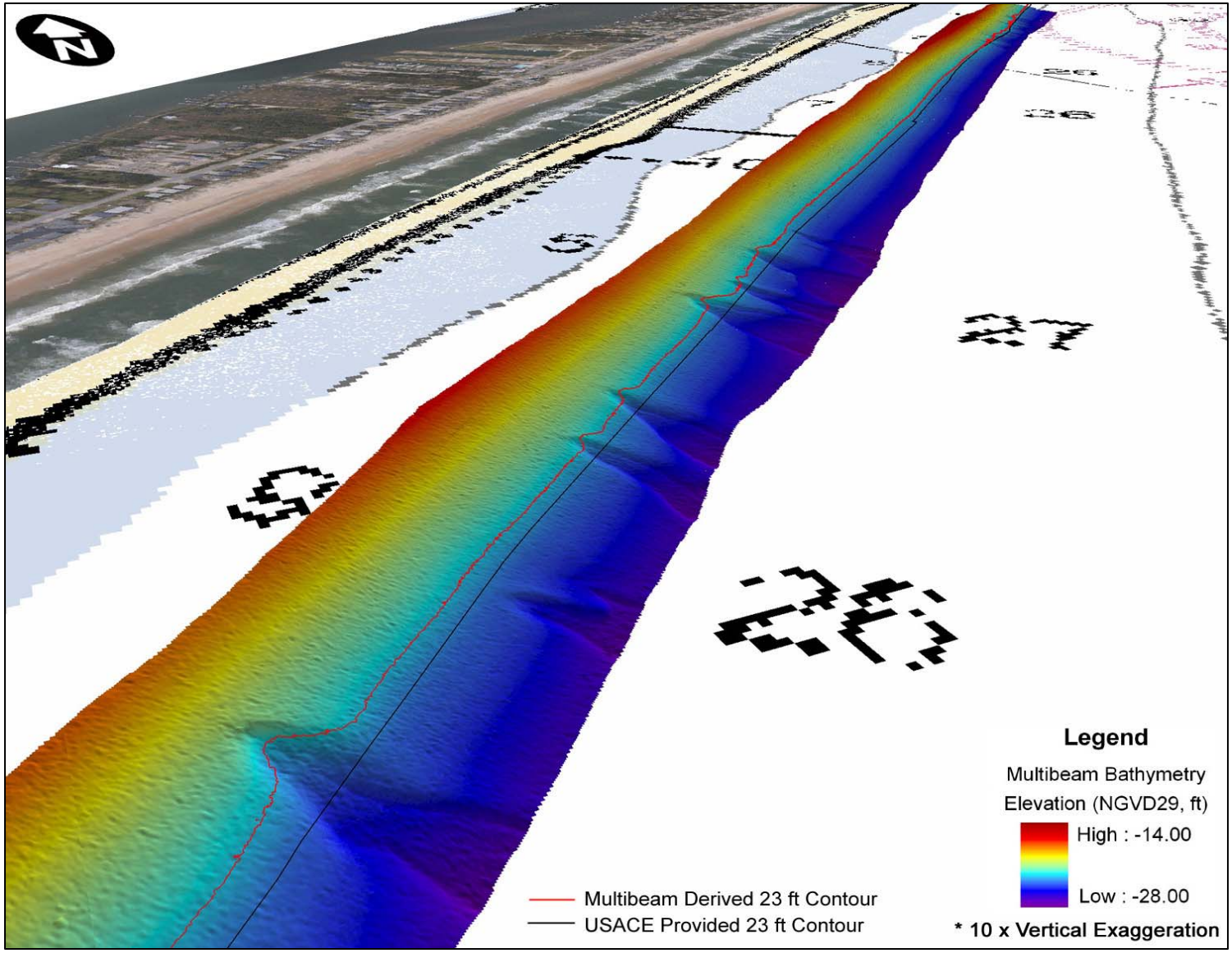


Figure 11. 23' multibeam and 23' USACE contours draped on 3D perspective view of the Topsail Beach inner shoreface.

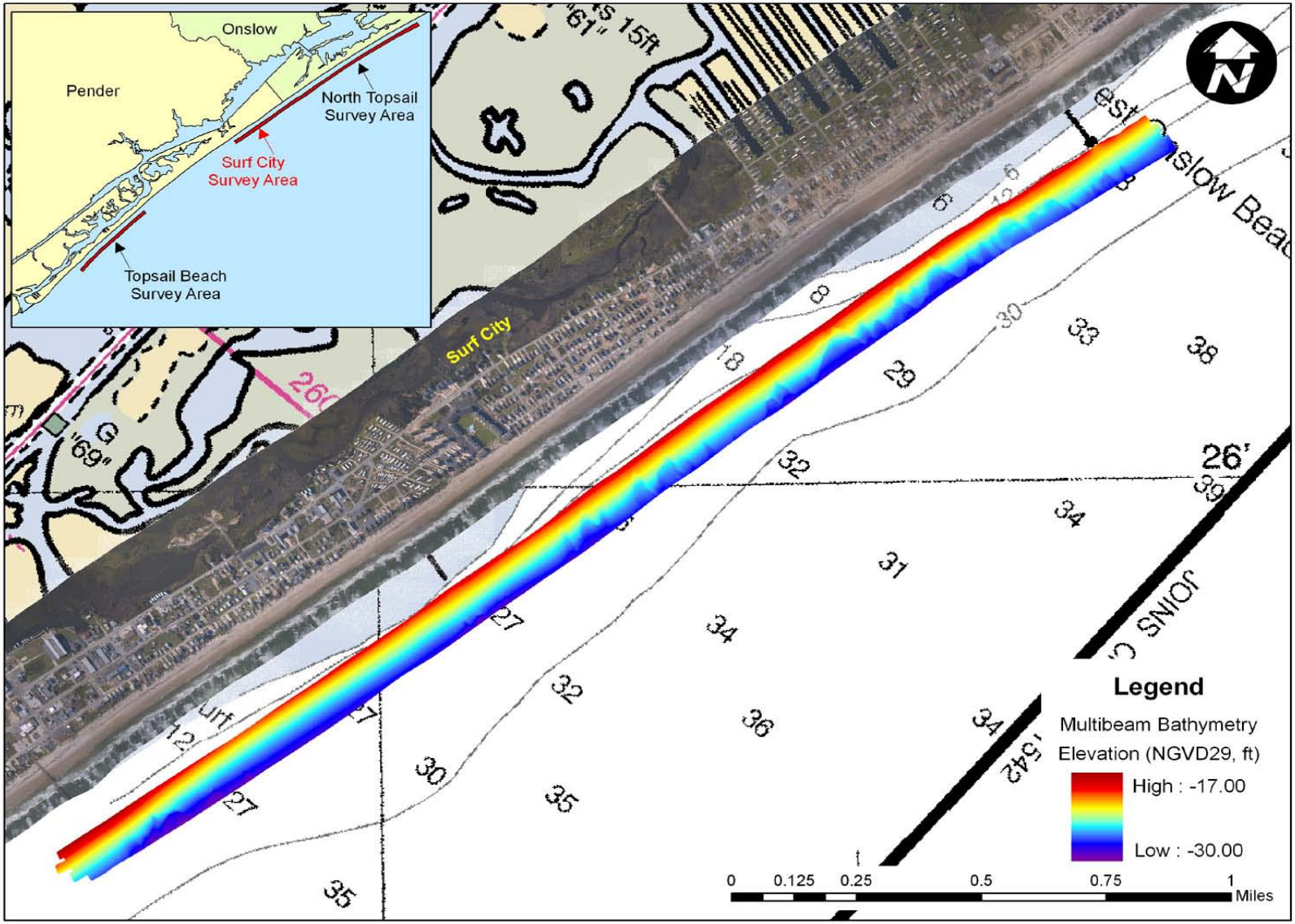


Figure 12. Plan view bathymetric map of the Surf City or “middle” survey area.

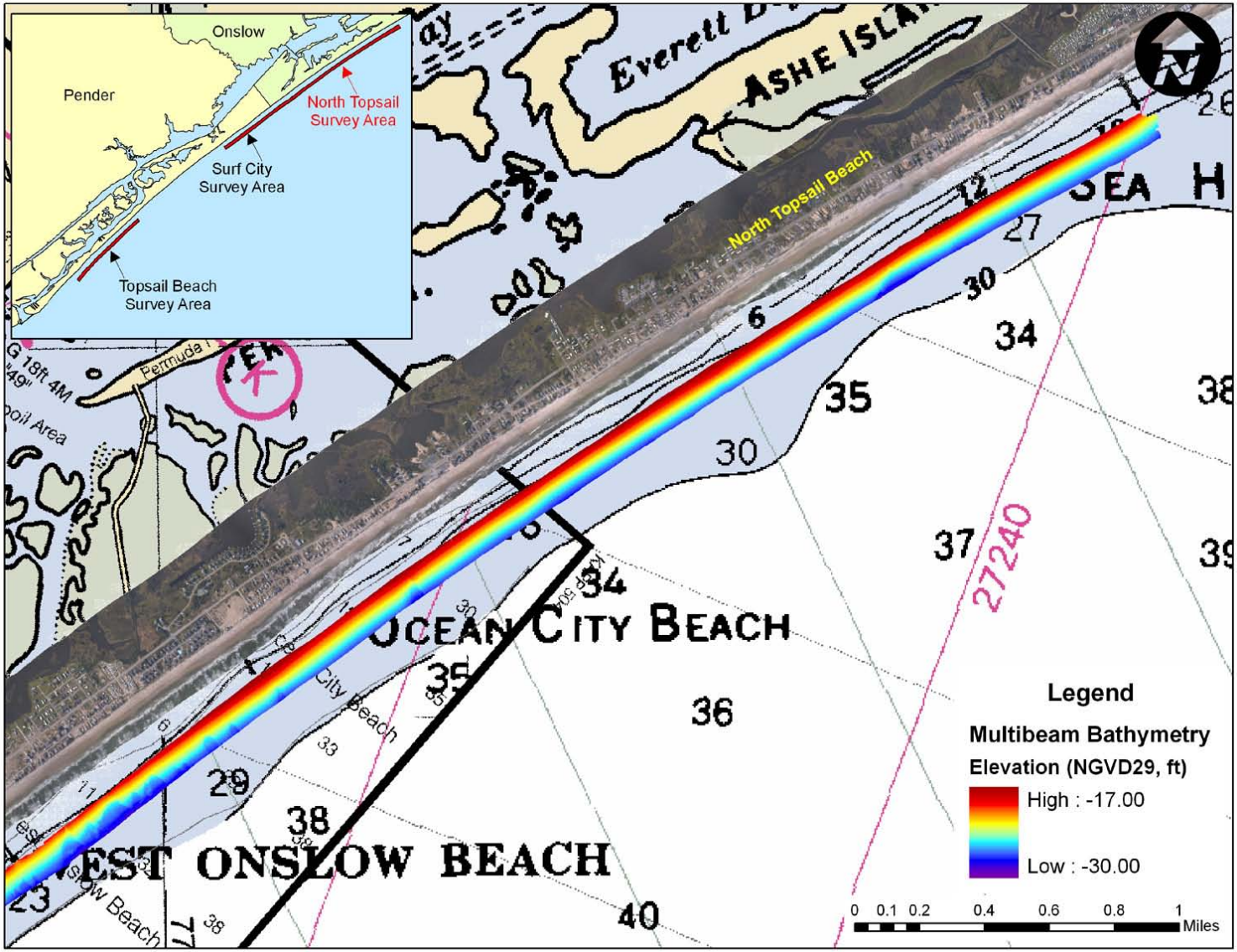


Figure 13. Plan view bathymetric map of the North Topsail or “northern” survey area.

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

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: 1/30/07

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 little 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.

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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: 2/5/07

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
Jan 29 - Feb 05, 2007 01-29-07 Page 1

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			

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				
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

Topsail Phase II Multibeam
Jan 29-Feb 5, 2007 01-30-07 Page 1

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

Topsail Phase II Multibeam
Jan 29-Feb 5, 2007 02-05-07 Page 1

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^{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

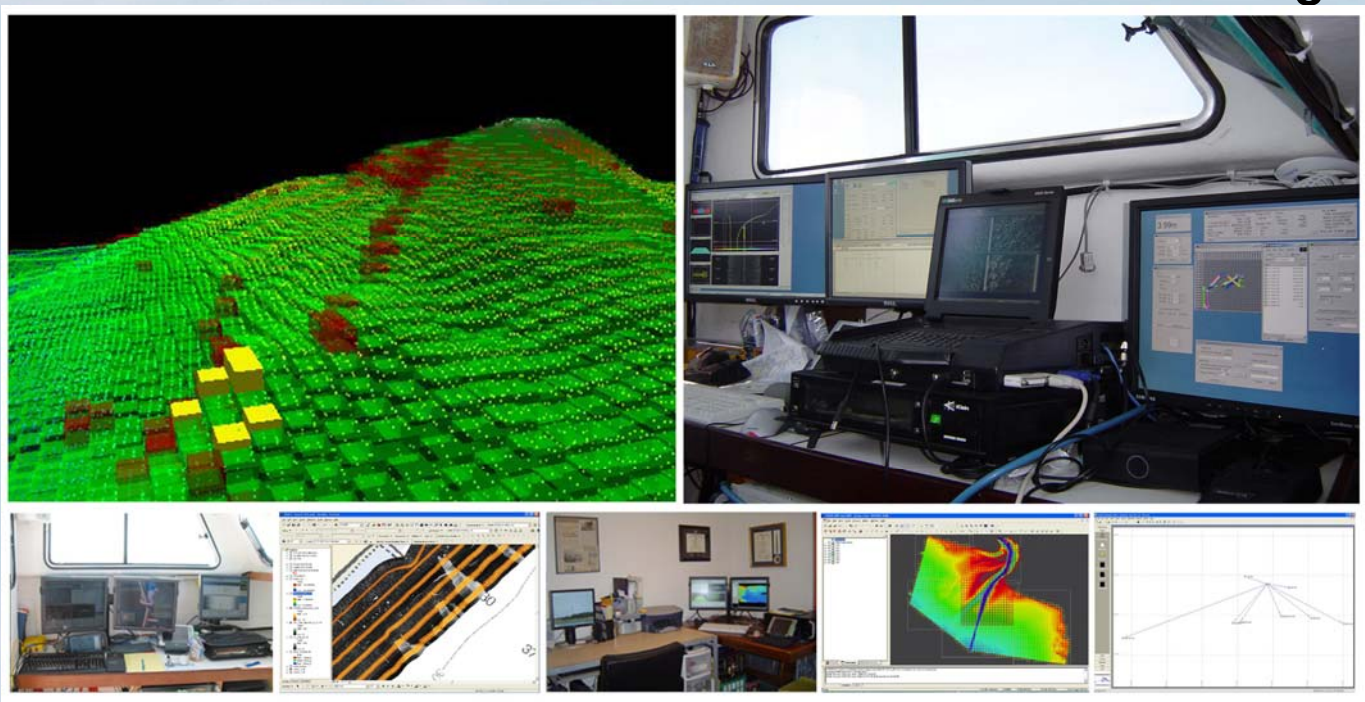
- **POS MV 320 v4 (with RTK Corrections)**
  - Roll, Pitch accuracy: 0.02° (1 sigma with GPS or DGPS)
  - 0.01° (1 sigma with RTK)
  - Heave Accuracy: 5 cm or 5% (whichever is greater)
  - Heading Accuracy: 0.02° (1 sigma) with 2 m antenna baseline
  - Position Accuracy: 0.02 - 0.10 m (RTK) with input

- **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

Final General Reevaluation Report
and
Final Environmental Impact Statement

on

Hurricane Protection and Beach Erosion Control

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix R
Attachment 4

Surf City / North Topsail Beach, N.C. Shore Protection Project, Hardbottom Resource Confirmation and Characterization Study

Feasibility Report
and
Final Environmental Impact Statement

on

Coastal Storm Damage Reduction

SURF CITY AND NORTH TOPSAIL BEACH
NORTH CAROLINA

Appendix S -

Topsail Beach
Benthic Community Characterization Survey

Appendix S -

Topsail Beach
Benthic Community Characterization Survey

The following pages contain the technical memorandum prepared by Dial Cordy and Associates, Inc., Environmental Consultants under contract to the U.S. Army Corps of Engineers, Wilmington District. The technical memorandum describes the benthic study of the Topsail Beach offshore borrow sites. The study also includes 4 additional appendices, which are included in the CDROM version of the Final Feasibility and Final EIS, but are not in the printed version.

Technical Memorandum

Topsail Beach Benthic Community Characterization Survey Pender County, NC

Final

May 2007

Prepared for:
U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402

Prepared by:

DIAL CORDY
AND ASSOCIATES INC
Environmental Consultants

Topsail Beach Benthic Community Characterization Survey Pender County, NC

Technical Memorandum

FINAL

May 2007

Prepared for:

U.S. Army Corps of Engineers
Wilmington District
P.O. Box 1890
Wilmington, NC 28402

Prepared by:

Dial Cordy and Associates Inc.
201 North Front Street
Suite 601
Wilmington, NC 28401

TABLE OF CONTENTS

Page

LIST OF TABLES iii

LIST OF FIGURES iii

1.0 INTRODUCTION 1

2.0 METHODS 1

3.0 RESULTS 4

3.1 Sediment Grain-size Analysis 4
3.2 Faunal Composition 6
3.3 Species Richness 6
3.4 Diversity Indices 6
3.5 Faunal Abundance 15
3.6 Biomass 15

4.0 DISCUSSION 20

5.0 LITERATURE CITED 21

Appendix A Data Quality Control Report

Appendix B Sediment Analysis Report

Appendix C Station Data Summary Report

Appendix D Supporting Data Tables

LIST OF TABLES

Page

Table 1. Depths and location coordinates for benthic sampling stations off Topsail Beach, NC. 4

Table 2. Sediment analysis results for benthic sampling stations off Topsail Beach, NC. 5

Table 3. Taxonomic species list for benthic sampling stations off Topsail Beach, NC. 7

Table 4. Comparison of major taxa occurrences and relative abundances for borrow sites off Topsail Beach, NC. 10

Table 5. Summary of community parameters for benthic sampling stations off Topsail Beach, NC. 13

Table 6. Total abundance and percent composition for taxa collected at borrow sites off Topsail Beach, NC. 16

Table 7. Mean biomass of major taxa at borrow sites off Topsail Beach, NC. 19

LIST OF FIGURES

Page

Figure 1. Location of borrow areas off Topsail Beach, NC. 2

Figure 2. Location of benthic sampling stations off Topsail Beach, NC. 3

Figure 3. Relative composition of major taxa for borrow sites off Topsail Beach, NC. 9

Figure 4. Mean number of species and density within borrow sites off Topsail Beach, NC. .12

Figure 5. Mean Shannon Wiener index (H´) and Pielou Evenness value for borrow sites off Topsail Beach, NC. 14

1.0 INTRODUCTION

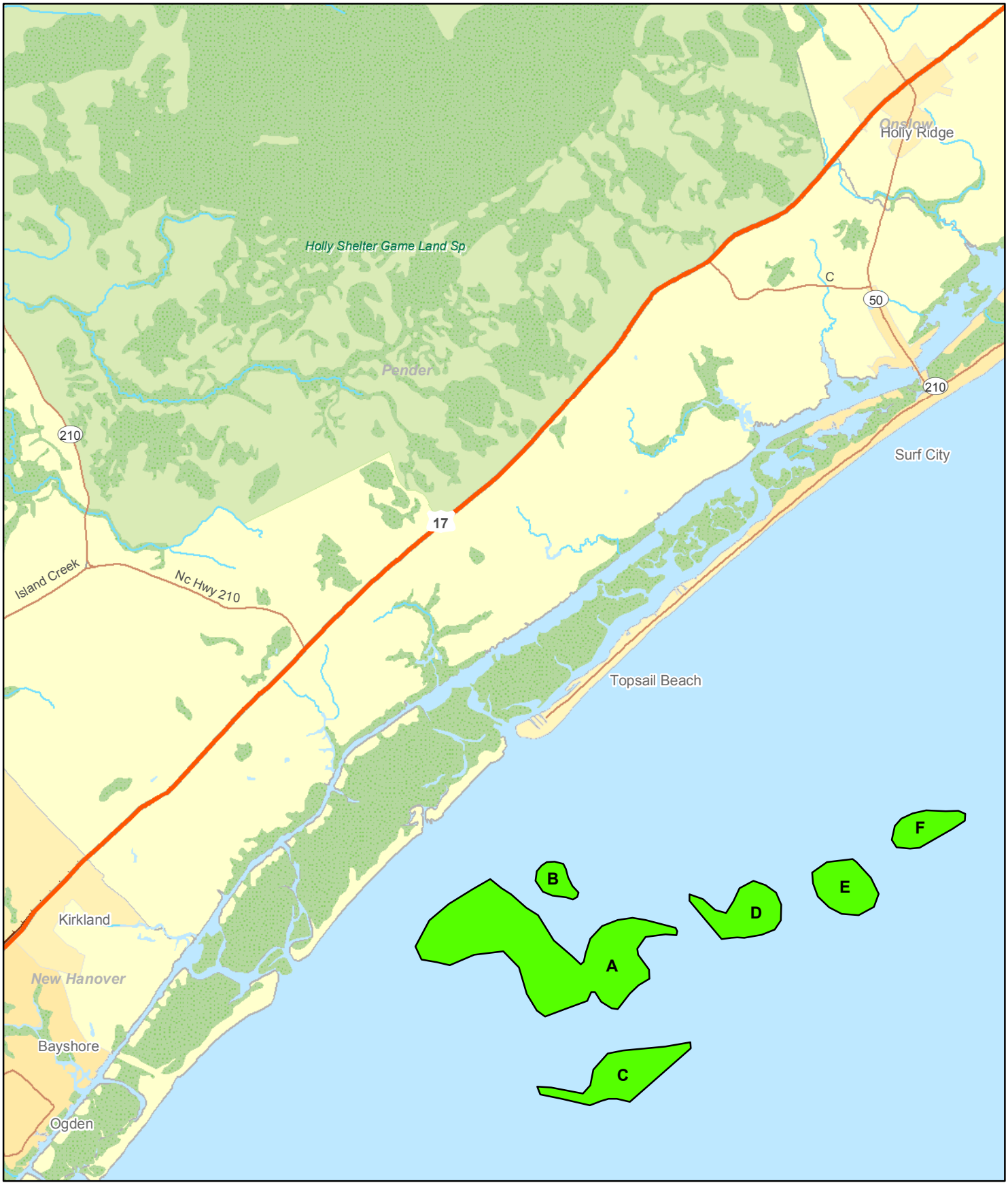
Dial Cordy and Associates Inc. (DC&A) was contracted (Contract DACW W912HN-05-D-0014) by the Wilmington District, Corps of Engineers, to conduct a characterization of the benthic community occurring within six proposed sand borrow sites selected for the proposed Shore Protection Project at Topsail Beach (Figure 1). The initial construction of the berm and dune project, extending along approximately five miles of oceanfront will require 3.2 million cubic yards of beach quality sand. The objectives of the study were to determine through benthic sampling the invertebrate abundance, species composition, and biomass within each of the borrow sites; and to perform a qualitative comparison of survey results to the results of other pertinent benthic studies completed along the coasts of North and South Carolina.

2.0 METHODS

Benthic infaunal samples were collected from three to five random locations within each of the six sand borrow sites shown in Figure 2. Five samples were taken at Borrow Site A, three samples at Borrow Site B, and four samples at each of Borrow Sites C, D, E and F. The borrow areas are located 3.0 to 5.5 miles off the south end of Topsail Island in the Atlantic Ocean. A total of 24 benthic samples were collected, along with one separate sediment sample per station (12 samples) for grain-size analysis. Coordinates for each of the 24 sampling stations are listed in Table 1.

Sampling was first attempted using a standard ponar grab on 13 November 2006; however, adequate bottom penetration was not achieved after 14 attempts within three of the six borrow areas. A Shipek grab (0.04 m^2) was used on November 28th and 29th to collect the benthic and sediment samples within each of the six borrow areas. Station positions were recorded using a Trimble GEO XT and real time positions were displayed on-board using a Hypach Navigation System. This allowed the boat operator to select stations throughout each of the borrow areas. To standardize samples, only grabs that collected full samples were saved for analysis. Faunal samples were sieved through a 0.5 mm sieve after collection, preserved in 10% buffered formalin, and subsequently transferred to 50% isoproponal once received by Barry Vittor and Associates Inc., prior to sorting and identification. Samples were sorted and all fauna identified to the lowest practical identification level possible. Wet weight biomass for the major taxa found in each sample was also performed following sample processing.

Grain-size analysis of the 12 sediment samples collected was completed using sieve sizes ranging from 4.75 mm (U.S. Standard Sieve No. 4) to 63 micron (U.S. Standard Sieve 230). A Data Quality Control Report summarizing the field activities for each survey day is provided in Appendix A.

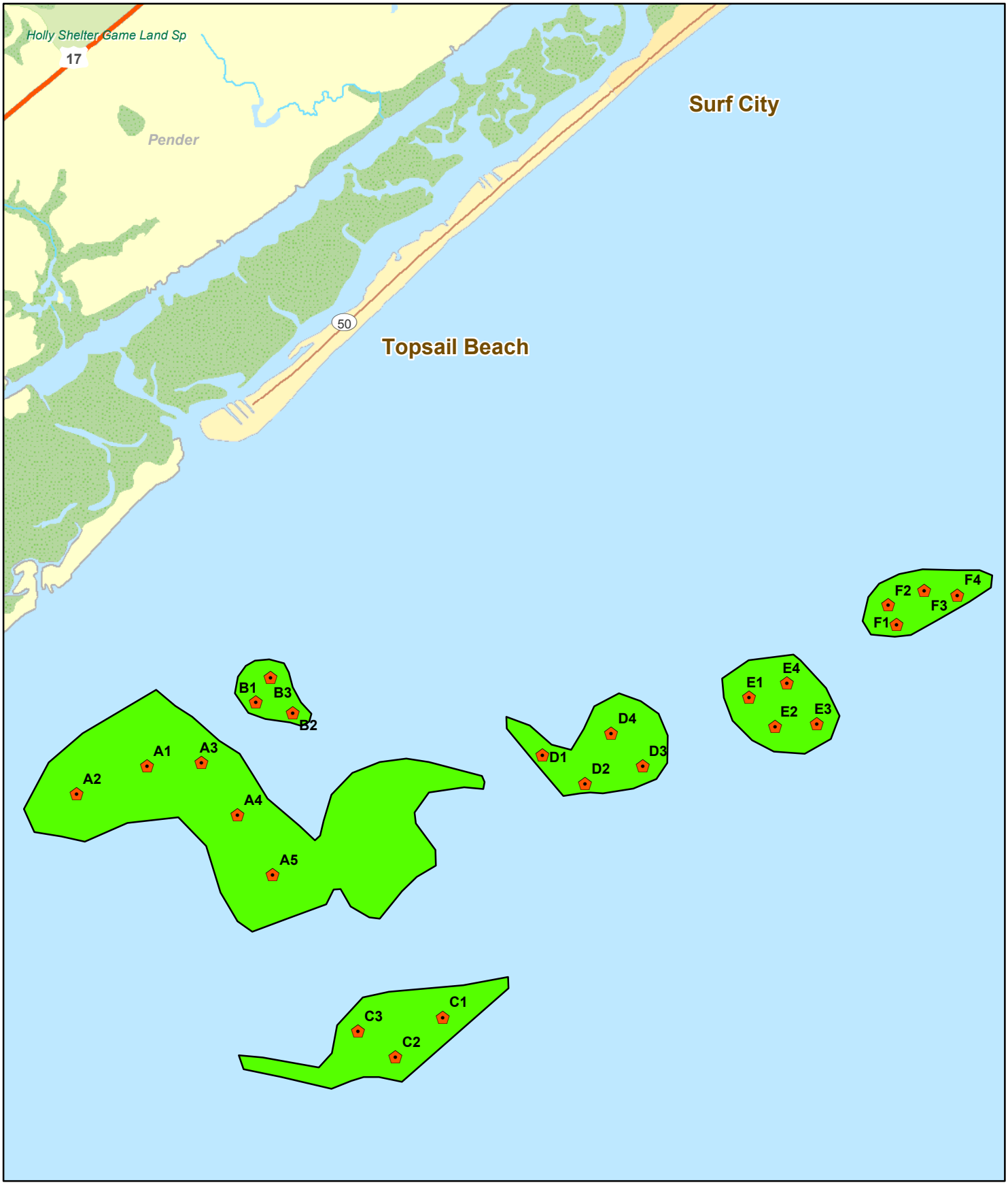


Legend

Topsail Beach Borrow Sites

0 2 4 6 8 Miles

Location of Borrow Sites off Topsail Beach	
Topsail Beach Benthic Community Characterization Survey, Pender County, NC	
Scale: 1 inch = 2 miles	Drawn By: MR
Date: April 2007	Approved By: SD
DIAL CORDY AND ASSOCIATES INC Environmental Consultants	J06-0989
	Figure 1



Legend

- Benthic Sampling Station
- Topsail Beach Borrow Sites

0 6,000 12,000 18,000 24,000 Feet

Location of Benthic Sampling Stations off Topsail Beach	
Topsail Beach Benthic Community Characterization Survey, Pender County, NC	
Scale: 1 inch = 6,000 feet	Drawn By: MR
Date: April 2007	Approved By: SD
DIAL CORDY AND ASSOCIATES INC Environmental Consultants	J06-0989
	Figure 2

Table 1. Depths and location coordinates for benthic sampling stations off Topsail Beach, NC.

Borrow Site Station	Depth (m)	Station Coordinates	
A1	13.7	34°18'16.072"	77°39'47.647"
A2	13.3	34°18'02.486"	77°40'21.868"
A3	13.3	34°18'18.236"	77°39'14.008
A4	14.2	34°17'54.945"	77°38'53.466"
A5	15.1	34°17'28.093"	77°38'33.163"
B1	12.2	34°18'46.266"	77°38'44.909"
B2	13.5	34°18'41.749"	77°38'24.575"
B3	13.2	34°18'57.558"	77°38'37.370"
C1	14.1	34°16'25.432"	77°36'58.081"
C2	14.9	34°16'06.703"	77°37'23.427"
C3	14.6	34°16'18.018"	77°37'44.459"
C4	15.2	34°15'57.406"	77°38'16.160"
D1	14.2	34°18'25.705"	77°36'07.197"
D2	15.3	34°18'13.213"	77°35'43.565"
D3	14.9	34°18'21.953"	77°35'12.038"
D4	14.3	34°18'36.383"	77°35'29.818"
E1	15.7	34°18'54.333"	77°34'14.820"
E2	15.4	34°18'41.374"	77°34'00.078"
E3	14.7	34°18'43.009"	77°33'37.360"
E4	15.3	34°19'01.135"	77°33'54.375"
F1	15.8	34°19'29.216"	77°32'55.069"
F2	15.4	34°19'37.710"	77°32'59.961"
F3	15.5	34°19'44.872"	77°32'40.239"
F4	14.7	34°19'43.171"	77°32'22.118"

3.0 RESULTS

The following results include a review of data pertaining to sediment grain-size analysis, faunal composition, species richness, diversity indices, faunal abundance, and biomass. A sediment analysis report prepared by Dr. Wayne Isfording is provided in Appendix B. Appendix C contains individual data summary reports for each sampling station and Appendix D includes the biomass data for all sampling stations and other supporting tables.

3.1 Sediment Grain-size Analysis

Results of the sediment grain-size analysis are summarized in Table 2 for each sampling station. The mean percent sand for Sites A, B, C, D, E, and F were 99.31%, 98.09%, 99.78%, 99.24%, 99.81%, and 99.84; respectively. The mean percent silt-clay fraction was 0.94%, 1.91%, 0.21%, 0.76%, 0.19%, and 0.16% for Sites A through F; respectively. The highest silt-clay content was recorded for Station B-2, with 5.31%; however, the fine fraction left was considered coarse silt rather than clay. The median particle size and sorting

Table 2. Sediment analysis results for benthic sampling stations off Topsail Beach, NC.

Station	% Sand	% Silt + Clay	USACE Description	Median Particle Size (phi)	Sorting Coefficient
A1	98.73	1.27	Sand	2.515	0.454
A2	99.00	1.00	Sand	2.496	0.470
A3	99.22	0.78	Sand	2.476	0.433
A4	99.72	0.28	Sand	2.470	0.504
A5	99.89	0.11	Sand	2.436	0.497
B1	100.00	0.00	Sand	*	*
B2	94.69	5.31	Sand	2.449	0.609
B3	99.59	0.41	Sand	*	*
C1	99.92	0.08	Sand	2.413	0.488
C2	99.82	0.18	Sand	2.445	0.436
C3	99.78	0.22	Sand	2.465	0.429
C4	99.57	0.43	Sand	2.469	0.415
D1	99.86	0.14	Sand	2.268	0.708
D2	99.84	0.16	Sand	2.412	0.505
D3	99.94	0.06	Sand	2.358	0.643
D4	99.61	0.39	Sand	1.885	0.726
E1	97.57	2.43	Sand	2.344	0.627
E2	99.82	0.18	Sand	2.271	0.693
E3	99.95	0.05	Sand	1.679	0.663
E4	99.82	0.18	Sand	1.798	0.711
F1	99.67	0.33	Sand	2.217	0.714
F2	99.78	0.22	Sand	*	0.934
F3	99.85	0.15	Sand	2.375	0.571
F4	99.91	0.09	Sand	2.339	0.618

* Insufficient data for any statistical calculations (See Appendix B).

coefficient for Sites A and E varied little between sampling stations (Table 2), while these parameters varied more between sampling stations at Sites C and D. Median particle size (phi) and sorting coefficients for Stations B-1, B-3, and F-2 could not be statistically calculated due to insufficient data (See Appendix B).

3.2 Faunal Composition

A total of 104 taxa were collected from the 24 samples collected within the six proposed borrow sites (Table 3). Of the taxa collected, the dominant faunal groups included polychaetes (43), crustaceans (26), mollusks (24), and echinoderms (6). Major taxa composition within each of the six borrow sites are illustrated in Figure 3 and Table 4. As shown, polychaetes were the major component of the benthos within all borrow sites; except for Site C, where crustaceans were more prevalent. The taxa within Site D were generally distributed evenly between polychaetes, mollusks, and crustaceans. Other, less frequently occurring faunal groups, included rhynchocoela (ribbon worms) that occurred within all five borrow sites, ranging from 2.6% to 4.8% of the total taxa collected; and echinoderms, which occurred within four of the five borrow sites, ranging from 3.8% to 14.3% of the total taxa collected. The total number of taxa collected within all of the samples taken at each borrow site ranged from a low of 21 taxa at Site C (n=4) to a high of 39 taxa at Sites B (n=3), E (n=4), and F (n=4) (Table 4).

Based on the total count of individuals collected per taxa within each borrow site, polychaetes were the dominant taxa at Sites A, B, D, and F. Polychaetes comprised greater than 30% of the total count (Table 4, Figure 3). Mollusks were the dominant taxa at Site E (44.6%) and secondary dominant taxa at Sites A (37.5%), B (15.4%), D (31.7%), and E (44.6%). The distribution of the total number of individuals within all Site F samples were fairly evenly distributed between the three most abundant taxa groups (polychaetes, mollusks, and crustaceans).

3.3 Species Richness

The mean number of species present within the six borrow sites ranged from a low of 7.8 within Site C to a high of 16.7 within Site B. The mean number of species present within Sites A (8.4) and D (8) were similar to Site C, while the mean number of species within Site E (15.8) was more similar to the mean number of species present within Site B. The mean number of species within Site F was 12.3 (Figure 4, Table 5). The total number of taxa collected within Sites C and D was also lower than observed within the other four sites (Table 4).

3.4 Diversity Indices

Diversity indices were calculated for each sample collected within the borrow sites (Table 5). Mean Shannon Wiener indices and Pielou Evenness values for the six borrow sites are illustrated on Figure 5. Diversity values expressed as one of the three diversity indices were consistently higher at Sites B, E, and F. High Evenness (J´) and Equitability (e) values for samples collected within the six borrow sites indicate that within each station, the abundance was evenly distributed among the taxa collected. Evenness values were greater than 0.90 at all but two of the 24 stations. Mean evenness values for the six sites ranged from 0.91 at Site E to 0.96 at Sites A and D. Variability in the evenness values within each site was highest at Site F (Figure 5).

Table 3. Taxonomic species list for benthic sampling stations off Topsail Beach, NC.

ANNELIDA
- CLASS OLIGOCHAETA
  - Order TUBIFICIDA
    - FAMILY ENCHYTRAEIDAE
      - *Enchytraeidae (LPIL)*
    - FAMILY TUBIFICIDAE
      - *Tubificidae (LPIL)*
- CLASS POLYCHAETA
  - Order CAPITELLIDA
    - FAMILY CAPITELLIDAE
      - *Capitellidae (LPIL)*
      - *Mediomastus (LPIL)*
      - *Mediomastus californiensis*
    - FAMILY MALDANIDAE
      - *Maldanidae (LPIL)*
  - Order EUNICIDA
    - FAMILY DORVILLEIDAE
      - *Schistomeringos pectinata*
    - FAMILY LUMBRINERIDAE
      - *Lumbrineris latreilli*
    - FAMILY OENONIDAE
      - *Arabella multidentata*
    - FAMILY ONUPHIDAE
      - *Onuphidae (LPIL)*
  - Order OPHELIIDA
    - FAMILY OPHELIIDAE
      - *Opheliidae (LPIL)*
      - *Armandia (LPIL)*
      - *Armandia maculata*
      - *Ophelia denticulata*
  - Order ORBINIIDA
    - FAMILY PARAONIDAE
      - *Aricidea (LPIL)*
      - *Aricidea catherinae*
      - *Aricidea suecica*
      - *Aricidea wassi*
      - *Cirrophorus (LPIL)*
  - Order OWENIIDA
    - FAMILY OWENIIDAE
      - *Owenia fusiformis*
  - Order PHYLLODOCIDA
    - FAMILY CHRYSOPETALIDAE
      - *Bhawania heteroseta*
    - FAMILY GLYCERIDAE
      - *Glyceridae (LPIL)*
    - FAMILY GONIADIDAE
      - *Goniada littorea*
      - *Goniadides carolinae*
    - FAMILY HESIONIDAE
      - *Microphthalmus (LPIL)*
    - FAMILY NEPHTYIDAE
      - *Aglaophamus verrilli*
      - *Nephtys picta*
      - *Nephtys simoni*
    - FAMILY NEREIDAE
      - *Nereididae (LPIL)*
      - *Ceratocephale oculata*
    - FAMILY PHYLLODOCIDAE
      - *Eumida sanguinea*
    - FAMILY PILARGIIDAE
      - *Ancistrosyllis (LPIL)*
      - *Ancistrosyllis hartmanae*
      - *Sigambra tentaculata*
  - Order SPIONIDA
    - FAMILY CHAETOPTERIDAE
      - *Spiochaetopterus oculatus*
    - FAMILY CIRRATULIDAE
      - *Cirratulidae (LPIL)*
      - *Caulleriella sp. J*
    - FAMILY MAGELONIDAE
      - *Magelona (LPIL)*
      - *Magelona papillicornis*
      - *Magelona pettiboneae*
    - FAMILY SPIONIDAE
      - *Spionidae (LPIL)*
      - *Paraprionospio pinnata*
      - *Spiophanes bombyx*
  - Order TEREBELLIDA
    - FAMILY PECTINARIIDAE
      - *Pectinaria gouldii*
    - FAMILY TEREBELLIDAE
      - *Terebellidae (LPIL)*

ARTHROPODA
- CLASS MALACOSTRACA
  - Order AMPHIPODA
    - Amphipoda (LPIL)
    - FAMILY AORIDAE
      - *Rildardanus laminosa*
      - *Unciola serrata*
    - FAMILY HAUSTORIIDAE
      - *Acanthohaustorius intermedius*
    - FAMILY ISAEIDAE
      - *Microprotopus raneyi*
    - FAMILY MELITIDAE
      - *Maera caroliniana*
    - FAMILY OEDICEROTIDAE
      - *Oedicerotidae (LPIL)*
      - *Americhelidium americanum*
    - FAMILY PHOXOCEPHALIDAE
      - *Metharpinia floridana*
      - *Rhepoxynius hudsoni*
    - FAMILY PLATYISCHNOPIDAE
      - *Eudevenopus honduranus*
    - FAMILY SYNOPIIDAE
      - *Metatiron (LPIL)*
      - *Metatiron triocellatus*
  - Order CUMACEA
    - FAMILY DIASTYLIDAE
      - *Oxyurostylis (LPIL)*
  - Order DECAPODA
    - FAMILY PAGURIDAE
      - *Pagurus (LPIL)*
    - FAMILY PASIPHAEIDAE
      - *Leptochela serratorbita*
    - FAMILY PINNOTHERIDAE
      - *Dissodactylus mellitae*
- CLASS OSTRACODA
  - Order MYODOCOPINA
    - FAMILY PHILOMEDIDAE
      - *Philomedidae (LPIL)*
      - *Harbansus paucichelatus*
    - FAMILY SARSIELLIDAE
      - Eusarsiella (LPIL)
      - *Eusarsiella radiicosta*
      - *Eusarsiella texana*

Table 3. (concluded)

Order PODOCOPIDA
Podocopida (LPIL)
BRYOZOA
Bryozoa (LPIL)
CHORDATA
CLASS LEPTOCARDIA
Order AMPHIOXI
FAMILY BRANCHIOSTOMIDAE
Branchiostoma (LPIL)
CNIDARIA
CLASS HYDROZOA
Hydrozoa (LPIL)
ECHINODERMATA
Echinodermata (LPIL)
CLASS ECHINOIDEA
Echinoidea (LPIL)
Order CLYPEASTEROIDA
FAMILY MELLITIDAE
Mellitidae (LPIL)
Mellita isometra
CLASS OPHIUROIDEA
Ophiuroidea (LPIL)
Order OPHIURIDA
FAMILY AMPHIURIDAE
Amphiuridae (LPIL)
MOLLUSCA
CLASS BIVALVIA
Bivalvia (LPIL)
Order OSTREOIDA
FAMILY ANOMIIDAE
Anomia simplex
Order VENEROIDA
FAMILY CRASSATELLIDAE
Crassinella dupliniana
Crassinella lunulata
FAMILY LUCINIDAE
Lucinidae (LPIL)
Lucina (LPIL)
Lucina multilineata
FAMILY MESODESMATIDAE
Ervilia concentrica
FAMILY MONTACUTIDAE
Montacutidae (LPIL)
FAMILY SEMELIDAE
Semelidae (LPIL)
FAMILY TELLINIDAE
Strigilla mirabilis
Tellina (LPIL)
Tellina iris
CLASS GASTROPODA
Order CEPHALASPIDEA
FAMILY SCAPHANDRIDAE
Acteocina canaliculata
Cylichna alba
Order MESOGASTROPODA
FAMILY CAECIDAE
Caecum pulchellum
FAMILY EULIMIDAE
Strombiformis bilineatus
FAMILY NATICIDAE
Tectonatica pusilla
Order NEOGASTROPODA
FAMILY OLIVIDAE
Olivella dealbata
Oliva sayana
FAMILY TURRIDAE
Kurtziella atrostyla
Order PYRAMIDELLOIDA
FAMILY PYRAMIDELLIDAE
Odostomia weberi
Turbonilla (LPIL)
PHORONIDA
FAMILY PHORONIDAE
Phoronis (LPIL)
PLATYHELMINTHES
CLASS TURBELLARIA
Turbellaria (LPIL)
RHYNCHOCOELA
Rhynchocoela (LPIL)
SIPUNCULA
FAMILY ASPIDOSIPHONIDAE
Aspidosiphon albus

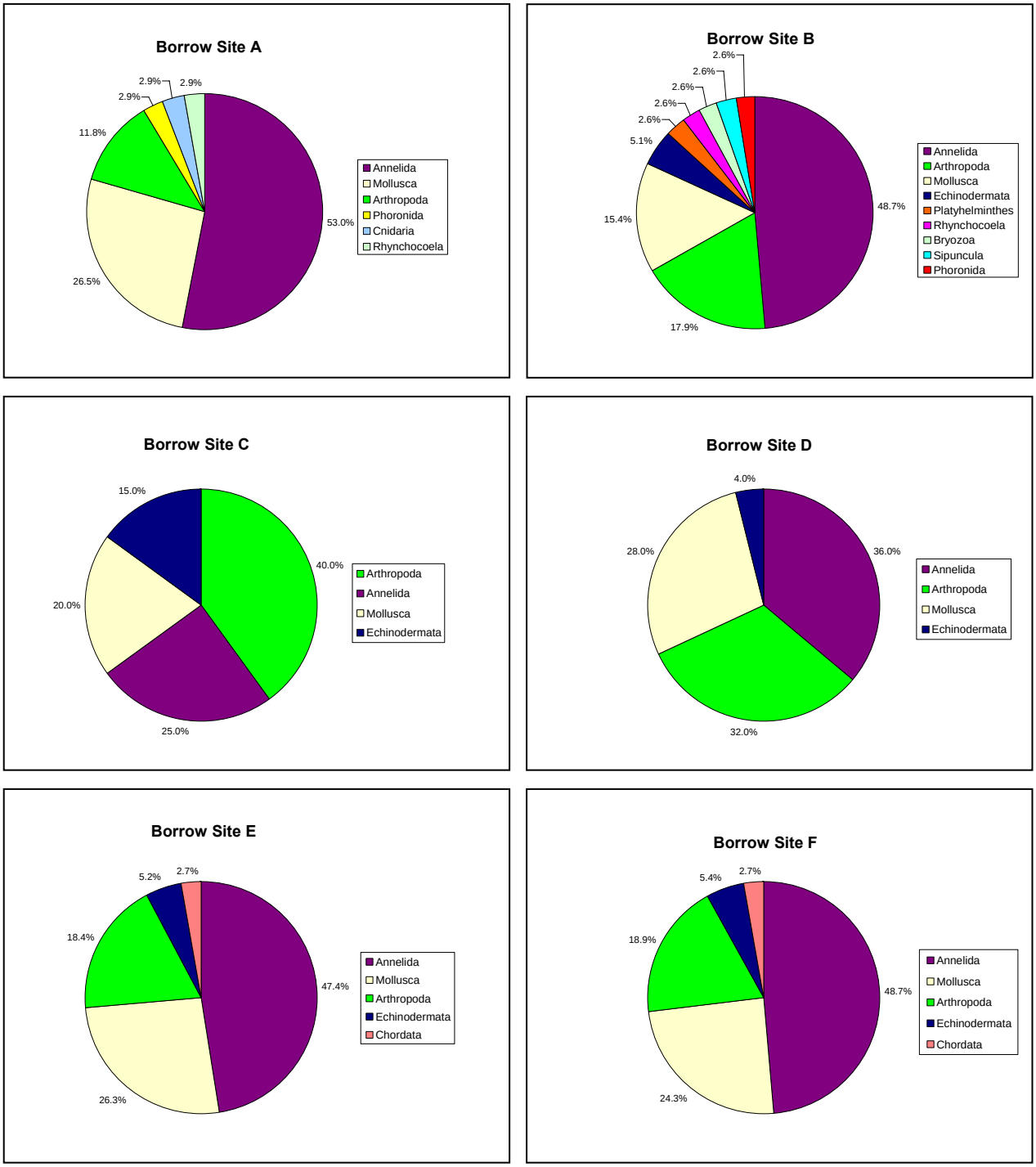


Figure 3. Relative composition of major taxa for borrow sites off Topsail Beach, NC.

Table 4. Comparison of major taxa occurrences and relative abundances for borrow sites off Topsail Beach, NC.

Site	Cnidaria	Rhynchocoela	Annelida	Mollusca	Platyhelminthes	Arthropoda	Bryozoa	Sipuncula	Phoronida	Echinodermata	Chordata	Total Per Site
Borrow Site A (n=5)												
Total # Taxa	1	1	18	9		4			1			34
Taxa % Total	2.9%	2.9%	52.9%	26.5%		11.8%			2.9%			
Total # Ind.	1	1	27	21		5			1			56
Ind. % Total	1.8%	1.8%	48.2%	37.5%		8.9%			1.8%			
Borrow Site B (n=3)												
Total # Taxa		1	19	6	1	7	1	1	1	2		39
Taxa % Total		2.6%	48.7%	15.4%	2.6%	17.9%	2.6%	2.6%	2.6%	5.1%		
Total # Ind.		3	44	16	4	9	1	1	1	9		88
Ind. % Total		3.4%	50.0%	18.2%	4.5%	10.2%	1.1%	1.1%	1.1%	10.2%		
Borrow Site C (n=4)												
Total # Taxa		1	5	4		8				3		21
Taxa % Total		4.8%	23.8%	19.0%		38.1%				14.3%		
Total # Ind.		1	12	16		20				6		55
Ind. % Total		1.8%	21.8%	29.1%		36.4%				10.9%		

Table 4. (concluded)

Site	Cnidaria	Rhynchocoela	Annelida	Mollusca	Platyhelminthes	Arthropoda	Bryozoa	Sipuncula	Phoronida	Echinodermata	Chordata	Total Per Site
Borrow Site D (n=4)												
Total # Taxa		1	9	7		8				1		26
Taxa % Total		3.8%	34.6%	26.9%		30.8%				3.8%		
Total # Ind.		1	15	13		11				1		41
Ind. % Total		2.4%	36.6%	31.7%		26.8%				2.4%		
Borrow Site E (n=4)												
Total # Taxa		1	18	10		7				2	1	39
Taxa % Total		2.6%	46.2%	25.6%		17.9%				5.1%	2.6%	
Total # Ind.		4	31	50		23				2	2	112
Ind. % Total		3.6%	27.7%	44.6%		20.5%				1.8%	1.8%	
Borrow Site F (n=4)												
Total # Taxa		1	18	9	1	7				2	1	39
Taxa % Total		2.6%	46.2%	23.1%	2.6%	17.9%				5.1%	2.6%	
Total # Ind.		3	23	21	1	21				4	3	76
Ind. % Total		3.9%	30.3%	27.6%	1.3%	27.6%				5.3%	3.9%	

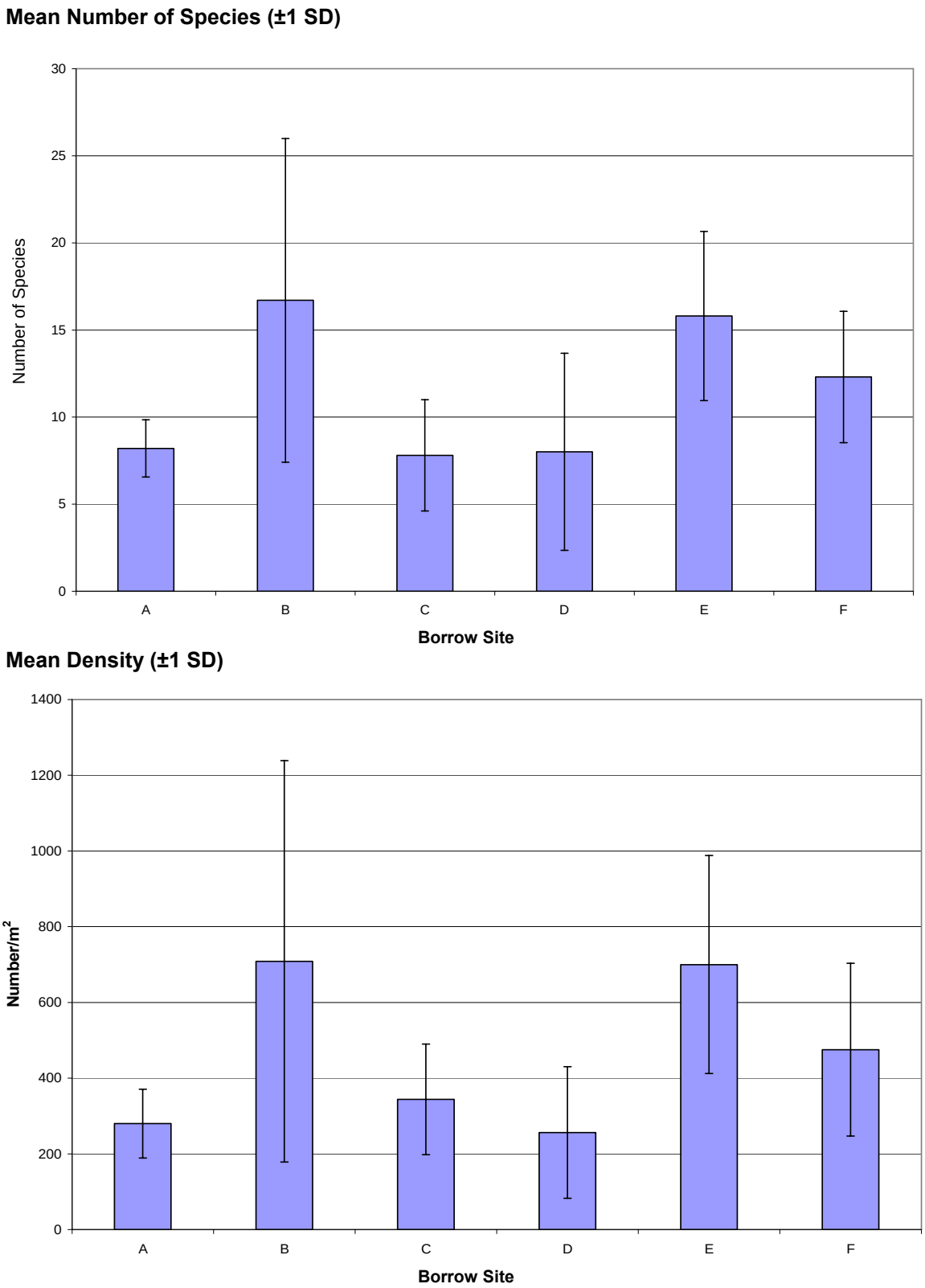
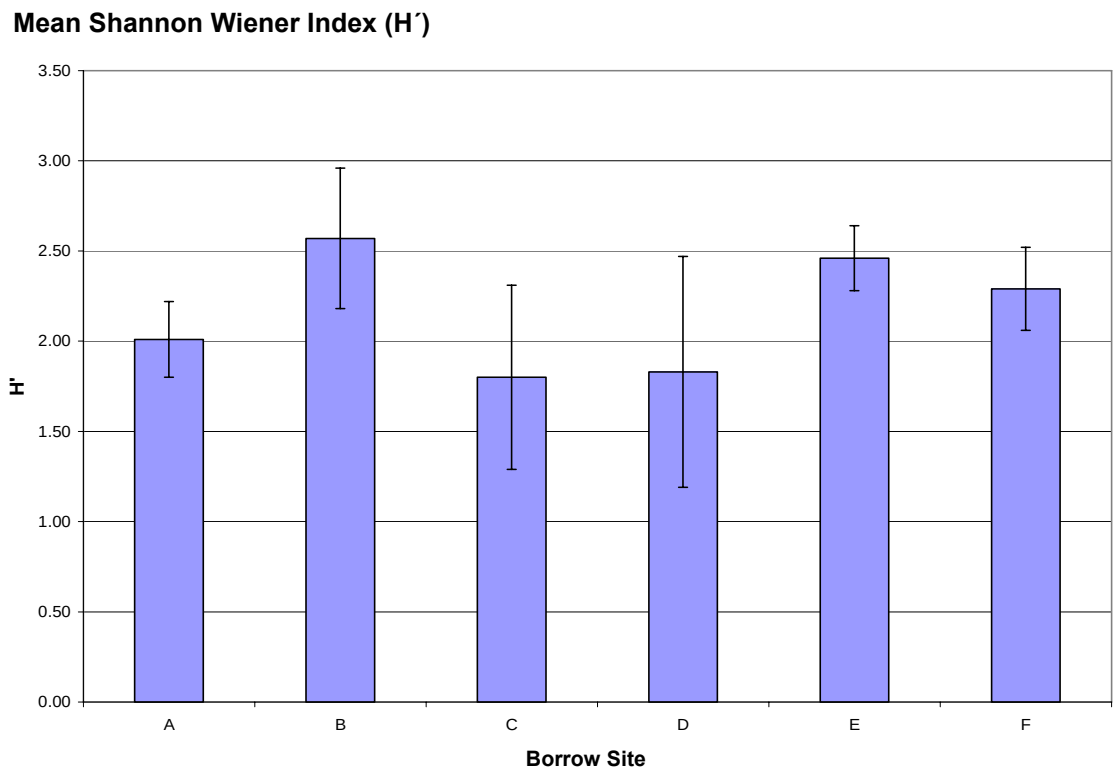


Figure 4. Mean number of species and density within borrow sites off Topsail Beach, NC.

Table 5. Summary of community parameters for benthic sampling stations off Topsail Beach, NC.

Station	Total No. Taxa	Total No. Individuals	Density (nos/m^2)	H' Shannon (log e)	d Diversity (log 2)	1/S Simpson Diversity	J' Pielou Evenness	D Margalef Richness	e Equitability
A1	6	7	175.0	1.75	2.52	21.00	0.98	2.57	1.33
A2	10	17	425.0	2.18	3.15	13.60	0.95	3.18	1.25
A3	9	10	250.0	2.16	3.12	45.00	0.98	3.47	1.37
A4	9	11	275.0	2.15	3.10	27.50	0.98	3.34	1.34
A5	7	11	275.0	1.80	2.59	9.17	0.92	2.50	1.20
B1	14	25	625.0	2.53	3.65	20.00	0.96	4.04	1.29
B2	9	9	225.0	2.20	3.17		1.00	3.64	1.41
B3	27	51	1275.0	2.98	4.29	19.92	0.90	6.61	1.06
C1	3	5	125.0	1.05	1.52	5.00	0.96	1.24	1.29
C2	9	17	425.0	2.04	2.94	10.46	0.93	2.82	1.20
C3	9	16	400.0	1.98	2.85	8.57	0.90	2.89	1.12
C4	10	17	425.0	2.15	3.10	12.36	0.93	3.18	1.21
D1	4	4	100.0	1.39	2.00		1.00	2.16	1.37
D2	8	10	250.0	1.97	2.85	15.00	0.95	3.04	1.26
D3	4	7	175.0	1.28	1.84	5.25	0.92	1.54	1.22
D4	16	20	500.0	2.67	3.85	31.67	0.96	5.01	1.30
E1	11	15	375.0	2.27	3.27	17.50	0.95	3.69	1.25
E2	13	26	650.0	2.34	3.38	11.21	0.91	3.68	1.14
E3	22	43	1075.0	2.64	3.82	10.38	0.86	5.58	0.92
E4	17	28	700.0	2.58	3.72	14.00	0.91	4.80	1.12
F1	9	9	225.0	2.20	3.17		1.00	3.64	1.41
F2	16	24	600.0	2.64	3.80	23.00	0.95	4.72	1.26
F3	9	14	350.0	2.14	3.09	18.20	0.98	3.03	1.34
F4	15	29	725.0	2.20	3.17	5.88	0.81	4.16	0.85



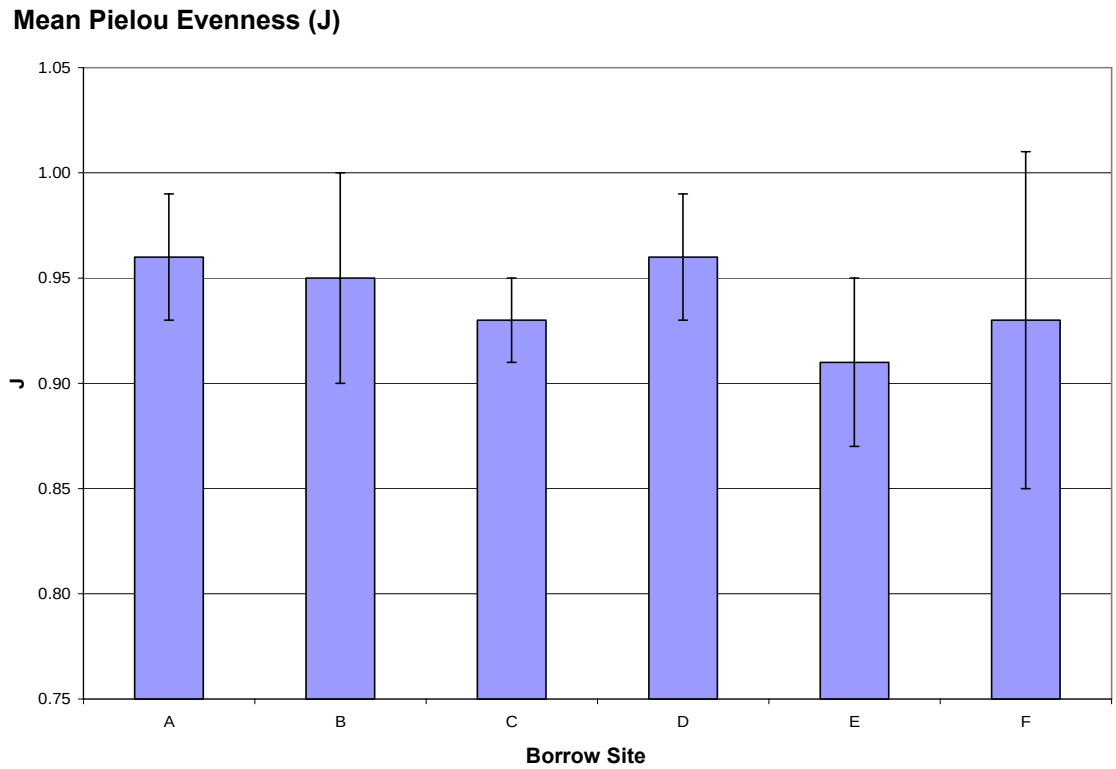


Figure 5. Mean Shannon Wiener index (H´) and Pielou Evenness value for borrow sites off Topsail Beach, NC.

3.5 Faunal Abundance

The total count and density of the benthic community collected at each station within the six borrow sites is provided in Table 5. The abundance and density for each species occurrence is provided in Tables D-1 and D-2 (Appendix D). A total of 425 individuals were collected during the study, ranging from a mean density of 256 individuals/m^2 within Site D to 708 individuals/m^2 at Site B (Figure 4). Variability in the density within each borrow site was highest at Site B, which ranged from 225 individuals/m^2 to 1,275 individuals/m^2 (n=3); followed by Site E, where density ranged from 375 individuals/m^2 to 1,075 individuals/m^2 (n=4). Mean density at Sites A, C, and D were all low compared to the mean density at Sites B, E, and F.

The ten most abundant species were: the polychaetes *Magelona papillicornis*, *Goniada littorea*, and *Goniadides carolinae*; the amphipod *Eudovenopus honduranus*; the bivalves *Crassinella lunicata*, *Lucinidae(LPIL)*, and *Tellina (LPIL)*; the gastropod *Caecum pulchellum*; the echinoderm *Ophiuroidea (LPIL)*; and the ribbon worm *Rhynchocoela (LPIL)*. These ten species together comprised 47.4% of the benthic infauna collected (Table 6). Other species found within at least two of the sites, and comprising about 2% of the total abundance included: the polychaetes *Onuphidae (LPIL)*, *Armandia maculata*, *Bhawania heteroseta*, and *Spionidae (LPIL);* the bivalve *Crassinella dupliniana*; and the gastropods *Acteocina canaliculata* and *Cylichna alba*. Of the balance of species remaining, 79 species each comprised less than 1% of the total abundance.

3.6 Biomass

The biomass for major faunal groups collected at all sampling stations is summarized in Table D-3 of Appendix D, while the mean biomass (g/m^2) for major faunal groups within each site is provided in Table 7. Mean biomass was lowest at Site A (36.69 g/m^2) and Site D (41.59 g/m^2); similar between Sites B (69.53 g/m^2), Site E (59.08 g/m^2), and Site F (57.85 g/m^2); and highest at Site C (182.61 g/m^2). Site C is skewed higher due to the occurrence of brittle stars (*Ophiuroidea*), which weigh more than other taxa present. Excluding this epibenthic taxa, the mean biomass for Site C would be 44.88 g/m^2.

Table 6. Total abundance and percent composition for taxa collected at borrow sites off Topsail Beach, NC.

Species	Total Count Per Site						% of Total
	A	B	C	D	E	F	
Enchytraeidae (LPIL)		2					0.48
Tubificidae (LPIL)		1					0.24
Capitellidae (LPIL)	1						0.24
Mediomastus (LPIL)		4			1		1.20
Mediomastus californiensis	1						0.24
Maldanidae (LPIL)					1		0.24
Schistomeringos pectinata		1					0.24
Lumbrineris latreilli				1		1	0.48
Arabella multidentata					1		0.24
Onuphidae (LPIL)	1	1	2	1		2	1.67
Opheliidae (LPIL)					2	1	0.72
Armandia (LPIL)					1		0.24
Armandia maculata	1	1	3		2		1.67
Ophelia denticulata						1	0.24
Aricidea (LPIL)				1	1		0.48
Aricidea catherinae	1	1					0.48
Aricidea suecica					1		0.24
Aricidea wassi				1	3		0.96
Cirrophorus (LPIL)		1			1		0.48
Owenia fusiformis	1			1			0.48
Bhawania heteroseta		7				1	1.91
Glyceridae (LPIL)	2	1	1		1		1.20
Goniada littorea	1		5	4	4	2	3.83
Goniadides carolinae		9				2	2.63
Microphthalmus (LPIL)						1	0.24
Aglaophamus verrilli	1						0.24
Nephtys picta						2	0.48
Nephtys simoni						1	0.24
Nereididae (LPIL)		1					0.24
Ceratocephale oculata					1	2	0.72
Eumida sanguinea		1					0.24
Ancistrosyllis (LPIL)		1			1		0.48
Ancistrosyllis hartmanae		1			1		0.48
Sigambra tentaculata	1						0.24
Spiochaetopterus oculatus	1		1				0.48
Cirratulidae (LPIL)		2				1	0.72
Caulleriella sp. J	4	1				1	1.44
Magelona (LPIL)	3						0.72

Table 6. (continued)

Species	Total Count Per Site						
	A	B	C	D	E	F	% of Total
Magelona papillicornis	3			4	7	2	3.83
Magelona pettiboneae						1	0.24
Spionidae (LPIL)	1	4		1	1	1	1.91
Paraprionospio pinnata	1				1	1	0.72
Spiophanes bombyx				1			0.24
Pectinaria gouldii	1						0.24
Terebellidae (LPIL)		1					0.24
Amphipoda (LPIL)			1	1			0.48
Rildardanus laminosa		1					0.24
Unciola serrata		1					0.24
Acanthohaustorius intermedius						2	0.48
Microprotopus raneyi		2					0.48
Maera caroliniana		2				1	0.72
Oedicerotidae (LPIL)		1					0.24
Americhelidium americanum				1	1		0.48
Metharpinia floridana					1		0.24
Rhepoxynius hudsoni			2	1	1	1	1.20
Eudevenopus honduranus			10	4	17	14	10.77
Metatiron (LPIL)		1					0.24
Metatiron triocellatus		1					0.24
Oxyurostylis (LPIL)				1	1	1	0.72
Pagurus (LPIL)		1			1		0.48
Leptochela serratorbita							
Dissodactylus mellitae			2				0.48
Philomedidae (LPIL)					1		0.24
Harbansus paucichelatus					1		0.24
Eusarsiella (LPIL)	1						0.24
Eusarsiella radiicosta						1	0.24
Eusarsiella texana	1		2	1	1	1	1.44
Podocopida (LPIL)			1				0.24
Bryozoa (LPIL)		1					0.24
Branchiostoma (LPIL)					2	3	1.20
Hydrozoa (LPIL)	1						0.24
Echinodermata (LPIL)					1		0.24
Echinoidea (LPIL)			2				0.48
Mellitidae (LPIL)						2	0.48
Mellita isometra			1				0.24
Ophiuroidea (LPIL)		8	3	1	1	2	3.59
Amphiuridae (LPIL)		1					0.24
Bivalvia (LPIL)	2	1					0.72

Table 6. (concluded)

Species	Total Count Per Site						
	A	B	C	D	E	F	% of Total
Anomia simplex						1	0.24
Crassinella dupliniana					4	4	1.91
Crassinella lunulata		10	2	3			3.59
Lucinidae (LPIL)	2			1	3	3	2.15
Lucina (LPIL)				1			0.24
Lucina multilineata		1			3		0.96
Ervilia concentrica	1			1		1	0.72
Montacutidae (LPIL)					1		0.24
Semelidae (LPIL)		1					0.24
Strigilla mirabilis					2		0.48
Tellina (LPIL)	5	1	9	1	3		4.54
Tellina iris	1						0.24
Acteocina canaliculata	1		1	1	4	1	1.91
Cylichna alba	5		2	1			1.91
Caecum pulchellum		1	4	7	24	3	9.33
Strombiformis bilineatus					2		0.48
Tectonatica pusilla		1			2		0.72
Oliva sayana	3						0.72
Olivella dealbata						2	0.48
Kurtziella atrostyla						1	0.24
Odostomia weberi	1						0.24
Turbonilla (LPIL)						1	0.24
Phoronis (LPIL)	1	1					0.48
Turbellaria (LPIL)		4				1	1.20
Rhynchocoela (LPIL)	1	3	1	1	4	3	3.11
Aspidosiphon albus		1					0.24

Table 7. Mean biomass of major taxa at borrow sites off Topsail Beach, NC.

Borrow Site A	
Faunal Group	**gm/m²**
Annelida	14.3835
Mollusca	14.0410
Arthropoda	5.5235
Echinodermata	0.0000
Other Taxa	2.7450
Total	36.6930

Borrow Site D	
Faunal Group	**gm/m²**
Annelida	14.1350
Mollusca	13.7320
Arthropoda	6.8550
Echinodermata	3.4325
Other Taxa	3.4325
Total	41.5881

Borrow Site B	
Faunal Group	**gm/m²**
Annelida	13.9200
Mollusca	13.7866
Arthropoda	13.9208
Echinodermata	13.9516
Other Taxa	13.9500
Total	69.5291

Borrow Site E	
Faunal Group	**gm/m²**
Annelida	14.0706
Mollusca	13.8350
Arthropoda	14.0100
Echinodermata	6.8643
Other Taxa	10.2950
Total	59.0750

Borrow Site C	
Faunal Group	**gm/m²**
Annelida	13.8419
Mollusca	13.7693
Arthropoda	13.8356
Echinodermata	137.7275
Other Taxa	3.4350
Total	182.6093

Borrow Site F	
Faunal Group	**gm/m²**
Annelida	15.0306
Mollusca	13.9231
Arthropoda	13.8325
Echinodermata	3.4350
Other Taxa	11.6306
Total	57.8518

4.0 DISCUSSION

In comparison to the results of baseline sampling performed for the Kure Beach restoration project (Posey and Alphin 2000, 2002) and for the Dare County beach shoreline protection project (Versar 2006), the benthic community found offshore of Topsail Beach was less diverse and abundant. Since the Topsail Beach benthic sampling in this survey was only performed in late fall/early winter, comparisons to other surveys should focus on the same seasonal time frame.

Baseline sampling performed off Kure Beach in October 1995 found 44 and 76 taxa, and faunal densities of 1,007 individuals/m^2 and 923 individuals/m^2, respectively, for the borrow and control sites (Posey and Alphin 2000). The number of total taxa occurring within each proposed borrow site off Topsail Beach ranged from 21 to 39 taxa, while mean density by site ranged from 280 individuals/m^2 to 708 individuals/m^2. Posey and Alphin (2000) reported 600 total taxa collected from the year long study, as compared to the 104 total taxa collected for the one-time sampling performed for the Topsail Beach study. However, the Kure Beach study was more extensive in that it involved five sampling periods, replicate samples at each location, and covered a variety of benthic substrates (some adjacent to hard bottom communities). All of these factors would be expected to yield a more diverse benthic community. The community studied off Kure Beach was dominated by polychaetes, with 29 taxa comprising at least 5% of the individuals sampled from a single sampling event. Off Topsail Beach, polychaetes dominated the community, comprising over 30% of the relative abundance at four of the six borrow sites.

Seasonal pre-construction benthic community sampling was performed within the proposed north borrow site and reference site for the Dare County shoreline protection project (Versar 2006). Sampling included benthic grabs at ten stations within each of the two sites during the four seasons from spring 2004 through winter 2005. A total of 168 taxa were collected during the study, with polychaetes being the dominant taxa group in occurrence and biomass, especially during the fall and winter. The mean number of taxa present in the fall at the proposed north borrow site was 16 (range of 8 to 26 taxa) and 8 (range of 6 to 11 taxa) in the winter. This is not too different than what was found in the six Topsail Beach borrow sites, where the mean number of species across the six borrow sites ranged from 8 to 17. However, the species richness in the Dare County reference site was significantly greater than the species richness found off Topsail Beach or in the Dare County proposed north borrow site. Mean faunal density in the fall at the Dare County proposed north borrow site (1,555 individuals/m^2) was slightly higher than the mean density within the Topsail Beach borrow sites (Figure 4, Table 5), while the mean density at the reference site (8,696 individuals/m^2) was significantly greater. Mean faunal density in the winter was exceptionally higher off Dare County than observed off Topsail Beach, with mean densities of 11,460 individuals/m^2 and 1,398 individuals/m^2 for the reference and borrow sites, respectively. The mean biomass of fall samples was 0.28 g/m^2 and 2.23 g/m^2 for the borrow and reference sites, respectively; as compared to a much higher mean biomass range of 37 g/m^2 to 182 g/m^2 for the six Topsail Beach borrow sites. This comparison also held true for the winter mean biomass values from Dare County.

In summary, the benthic community found within the six proposed borrow sites off Topsail Beach is similar in composition and taxa dominance to those described in other studies along the North Carolina and South Carolina coasts (Byrnes et al. 2003; Versar 2002, 2006; and

Posey and Alphin 2000, 2002). However, the number of species present and abundance were noticeably lower off Topsail Beach than found off Kure Beach (Posey and Alphin 2000) or Dare County (Versar 2006). It is likely that the differences between the benthic community off Topsail Beach, as reported here, and the two referenced studies are due to the more extensive sampling effort associated with baseline monitoring programs, as compared to a less intensive sampling regime for a general characterization study (e.g. ten sampling stations per site off Dare County as compared to three to five stations per site for this study)

5.0 LITERATURE CITED

Byrnes, M.R., R.M. Hammer, B.A. Vittor, S.W. Kelley, D.B. Snyder, J.M. Côté, J.S. Ramsey, T.D. Thibaut, N.W. Phillips, J.D. Wood, and J.D. Germano. 2003. Collection of environmental data within sand resource areas offshore North Carolina and the environmental implications of sand removal for coastal and beach restoration. U.S. Department of the Interior, Minerals Management Service, Leasing Division, Sand and Gravel Unit, Herndon, VA. OCS Report MMS 2000-056, Volume I: Main Text 256 pp. + Volume II: Appendices 69 pp.

Posey, M.H. and T.D. Alphin. 2000. Monitoring of benthic faunal responses to sediment removal associated with the Carolina Beach and vicinity - Area South Project. Prepared for the Wilmington District, US Army Corps of Engineers, Wilmington, NC. 20 pp. plus appendices.

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Versar. 2002. Effects of dredged material beach disposal on surf zone and nearshore fish and benthic resources on Bald Head Island, Caswell Beach, Oak Island, and Holden Beach, North Carolina: Interim study findings. Prepared by Versar, Inc., Columbia, MD, for U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. 2 volumes.

Versar. 2006. Year one pre-construction environmental monitoring for the Dare County beach shoreline protection project, Dare County, North Carolina. Prepared by Versar Inc., Columbia, MD, for the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC. 5 sections plus appendices.

APPENDIX A

Data Quality Control Report

Table A-1. Data Quality Control Report

Date: 13 Nov 06
Wind speed/direction (estimated): NW @ 10-12 knots
Wave height (estimated): 1' swells within 2 miles of shore. Beyond 2 miles, 2', steep and building slightly throughout the day.
Water temperature: 60.9˚F
Vessel: F/V Emma K
Personnel on board: Capt. Jeff Coward, Duke Hunsaker
Sampling Equipment employed: Trimble GEO XT handheld gps (sub-meter accuracy)
SI-TEX CVS106 (120 kHz)
Standard Ponar grab

Sample Site	Time	Depth (m)	Sample Coordinates	Sediment Sample	Benthic sample?
F1	10:30	16.3		No	No
F1	10:40	16.3		No	No
F1	11:00	16.3		No	No
F1	11:25	16.3		No	No
F1	11:50	16.3		No	No
B1	12:15	13.4		No	No
B1	12:30	13.4		No	No
B1	12:50	13.4		No	No
B1	1:00	13.4		No	No
B1	1:20	13.4		No	No
B1	1:35	13.4		No	No
B1	1:45	13.4		No	No
B1	2:00	13.4		No	No
B1	2:20	13.4		No	No

Comments: Pot hauler works well in calm water, but sheaves aren't grooved deep enough. When trying to pull the sampler up in rolling sea, the line jumps off the pulley. To avoid injury and/or damage to the vessel, it was necessary to pull the ponar by hand all day. While we have listed 14 sampling attempts, there were numerous drops in between in which misfires occured or the ponar did not fire. When the ponar did fire properly, it was unable to penetrate the substrate. Only a light dusting of sand was retrieved with each grab. Not enough substrate for analysis. GPS points not taken, since no samples were obtained at the sites. Crossed the bar around 3:00pm. Off water at 3:45pm.

Table A-1. (continued)

Date: 28 Nov 06
Wind speed/direction (estimated): NE @ 10 knots
Wave height (estimated): 2-3' swells within 2.5 miles of shore. Beyond 2.5 miles, 3-4' rolling swells
Water temperature: 58.9˚F
Vessel: F/V Emma K
Personnel on board: Capt. Jeff Coward, Duke Hunsaker, Ryan Lewis
Sampling Equipment employed: Trimble GEO XT handheld gps (sub-meter accuracy)
SI-TEX CVS106 (120 kHz)
Wildco Shipek grab sampler
Plastic jars/labels prepared for each station

Sample Site	Time	Depth (m)	Sample Coordinates	Sediment Sample	Benthic sample?
A1	8:40	13.7	34°18'16.072"	Yes	Yes
			77°39'47.647"	Yes	Yes
A2	9:05	13.3	34°18'02.486"	Yes	Yes
			77°40'21.868"	Yes	Yes
A3	9:30	13.3	34°18'18.236"	Yes	Yes
			77°39'14.008"	Yes	Yes
A4	9:55	14.2	34°17'54.945"	Yes	Yes
			77°38'53.466"	Yes	Yes
A5	10:30	15.1	34°17'28.093"	Yes	Yes
			77°38'33.163"	Yes	Yes
D1	11:15	14.2	34°18'25.705"	Yes	Yes
			77°36'07.197"	Yes	Yes
D2	11:40	15.3	34°18'13.213"	Yes	Yes
			77°35'43.565"	Yes	Yes
D3	12:00	14.9	34°18'21.953"	Yes	Yes
			77°35'12.038"	Yes	Yes
D4	12:35	14.3	34°18'36.383"	Yes	Yes
			77°35'29.818"	Yes	Yes
E1	1:00	15.7	34°18'54.333"	Yes	Yes
			77°34'14.820"	Yes	Yes
E2	1:25	15.4	34°18'41.374"	Yes	Yes
			77°34'00.078"	Yes	Yes
E3	1:45	14.7	34°18'43.009"	Yes	Yes
			77°33'37.360"	Yes	Yes
E4	2:10	15.3	34°19'01.135"	Yes	Yes
			77°33'54.375"	Yes	Yes
F1	2:40	15.8	34°19'29.216"	Yes	Yes
			77°32'55.069"	Yes	Yes
F2	3:15	15.4	34°19'37.710"	Yes	Yes
			77°32'59.961"	Yes	Yes
F3	3:40	15.5	34°19'44.872"	Yes	Yes
			77°32'40.239"	Yes	Yes
F4	4:15	14.7	34°19'43.171"	Yes	Yes
			77°32'22.118"	Yes	Yes

Comments: Ponar replaced with Wildco Shipek grab sampler. Shipek grab very effective. Sampling went very smoothly. Crossed the bar approximately 5:00pm. Off water at 5:45pm.

Table A-1. (concluded)

Date: 29 Nov 06
Wind speed/direction (estimated): ENE @ 5-10 knots
Wave height (estimated): 2' swells within 2 miles of shore. Beyond 2 miles, 3' swells with occasional 4' swell. Sea slightly confused.
Water temperature: 59.2˚F
Vessel: F/V Emma K
Personnel on board: Capt. Jeff Coward, Duke Hunsaker, Ryan Lewis
Sampling Equipment employed: Trimble GEO XT handheld gps (sub-meter accuracy)
SI-TEX CVS106 (120 kHz)
Wildco Shipek grab sampler

Sample Site	Time	Depth (m)	Sample Coordinates	Sediment Sample	Benthic sample?
B1	9:30	12.2	34°18'46.266"	Yes	Yes
			77°38'44.909"	Yes	Yes
B2	10:00	13.5	34°18'41.749"	Yes	Yes
			77°38'24.575"	Yes	Yes
B3	10:20	13.2	34°18'57.558"	Yes	Yes
			77°38'37.370"	Yes	Yes
C1	10:55	14.1	34°16'25.432"	Yes	Yes
			77°36'58.081"	Yes	Yes
C2	11:20	14.9	34°16'06.703"	Yes	Yes
			77°37'23.427"	Yes	Yes
C3	11:40	14.6	34°16'18.018"	Yes	Yes
			77°37'44.459"	Yes	Yes
C4	11:55	15.2	34°15'57.406"	Yes	Yes
			77°38'16.160"	Yes	Yes

Comments: Sampling went smoothly. No problems. Crossed the bar at approximately 1:00pm. Off water at 1:45pm.

APPENDIX B

Sediment Analysis Report

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: A-1

PAN=0.52=1.09%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 47.33

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.54	1.14	98.86	1.14
500.00	1.00	.63	1.33	97.53	2.47
250.00	2.00	4.23	8.94	88.59	11.41
125.00	3.00	35.47	74.94	13.65	86.35
62.50	4.00	5.86	12.38	1.27	98.73

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 98.73

PERCENT SILT AND CLAY 1.27

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.28	PHI	410.98	MICRONS
PHI(16)	2.06	PHI	239.61	MICRONS
PHI(25)	2.18	PHI	220.47	MICRONS
PHI(50)	2.51	PHI	174.96	MICRONS
PHI(75)	2.85	PHI	138.84	MICRONS
PHI(84)	2.97	PHI	127.75	MICRONS
PHI(95)	3.70	PHI	77.02	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE A-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	1.14	98.86
.25	840.90	.8409E+00	1.47	98.53
.50	707.11	.7071E+00	1.81	98.19
.75	594.60	.5946E+00	2.14	97.86
1.00	500.00	.5000E+00	2.47	97.53
1.25	420.45	.4204E+00	4.71	95.29
1.50	353.55	.3536E+00	6.94	93.06
1.75	297.30	.2973E+00	9.17	90.83
2.00	250.00	.2500E+00	11.41	88.59
2.25	210.22	.2102E+00	30.14	69.86
2.50	176.78	.1768E+00	48.88	51.12
2.75	148.65	.1487E+00	67.62	32.38
3.00	125.00	.1250E+00	86.35	13.65
3.25	105.11	.1051E+00	89.45	10.55
3.50	88.39	.8839E-01	92.54	7.46
3.75	74.33	.7433E-01	95.64	4.36
4.00	62.50	.6250E-01	98.73	1.27

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-1

INMAN'S STATISTICS:

MEDIAN	2.515	PHI	174.955	MICRONS
MEAN	2.515	PHI	174.955	MICRONS
STANDARD DEVIATION	.454	WELL SORTED		
SKEWNESS	.000	NEAR-SYMMETRICAL		
KURTOSIS	1.662	VERY LEPTOKURTIC		

FOLK'S STATISTICS:

MEAN	2.515 PHI	174.955 MICRONS	
STANDARD DEVIATION	.593	MODERATELY WELL SORTED	
SKEWNESS	-.010	NEAR-SYMMETRICAL	
KURTOSIS	1.484	LEPTOKURTIC	

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MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

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ENGINEERING PARAMETERS:

D60	2.382 PHI	191.909 MICRONS
D30	2.782 PHI	145.409 MICRONS
D10	3.295 PHI	101.905 MICRONS
COEF. OF UNIFORMITY	1.883	
COEF. OF CURVATURE	1.081	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: A-2

PAN=0.26=0.60%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 42.99

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.18	.42	99.58	.42
500.00	1.00	.73	1.70	97.88	2.12
250.00	2.00	5.17	12.03	85.86	14.14
125.00	3.00	31.07	72.27	13.58	86.42
62.50	4.00	5.41	12.58	1.00	99.00

TEXTURAL CLASSIFICATION AND PHI PERCENTILES — SAMPLE A-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.00
PERCENT SILT AND CLAY	1.00

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.24	PHI	423.45	MICRONS
PHI(16)	2.03	PHI	245.59	MICRONS
PHI(25)	2.15	PHI	225.28	MICRONS
PHI(50)	2.50	PHI	177.25	MICRONS
PHI(75)	2.84	PHI	139.46	MICRONS
PHI(84)	2.97	PHI	127.93	MICRONS
PHI(95)	3.68	PHI	77.90	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES — SAMPLE A-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.42	99.58
.25	840.90	.8409E+00	.84	99.16
.50	707.11	.7071E+00	1.27	98.73
.75	594.60	.5946E+00	1.69	98.31
1.00	500.00	.5000E+00	2.12	97.88
1.25	420.45	.4204E+00	5.12	94.88
1.50	353.55	.3536E+00	8.13	91.87
1.75	297.30	.2973E+00	11.14	88.86

2.00	250.00	.2500E+00	14.14	85.86
2.25	210.22	.2102E+00	32.21	67.79
2.50	176.78	.1768E+00	50.28	49.72
2.75	148.65	.1487E+00	68.35	31.65
3.00	125.00	.1250E+00	86.42	13.58
3.25	105.11	.1051E+00	89.56	10.44
3.50	88.39	.8839E-01	92.71	7.29
3.75	74.33	.7433E-01	95.85	4.15
4.00	62.50	.6250E-01	99.00	1.00

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STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-2

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INMAN'S STATISTICS:

MEDIAN	2.496	PHI	177.251	MICRONS
MEAN	2.496	PHI	177.251	MICRONS
STANDARD DEVIATION	.470	WELL SORTED		
SKEWNESS	.000	NEAR-SYMMETRICAL		
KURTOSIS	1.596	VERY LEPTOKURTIC		

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FOLK'S STATISTICS:

MEAN	2.496	PHI	177.251	MICRONS
STANDARD DEVIATION	.605	MODERATELY WELL SORTED		
SKEWNESS	-.014	NEAR-SYMMETRICAL		
KURTOSIS	1.447	LEPTOKURTIC		

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MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

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ENGINEERING PARAMETERS:

D60	2.358	PHI	195.092	MICRONS
D30	2.773	PHI	146.313	MICRONS
D10	3.285	PHI	102.604	MICRONS
COEF. OF UNIFORMITY	1.901			
COEF. OF CURVATURE	1.069			

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: A-3

PAN=.30=.6%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 47.21

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.11	.23	99.77	.23
500.00	1.00	1.15	2.44	97.33	2.67
250.00	2.00	4.71	9.98	87.35	12.65
125.00	3.00	37.05	78.48	8.88	91.12
62.50	4.00	3.82	8.09	.78	99.22

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-3

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.22

PERCENT SILT AND CLAY .78

==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	1.23 PHI	425.24 MICRONS
PHI(16)	2.04 PHI	242.70 MICRONS
PHI(25)	2.16 PHI	224.16 MICRONS
PHI(50)	2.48 PHI	179.74 MICRONS
PHI(75)	2.79 PHI	144.13 MICRONS
PHI(84)	2.91 PHI	133.12 MICRONS
PHI(95)	3.48 PHI	89.69 MICRONS

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EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE A-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.23	99.77
.25	840.90	.8409E+00	.84	99.16
.50	707.11	.7071E+00	1.45	98.55
.75	594.60	.5946E+00	2.06	97.94
1.00	500.00	.5000E+00	2.67	97.33
1.25	420.45	.4204E+00	5.16	94.84
1.50	353.55	.3536E+00	7.66	92.34
1.75	297.30	.2973E+00	10.15	89.85
2.00	250.00	.2500E+00	12.65	87.35
2.25	210.22	.2102E+00	32.27	67.73
2.50	176.78	.1768E+00	51.89	48.11
2.75	148.65	.1487E+00	71.50	28.50
3.00	125.00	.1250E+00	91.12	8.88
3.25	105.11	.1051E+00	93.15	6.85
3.50	88.39	.8839E-01	95.17	4.83
3.75	74.33	.7433E-01	97.19	2.81
4.00	62.50	.6250E-01	99.22	.78

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-3

INMAN'S STATISTICS:

MEDIAN	2.476	PHI	179.745	MICRONS
MEAN	2.476	PHI	179.745	MICRONS
STANDARD DEVIATION	.433	WELL SORTED		
SKEWNESS	.000	NEAR-SYMMETRICAL		
KURTOSIS	1.591	VERY LEPTOKURTIC		

FOLK'S STATISTICS:

MEAN	2.476	PHI	179.745	MICRONS
STANDARD DEVIATION	.557	MODERATELY WELL SORTED		
SKEWNESS	-.053	NEAR-SYMMETRICAL		
KURTOSIS	1.444	LEPTOKURTIC		

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

ENGINEERING PARAMETERS:

D60	2.349	PHI	196.342	MICRONS
D30	2.731	PHI	150.640	MICRONS
D10	2.986	PHI	126.248	MICRONS

COEF. OF UNIFORMITY 1.555
COEF. OF CURVATURE .915

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TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: A-4

PAN=0.07=.16%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 42.79

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.30	.70	99.30	.70
500.00	1.00	1.52	3.55	95.75	4.25
250.00	2.00	5.33	12.46	83.29	16.71
125.00	3.00	30.28	70.76	12.53	87.47
62.50	4.00	5.24	12.25	.28	99.72

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-4

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.72

PERCENT SILT AND CLAY .28

==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

==========

PHI PERCENTILES

PHI(05)	1.06 PHI	479.65	MICRONS
PHI(16)	1.94 PHI	260.07	MICRONS
PHI(25)	2.12 PHI	230.50	MICRONS
PHI(50)	2.47 PHI	180.44	MICRONS
PHI(75)	2.82 PHI	141.24	MICRONS
PHI(84)	2.95 PHI	129.33	MICRONS
PHI(95)	3.61 PHI	81.64	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE A-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.70	99.30
.25	840.90	.8409E+00	1.59	98.41
.50	707.11	.7071E+00	2.48	97.52
.75	594.60	.5946E+00	3.37	96.63
1.00	500.00	.5000E+00	4.25	95.75
1.25	420.45	.4204E+00	7.37	92.63
1.50	353.55	.3536E+00	10.48	89.52
1.75	297.30	.2973E+00	13.60	86.40
2.00	250.00	.2500E+00	16.71	83.29
2.25	210.22	.2102E+00	34.40	65.60
2.50	176.78	.1768E+00	52.09	47.91
2.75	148.65	.1487E+00	69.78	30.22
3.00	125.00	.1250E+00	87.47	12.53
3.25	105.11	.1051E+00	90.54	9.46
3.50	88.39	.8839E-01	93.60	6.40
3.75	74.33	.7433E-01	96.66	3.34
4.00	62.50	.6250E-01	99.72	.28

STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-4

INMAN'S STATISTICS:

MEDIAN	2.470 PHI	180.436	MICRONS
MEAN	2.447 PHI	183.395	MICRONS
STANDARD DEVIATION	.504	MODERATELY WELL SORTED	
SKEWNESS	-.047	NEAR-SYMMETRICAL	
KURTOSIS	1.535	VERY LEPTOKURTIC	

FOLK'S STATISTICS:

MEAN	2.455 PHI	182.403	MICRONS
STANDARD DEVIATION	.639	MODERATELY WELL SORTED	
SKEWNESS	-.075	NEAR-SYMMETRICAL	
KURTOSIS	1.482	LEPTOKURTIC	

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 MOMENT MEASURES:

 MEAN                    2.399 PHI        189.621 MICRONS
 SECOND MOMENT            .443
 STANDARD DEVIATION       .666 MODERATELY WELL SORTED
 THIRD MOMENT            -.340
 SKEWNESS               -1.152 STRONGLY COARSE-SKEWED
 FOURTH MOMENT           1.218
 KURTOSIS                2.066 VERY LEPTOKURTIC
==============================================================================

 ENGINEERING PARAMETERS:

 D60                     2.329 PHI        199.004 MICRONS
 D30                     2.753 PHI        148.335 MICRONS
 D10                     3.206 PHI        108.345 MICRONS
 COEF. OF UNIFORMITY     1.837
 COEF. OF CURVATURE     1.021


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                            TIERRA CONSULTING
          SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM
==============================================================================

 ANALYSIS OF SAMPLE: A-5

 PAN=0.05=.11%

 BVA DIAL CORDY 2-26-07

 SIEVE ANALYSIS
 ==============

 SAMPLE WEIGHT =     45.18

                                          WEIGHT     CUMULATIVE   CUMULATIVE
 SIEVE SIZE   SIEVE SIZE    SIEVE WT     PERCENT      PERCENT      PERCENT
 (MICRONS)      (PHI)        (GRAMS)     RETAINED     THROUGH      RETAINED

 1000.00          .00          .17          .38        99.62          .38
  500.00         1.00          .49         1.08        98.54         1.46
  250.00         2.00         7.30        16.16        82.38        17.62
  125.00         3.00        33.57        74.30         8.08        91.92
   62.50         4.00         3.60         7.97          .11        99.89
```

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE A-5

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.89
PERCENT SILT AND CLAY	.11

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.22	PHI	429.57	MICRONS
PHI(16)	1.90	PHI	267.97	MICRONS
PHI(25)	2.10	PHI	233.36	MICRONS
PHI(50)	2.44	PHI	184.82	MICRONS
PHI(75)	2.77	PHI	146.37	MICRONS
PHI(84)	2.89	PHI	134.59	MICRONS
PHI(95)	3.39	PHI	95.63	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE A-5

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.38	99.62
.25	840.90	.8409E+00	.65	99.35
.50	707.11	.7071E+00	.92	99.08
.75	594.60	.5946E+00	1.19	98.81
1.00	500.00	.5000E+00	1.46	98.54
1.25	420.45	.4204E+00	5.50	94.50
1.50	353.55	.3536E+00	9.54	90.46
1.75	297.30	.2973E+00	13.58	86.42
2.00	250.00	.2500E+00	17.62	82.38

2.25	210.22	.2102E+00	36.19	63.81
2.50	176.78	.1768E+00	54.77	45.23
2.75	148.65	.1487E+00	73.35	26.65
3.00	125.00	.1250E+00	91.92	8.08
3.25	105.11	.1051E+00	93.91	6.09
3.50	88.39	.8839E-01	95.91	4.09
3.75	74.33	.7433E-01	97.90	2.10
4.00	62.50	.6250E-01	99.89	.11

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STATISTICS AND ENGINEERING PARAMETERS SAMPLE A-5

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INMAN'S STATISTICS:

MEDIAN	2.436	PHI	184.820 MICRONS
MEAN	2.397	PHI	189.910 MICRONS
STANDARD DEVIATION	.497	WELL SORTED	
SKEWNESS	-.079	NEAR-SYMMETRICAL	
KURTOSIS	1.181	LEPTOKURTIC	

==========

FOLK'S STATISTICS:

MEAN	2.410	PHI	188.198 MICRONS
STANDARD DEVIATION	.577	MODERATELY WELL SORTED	
SKEWNESS	-.101	COARSE-SKEWED	
KURTOSIS	1.320	LEPTOKURTIC	

==========

MOMENT MEASURES:

MEAN	2.382	PHI	191.795 MICRONS
SECOND MOMENT	.305		
STANDARD DEVIATION	.553	MODERATELY WELL SORTED	
THIRD MOMENT	-.161		
SKEWNESS	-.954	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.618		
KURTOSIS	2.211	VERY LEPTOKURTIC	

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ENGINEERING PARAMETERS:

D60	2.301	PHI	202.891 MICRONS
D30	2.705	PHI	153.363 MICRONS
D10	2.974	PHI	127.260 MICRONS
COEF. OF UNIFORMITY	1.594		
COEF. OF CURVATURE	.911		

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: B-1

PAN=0.00
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 48.25

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	24.92	51.65	48.35	51.65
500.00	1.00	8.30	17.20	31.15	68.85
250.00	2.00	9.19	19.05	12.10	87.90
125.00	3.00	5.56	11.52	.58	99.42
62.50	4.00	.43	.89	-.31	100.31

****
* ***ERROR*** ***ERROR*** CUMULATIVE PERCENT RETAINED GREATER THAN 100% *
*
****

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE B-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 100.31

PERCENT SILT AND CLAY -.31

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(75)	1.32 PHI	399.73 MICRONS
PHI(84)	1.80 PHI	288.09 MICRONS
PHI(95)	2.62 PHI	163.07 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE B-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	51.65	48.35
.25	840.90	.8409E+00	55.95	44.05
.50	707.11	.7071E+00	60.25	39.75
.75	594.60	.5946E+00	64.55	35.45
1.00	500.00	.5000E+00	68.85	31.15
1.25	420.45	.4204E+00	73.61	26.39
1.50	353.55	.3536E+00	78.37	21.63
1.75	297.30	.2973E+00	83.13	16.87
2.00	250.00	.2500E+00	87.90	12.10
2.25	210.22	.2102E+00	90.78	9.22
2.50	176.78	.1768E+00	93.66	6.34
2.75	148.65	.1487E+00	96.54	3.46
3.00	125.00	.1250E+00	99.42	.58
3.25	105.11	.1051E+00	99.64	.36
3.50	88.39	.8839E-01	99.87	.13
3.75	74.33	.7433E-01	100.09	-.09
4.00	62.50	.6250E-01	100.31	-.31

STATISTICS AND ENGINEERING PARAMETERS SAMPLE B-1

INSUFFICIENT DATA FOR ANY STATISTICAL CALCULATIONS

ENGINEERING PARAMETERS:

D60 IS NOT CALCULATED--FIRST SIEVE RETAINS OVER 40%

D30	1.060 PHI	479.502 MICRONS
D10	2.183 PHI	220.285 MICRONS

COEF. OF UNIFORMITY IS NOT CALCULATED

COEF. OF CURVATURE IS NOT CALCULATED

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: B-2

PAN=.05=.10%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 49.36

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.55	1.11	98.89	1.11
500.00	1.00	1.62	3.28	95.60	4.40
250.00	2.00	7.73	15.66	79.94	20.06
125.00	3.00	32.93	66.71	13.23	86.77
62.50	4.00	3.91	7.92	5.31	94.69

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE B-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 94.69
PERCENT SILT AND CLAY 5.31

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.04 PHI	486.82 MICRONS
PHI(16)	1.74 PHI	299.17 MICRONS
PHI(25)	2.07 PHI	237.48 MICRONS
PHI(50)	2.45 PHI	183.16 MICRONS
PHI(75)	2.82 PHI	141.26 MICRONS
PHI(84)	2.96 PHI	128.65 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES SAMPLE B-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	1.11	98.89
.25	840.90	.8409E+00	1.93	98.07
.50	707.11	.7071E+00	2.76	97.24
.75	594.60	.5946E+00	3.58	96.42
1.00	500.00	.5000E+00	4.40	95.60
1.25	420.45	.4204E+00	8.31	91.69
1.50	353.55	.3536E+00	12.23	87.77
1.75	297.30	.2973E+00	16.14	83.86
2.00	250.00	.2500E+00	20.06	79.94
2.25	210.22	.2102E+00	36.74	63.26
2.50	176.78	.1768E+00	53.41	46.59
2.75	148.65	.1487E+00	70.09	29.91
3.00	125.00	.1250E+00	86.77	13.23
3.25	105.11	.1051E+00	88.75	11.25
3.50	88.39	.8839E-01	90.73	9.27
3.75	74.33	.7433E-01	92.71	7.29
4.00	62.50	.6250E-01	94.69	5.31

STATISTICS AND ENGINEERING PARAMETERS SAMPLE B-2

INMAN'S STATISTICS:

MEDIAN	2.449 PHI	183.159 MICRONS
MEAN	2.350 PHI	196.185 MICRONS
STANDARD DEVIATION	.609 MODERATELY WELL SORTED	
SKEWNESS	-.163 COARSE-SKEWED	

FOLK'S STATISTICS:

MEAN	2.383 PHI	191.743 MICRONS

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

==========

ENGINEERING PARAMETERS:

D60	2.299 PHI	203.213 MICRONS
D30	2.749 PHI	148.793 MICRONS
D10	3.408 PHI	94.230 MICRONS
COEF. OF UNIFORMITY	2.157	
COEF. OF CURVATURE	1.156	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: B-3

PAN=0.11=0.25%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 43.90

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	27.79	63.30	36.70	63.30
500.00	1.00	9.11	20.75	15.95	84.05
250.00	2.00	3.80	8.66	7.29	92.71
125.00	3.00	2.70	6.15	1.14	98.86
62.50	4.00	.32	.73	.41	99.59

==========

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE B-3

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.59
PERCENT SILT AND CLAY	.41

==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

==========

PHI PERCENTILES

PHI(75)	.56 PHI	676.58 MICRONS
PHI(84)	1.00 PHI	500.91 MICRONS
PHI(95)	2.37 PHI	193.15 MICRONS

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EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

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INTERPOLATED PHI PERCENTILES SAMPLE B-3

==========

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	63.30	36.70
.25	840.90	.8409E+00	68.49	31.51
.50	707.11	.7071E+00	73.68	26.32
.75	594.60	.5946E+00	78.87	21.13
1.00	500.00	.5000E+00	84.05	15.95
1.25	420.45	.4204E+00	86.22	13.78
1.50	353.55	.3536E+00	88.38	11.62
1.75	297.30	.2973E+00	90.55	9.45
2.00	250.00	.2500E+00	92.71	7.29
2.25	210.22	.2102E+00	94.25	5.75
2.50	176.78	.1768E+00	95.79	4.21
2.75	148.65	.1487E+00	97.32	2.68
3.00	125.00	.1250E+00	98.86	1.14
3.25	105.11	.1051E+00	99.04	.96
3.50	88.39	.8839E-01	99.23	.77
3.75	74.33	.7433E-01	99.41	.59
4.00	62.50	.6250E-01	99.59	.41

==========

STATISTICS AND ENGINEERING PARAMETERS SAMPLE B-3

==========

INSUFFICIENT DATA FOR ANY STATISTICAL CALCULATIONS

==========

ENGINEERING PARAMETERS:

D60 IS NOT CALCULATED--FIRST SIEVE RETAINS OVER 40%

D30	.323 PHI	799.560 MICRONS
D10	1.687 PHI	310.606 MICRONS

COEF. OF UNIFORMITY IS NOT CALCULATED
COEF. OF CURVATURE IS NOT CALCULATED

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C-3

PAN=.08=.17%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 44.59

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.02	.04	99.96	.04
500.00	1.00	.28	.63	99.33	.67
250.00	2.00	5.58	12.51	86.81	13.19
125.00	3.00	35.30	79.17	7.65	92.35
62.50	4.00	3.31	7.42	.22	99.78

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.78

PERCENT SILT AND CLAY .22

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.35	PHI	393.44	MICRONS
PHI(16)	2.04	PHI	243.92	MICRONS
PHI(25)	2.15	PHI	225.43	MICRONS
PHI(50)	2.47	PHI	181.12	MICRONS
PHI(75)	2.78	PHI	145.51	MICRONS
PHI(84)	2.89	PHI	134.48	MICRONS
PHI(95)	3.36	PHI	97.62	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.04	99.96
.25	840.90	.8409E+00	.20	99.80
.50	707.11	.7071E+00	.36	99.64
.75	594.60	.5946E+00	.52	99.48
1.00	500.00	.5000E+00	.67	99.33
1.25	420.45	.4204E+00	3.80	96.20
1.50	353.55	.3536E+00	6.93	93.07
1.75	297.30	.2973E+00	10.06	89.94
2.00	250.00	.2500E+00	13.19	86.81
2.25	210.22	.2102E+00	32.98	67.02
2.50	176.78	.1768E+00	52.77	47.23
2.75	148.65	.1487E+00	72.56	27.44
3.00	125.00	.1250E+00	92.35	7.65
3.25	105.11	.1051E+00	94.21	5.79
3.50	88.39	.8839E-01	96.06	3.94
3.75	74.33	.7433E-01	97.92	2.08
4.00	62.50	.6250E-01	99.78	.22

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C-3

INMAN'S STATISTICS:

MEDIAN	2.465	PHI	181.116	MICRONS
MEAN	2.465	PHI	181.116	MICRONS
STANDARD DEVIATION	.429	WELL SORTED		
SKEWNESS	.000	NEAR-SYMMETRICAL		
KURTOSIS	1.341	LEPTOKURTIC		

FOLK'S STATISTICS:

MEAN	2.465 PHI	181.116 MICRONS	
STANDARD DEVIATION	.519 MODERATELY WELL SORTED		
SKEWNESS	-.057 NEAR-SYMMETRICAL		
KURTOSIS	1.305 LEPTOKURTIC		

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MOMENT MEASURES:

MEAN	2.430 PHI	185.619 MICRONS
SECOND MOMENT	.224	
STANDARD DEVIATION	.474 WELL SORTED	
THIRD MOMENT	-.066	
SKEWNESS	-.617 STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.311	
KURTOSIS	2.060 VERY LEPTOKURTIC	

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ENGINEERING PARAMETERS:

D60	2.339 PHI	197.689 MICRONS
D30	2.718 PHI	152.022 MICRONS
D10	2.970 PHI	127.601 MICRONS
COEF. OF UNIFORMITY	1.549	
COEF. OF CURVATURE	.916	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: C-4

PAN=.06=.12%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS
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SAMPLE WEIGHT = 48.86

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.06	.12	99.88	.12
500.00	1.00	1.00	2.05	97.83	2.17
250.00	2.00	4.59	9.39	88.44	11.56
125.00	3.00	40.06	81.99	6.45	93.55
62.50	4.00	2.94	6.02	.43	99.57

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C-4

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.57
PERCENT SILT AND CLAY	.43

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.30	PHI	405.76	MICRONS
PHI(16)	2.05	PHI	240.80	MICRONS
PHI(25)	2.16	PHI	223.16	MICRONS
PHI(50)	2.47	PHI	180.64	MICRONS
PHI(75)	2.77	PHI	146.23	MICRONS
PHI(84)	2.88	PHI	135.51	MICRONS
PHI(95)	3.24	PHI	105.81	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.12	99.88
.25	840.90	.8409E+00	.63	99.37
.50	707.11	.7071E+00	1.15	98.85
.75	594.60	.5946E+00	1.66	98.34
1.00	500.00	.5000E+00	2.17	97.83
1.25	420.45	.4204E+00	4.52	95.48
1.50	353.55	.3536E+00	6.87	93.13
1.75	297.30	.2973E+00	9.22	90.78
2.00	250.00	.2500E+00	11.56	88.44
2.25	210.22	.2102E+00	32.06	67.94
2.50	176.78	.1768E+00	52.56	47.44

2.75	148.65	.1487E+00	73.06	26.94
3.00	125.00	.1250E+00	93.55	6.45
3.25	105.11	.1051E+00	95.06	4.94
3.50	88.39	.8839E-01	96.56	3.44
3.75	74.33	.7433E-01	98.07	1.93
4.00	62.50	.6250E-01	99.57	.43

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C-4

INMAN'S STATISTICS:

MEDIAN	2.469	PHI	180.642 MICRONS
MEAN	2.469	PHI	180.642 MICRONS
STANDARD DEVIATION	.415	WELL SORTED	
SKEWNESS	.000	NEAR-SYMMETRICAL	
KURTOSIS	1.338	LEPTOKURTIC	

FOLK'S STATISTICS:

MEAN	2.469	PHI	180.642 MICRONS
STANDARD DEVIATION	.501	MODERATELY WELL SORTED	
SKEWNESS	-.102	COARSE-SKEWED	
KURTOSIS	1.303	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.411	PHI	188.043 MICRONS
SECOND MOMENT	.241		
STANDARD DEVIATION	.491	WELL SORTED	
THIRD MOMENT	-.166		
SKEWNESS	-1.401	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.510		
KURTOSIS	2.930	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.347	PHI	196.578 MICRONS
D30	2.713	PHI	152.541 MICRONS
D10	2.957	PHI	128.812 MICRONS
COEF. OF UNIFORMITY	1.526		
COEF. OF CURVATURE	.919		

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C1

PAN=.03=.06%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS
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SAMPLE WEIGHT = 48.84

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
500.00	1.00	1.12	2.29	97.71	2.29
250.00	2.00	7.65	15.66	82.04	17.96
125.00	3.00	37.92	77.64	4.40	95.60
62.50	4.00	2.11	4.32	.08	99.92

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C1

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.92

PERCENT SILT AND CLAY .08

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	1.17 PHI	443.56 MICRONS
PHI(16)	1.88 PHI	272.61 MICRONS
PHI(25)	2.09 PHI	234.76 MICRONS
PHI(50)	2.41 PHI	187.80 MICRONS
PHI(75)	2.73 PHI	150.24 MICRONS
PHI(84)	2.85 PHI	138.64 MICRONS
PHI(95)	2.99 PHI	125.67 MICRONS

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EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
1.00	500.00	.5000E+00	2.29	97.71
1.25	420.45	.4204E+00	6.21	93.79
1.50	353.55	.3536E+00	10.12	89.88
1.75	297.30	.2973E+00	14.04	85.96
2.00	250.00	.2500E+00	17.96	82.04
2.25	210.22	.2102E+00	37.37	62.63
2.50	176.78	.1768E+00	56.78	43.22
2.75	148.65	.1487E+00	76.19	23.81
3.00	125.00	.1250E+00	95.60	4.40
3.25	105.11	.1051E+00	96.68	3.32
3.50	88.39	.8839E-01	97.76	2.24
3.75	74.33	.7433E-01	98.84	1.16
4.00	62.50	.6250E-01	99.92	.08

STATISTICS AND ENGINEERING PARAMETERS SAMPLE C1

INMAN'S STATISTICS:

MEDIAN	2.413 PHI	187.803 MICRONS	
MEAN	2.363 PHI	194.406 MICRONS	
STANDARD DEVIATION	.488	WELL SORTED	
SKEWNESS	-.102	COARSE-SKEWED	
KURTOSIS	.865	PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.379 PHI	192.180 MICRONS	
STANDARD DEVIATION	.520	MODERATELY WELL SORTED	
SKEWNESS	-.233	COARSE-SKEWED	
KURTOSIS	1.158	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.339 PHI	197.694 MICRONS	
SECOND MOMENT	.266		
STANDARD DEVIATION	.516	MODERATELY WELL SORTED	
THIRD MOMENT	-.164		
SKEWNESS	-1.194	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.419		
KURTOSIS	1.970	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.284 PHI	205.340 MICRONS
D30	2.670 PHI	157.093 MICRONS
D10	2.928 PHI	131.406 MICRONS
COEF. OF UNIFORMITY	1.563	
COEF. OF CURVATURE	.915	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: C-2

PAN=0.06g=.12%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 49.58

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.07	.14	99.86	.14
500.00	1.00	.75	1.51	98.35	1.65
250.00	2.00	6.78	13.67	84.67	15.33
125.00	3.00	38.64	77.93	6.74	93.26
62.50	4.00	3.25	6.56	.18	99.82

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE C-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.82
PERCENT SILT AND CLAY	.18

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.24 PHI	422.00 MICRONS
PHI(16)	2.01 PHI	248.51 MICRONS
PHI(25)	2.12 PHI	229.39 MICRONS
PHI(50)	2.44 PHI	183.66 MICRONS
PHI(75)	2.77 PHI	147.05 MICRONS
PHI(84)	2.88 PHI	135.73 MICRONS
PHI(95)	3.26 PHI	104.03 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE C-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.14	99.86
.25	840.90	.8409E+00	.52	99.48
.50	707.11	.7071E+00	.90	99.10
.75	594.60	.5946E+00	1.28	98.72
1.00	500.00	.5000E+00	1.65	98.35
1.25	420.45	.4204E+00	5.07	94.93
1.50	353.55	.3536E+00	8.49	91.51
1.75	297.30	.2973E+00	11.91	88.09
2.00	250.00	.2500E+00	15.33	84.67
2.25	210.22	.2102E+00	34.81	65.19
2.50	176.78	.1768E+00	54.30	45.70
2.75	148.65	.1487E+00	73.78	26.22
3.00	125.00	.1250E+00	93.26	6.74
3.25	105.11	.1051E+00	94.90	5.10
3.50	88.39	.8839E-01	96.54	3.46
3.75	74.33	.7433E-01	98.18	1.82
4.00	62.50	.6250E-01	99.82	.18

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                STATISTICS AND ENGINEERING PARAMETERS          SAMPLE C-2
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 INMAN'S STATISTICS:

 MEDIAN                  2.445 PHI        183.662 MICRONS
 MEAN                    2.445 PHI        183.662 MICRONS
 STANDARD DEVIATION       .436 WELL SORTED
 SKEWNESS                 .000 NEAR-SYMMETRICAL
 KURTOSIS                1.315 LEPTOKURTIC
================================================================================

 FOLK'S STATISTICS:

 MEAN                    2.445 PHI        183.662 MICRONS
 STANDARD DEVIATION       .524 MODERATELY WELL SORTED
 SKEWNESS                -.094 NEAR-SYMMETRICAL
 KURTOSIS                1.291 LEPTOKURTIC
================================================================================

 MOMENT MEASURES:

 MEAN                    2.390 PHI        190.812 MICRONS
 SECOND MOMENT            .264
 STANDARD DEVIATION       .514 MODERATELY WELL SORTED
 THIRD MOMENT            -.142
 SKEWNESS               -1.043 STRONGLY COARSE-SKEWED
 FOURTH MOMENT            .477
 KURTOSIS                2.274 VERY LEPTOKURTIC
================================================================================

 ENGINEERING PARAMETERS:

 D60                     2.317 PHI        200.745 MICRONS
 D30                     2.702 PHI        153.733 MICRONS
 D10                     2.958 PHI        128.681 MICRONS
 COEF. OF UNIFORMITY     1.560
 COEF. OF CURVATURE       .915

================================================================================
                           TIERRA CONSULTING
           SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM
================================================================================

 ANALYSIS OF SAMPLE: D-1

 PAN=0.05=<5%
 BVA DIAL CORDY 2-26-07
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SIEVE ANALYSIS
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SAMPLE WEIGHT = 49.48

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.21	.42	99.58	.42
500.00	1.00	2.48	5.01	94.56	5.44
250.00	2.00	13.61	27.51	67.06	32.94
125.00	3.00	31.55	63.76	3.29	96.71
62.50	4.00	1.56	3.15	.14	99.86

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-1

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.86

PERCENT SILT AND CLAY .14

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	.91 PHI	531.12 MICRONS
PHI(16)	1.38 PHI	383.14 MICRONS
PHI(25)	1.71 PHI	305.40 MICRONS
PHI(50)	2.27 PHI	207.69 MICRONS
PHI(75)	2.66 PHI	158.26 MICRONS
PHI(84)	2.80 PHI	143.51 MICRONS
PHI(95)	2.97 PHI	127.34 MICRONS

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EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE D-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.42	99.58
.25	840.90	.8409E+00	1.68	98.32
.50	707.11	.7071E+00	2.93	97.07
.75	594.60	.5946E+00	4.18	95.82
1.00	500.00	.5000E+00	5.44	94.56
1.25	420.45	.4204E+00	12.31	87.69
1.50	353.55	.3536E+00	19.19	80.81
1.75	297.30	.2973E+00	26.07	73.93
2.00	250.00	.2500E+00	32.94	67.06
2.25	210.22	.2102E+00	48.88	51.12
2.50	176.78	.1768E+00	64.82	35.18
2.75	148.65	.1487E+00	80.76	19.24
3.00	125.00	.1250E+00	96.71	3.29
3.25	105.11	.1051E+00	97.49	2.51
3.50	88.39	.8839E-01	98.28	1.72
3.75	74.33	.7433E-01	99.07	.93
4.00	62.50	.6250E-01	99.86	.14

STATISTICS AND ENGINEERING PARAMETERS SAMPLE D-1

INMAN'S STATISTICS:

MEDIAN	2.268 PHI	207.688 MICRONS	
MEAN	2.092 PHI	234.492 MICRONS	
STANDARD DEVIATION	.708	MODERATELY WELL SORTED	
SKEWNESS	-.247	COARSE-SKEWED	
KURTOSIS	.454	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.151 PHI	225.194 MICRONS	
STANDARD DEVIATION	.666	MODERATELY WELL SORTED	
SKEWNESS	-.281	COARSE-SKEWED	
KURTOSIS	.890	PLATYKURTIC	

MOMENT MEASURES:

MEAN	2.140 PHI	226.887 MICRONS	
SECOND MOMENT	.418		
STANDARD DEVIATION	.647	MODERATELY WELL SORTED	
THIRD MOMENT	-.262		
SKEWNESS	-.970	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.733		
KURTOSIS	1.399	LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.111 PHI	231.538 MICRONS
D30	2.581 PHI	167.105 MICRONS
D10	2.895 PHI	134.452 MICRONS
COEF. OF UNIFORMITY	1.722	
COEF. OF CURVATURE	.897	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: D-2

PAN=.07=.1%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
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SAMPLE WEIGHT = 44.00

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.16	.36	99.64	.36
500.00	1.00	.89	2.02	97.61	2.39
250.00	2.00	7.08	16.09	81.52	18.48
125.00	3.00	33.69	76.57	4.95	95.05
62.50	4.00	2.11	4.80	.16	99.84

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-2

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.84
PERCENT SILT AND CLAY	.16

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.16 PHI	446.76 MICRONS
PHI(16)	1.85 PHI	278.15 MICRONS
PHI(25)	2.09 PHI	235.67 MICRONS
PHI(50)	2.41 PHI	187.93 MICRONS
PHI(75)	2.74 PHI	149.87 MICRONS
PHI(84)	2.86 PHI	138.15 MICRONS
PHI(95)	3.00 PHI	125.05 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE D-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.36	99.64
.25	840.90	.8409E+00	.87	99.13
.50	707.11	.7071E+00	1.38	98.63
.75	594.60	.5946E+00	1.88	98.12
1.00	500.00	.5000E+00	2.39	97.61
1.25	420.45	.4204E+00	6.41	93.59
1.50	353.55	.3536E+00	10.43	89.57
1.75	297.30	.2973E+00	14.45	85.55
2.00	250.00	.2500E+00	18.48	81.52
2.25	210.22	.2102E+00	37.62	62.38
2.50	176.78	.1768E+00	56.76	43.24
2.75	148.65	.1487E+00	75.90	24.10
3.00	125.00	.1250E+00	95.05	4.95
3.25	105.11	.1051E+00	96.24	3.76
3.50	88.39	.8839E-01	97.44	2.56
3.75	74.33	.7433E-01	98.64	1.36
4.00	62.50	.6250E-01	99.84	.16

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================================================================================
                STATISTICS AND ENGINEERING PARAMETERS          SAMPLE D-2
================================================================================

 INMAN'S STATISTICS:

 MEDIAN                  2.412 PHI        187.935 MICRONS
 MEAN                    2.351 PHI        196.024 MICRONS
 STANDARD DEVIATION       .505 MODERATELY WELL SORTED
 SKEWNESS                -.120 COARSE-SKEWED
 KURTOSIS                 .819 PLATYKURTIC
================================================================================

 FOLK'S STATISTICS:

 MEAN                    2.371 PHI        193.290 MICRONS
 STANDARD DEVIATION       .531 MODERATELY WELL SORTED
 SKEWNESS                -.240 COARSE-SKEWED
 KURTOSIS                1.153 LEPTOKURTIC
================================================================================

 MOMENT MEASURES:

 MEAN                    2.332 PHI        198.649 MICRONS
 SECOND MOMENT            .295
 STANDARD DEVIATION       .544 MODERATELY WELL SORTED
 THIRD MOMENT            -.219
 SKEWNESS               -1.366 STRONGLY COARSE-SKEWED
 FOURTH MOMENT            .628
 KURTOSIS                2.400 VERY LEPTOKURTIC
================================================================================

 ENGINEERING PARAMETERS:

 D60                     2.281 PHI        205.742 MICRONS
 D30                     2.673 PHI        156.811 MICRONS
 D10                     2.934 PHI        130.842 MICRONS
 COEF. OF UNIFORMITY     1.572
 COEF. OF CURVATURE      .913


================================================================================
                           TIERRA CONSULTING
           SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM
================================================================================

 ANALYSIS OF SAMPLE: D-3

 PAN=0.02=.04%

 BVA-DIAL CORDY 2-26-07
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SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 47.34

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.82	1.73	98.27	1.73
500.00	1.00	1.87	3.95	94.32	5.68
250.00	2.00	8.89	18.78	75.54	24.46
125.00	3.00	33.77	71.34	4.20	95.80
62.50	4.00	1.96	4.14	.06	99.94

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-3

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.94

PERCENT SILT AND CLAY .06

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	.83 PHI	563.59 MICRONS
PHI(16)	1.55 PHI	341.65 MICRONS
PHI(25)	2.01 PHI	248.69 MICRONS
PHI(50)	2.36 PHI	195.06 MICRONS
PHI(75)	2.71 PHI	152.99 MICRONS
PHI(84)	2.83 PHI	140.18 MICRONS
PHI(95)	2.99 PHI	125.97 MICRONS

==========

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE D-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	1.73	98.27
.25	840.90	.8409E+00	2.72	97.28
.50	707.11	.7071E+00	3.71	96.29
.75	594.60	.5946E+00	4.69	95.31
1.00	500.00	.5000E+00	5.68	94.32
1.25	420.45	.4204E+00	10.38	89.62
1.50	353.55	.3536E+00	15.07	84.93
1.75	297.30	.2973E+00	19.77	80.23
2.00	250.00	.2500E+00	24.46	75.54
2.25	210.22	.2102E+00	42.30	57.70
2.50	176.78	.1768E+00	60.13	39.87
2.75	148.65	.1487E+00	77.96	22.04
3.00	125.00	.1250E+00	95.80	4.20
3.25	105.11	.1051E+00	96.83	3.17
3.50	88.39	.8839E-01	97.87	2.13
3.75	74.33	.7433E-01	98.90	1.10
4.00	62.50	.6250E-01	99.94	.06

STATISTICS AND ENGINEERING PARAMETERS SAMPLE D-3

INMAN'S STATISTICS:

MEDIAN	2.358 PHI	195.060 MICRONS	
MEAN	2.192 PHI	218.843 MICRONS	
STANDARD DEVIATION	.643	MODERATELY WELL SORTED	
SKEWNESS	-.258	COARSE-SKEWED	
KURTOSIS	.682	PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.247 PHI	210.610 MICRONS	
STANDARD DEVIATION	.649	MODERATELY WELL SORTED	
SKEWNESS	-.337	STRONGLY COARSE-SKEWED	
KURTOSIS	1.264	LEPTOKURTIC	

MOMENT MEASURES:

MEAN	2.221 PHI	214.484 MICRONS	
SECOND MOMENT	.466		
STANDARD DEVIATION	.683	MODERATELY WELL SORTED	
THIRD MOMENT	-.519		
SKEWNESS	-1.630	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	1.462		
KURTOSIS	2.243	VERY LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.218 PHI	214.965 MICRONS
D30	2.638 PHI	160.609 MICRONS
D10	2.919 PHI	132.242 MICRONS
COEF. OF UNIFORMITY	1.626	
COEF. OF CURVATURE	.907	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: D-4

PAN=.01=.02%

BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS

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SAMPLE WEIGHT = 44.00

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.13	.30	99.70	.30
500.00	1.00	1.84	4.18	95.52	4.48
250.00	2.00	22.62	51.41	44.11	55.89
125.00	3.00	18.28	41.55	2.57	97.43
62.50	4.00	.96	2.18	.39	99.61

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE D-4

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.61
PERCENT SILT AND CLAY	.39

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	1.01 PHI	496.49 MICRONS
PHI(16)	1.22 PHI	428.05 MICRONS
PHI(25)	1.40 PHI	379.14 MICRONS
PHI(50)	1.89 PHI	270.65 MICRONS
PHI(75)	2.46 PHI	181.74 MICRONS
PHI(84)	2.68 PHI	156.40 MICRONS
PHI(95)	2.94 PHI	130.18 MICRONS

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EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

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INTERPOLATED PHI PERCENTILES SAMPLE D-4

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PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.30	99.70
.25	840.90	.8409E+00	1.34	98.66
.50	707.11	.7071E+00	2.39	97.61
.75	594.60	.5946E+00	3.43	96.57
1.00	500.00	.5000E+00	4.48	95.52
1.25	420.45	.4204E+00	17.33	82.67
1.50	353.55	.3536E+00	30.18	69.82
1.75	297.30	.2973E+00	43.03	56.97
2.00	250.00	.2500E+00	55.89	44.11
2.25	210.22	.2102E+00	66.27	33.73
2.50	176.78	.1768E+00	76.66	23.34
2.75	148.65	.1487E+00	87.05	12.95
3.00	125.00	.1250E+00	97.43	2.57
3.25	105.11	.1051E+00	97.98	2.02
3.50	88.39	.8839E-01	98.52	1.48
3.75	74.33	.7433E-01	99.07	.93
4.00	62.50	.6250E-01	99.61	.39

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STATISTICS AND ENGINEERING PARAMETERS SAMPLE D-4

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INMAN'S STATISTICS:

MEDIAN	1.885 PHI	270.650 MICRONS
MEAN	1.950 PHI	258.741 MICRONS

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 STANDARD DEVIATION       .726 MODERATELY SORTED
 SKEWNESS                 .089 NEAR-SYMMETRICAL
 KURTOSIS                 .330 VERY PLATYKURTIC
================================================================================
 FOLK'S STATISTICS:

 MEAN                    1.929 PHI        262.652 MICRONS
 STANDARD DEVIATION       .656 MODERATELY WELL SORTED
 SKEWNESS                 .091 NEAR-SYMMETRICAL
 KURTOSIS                 .746 PLATYKURTIC
================================================================================

 MOMENT MEASURES:

 MEAN                    1.906 PHI        266.911 MICRONS
 SECOND MOMENT            .387
 STANDARD DEVIATION       .622 MODERATELY WELL SORTED
 THIRD MOMENT            -.016
 SKEWNESS                -.066 NEAR-SYMMETRICAL
 FOURTH MOMENT            .469
 KURTOSIS                1.046 MESOKURTIC
================================================================================
 ENGINEERING PARAMETERS:

 D60                     1.691 PHI        309.716 MICRONS
 D30                     2.340 PHI        197.549 MICRONS
 D10                     2.821 PHI        141.501 MICRONS
 COEF. OF UNIFORMITY     2.189
 COEF. OF CURVATURE      .890

================================================================================
                            TIERRA CONSULTING
           SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM
================================================================================

 ANALYSIS OF SAMPLE: E-1

 PAN=1.15=2.34%
 BVA- DIAL CORDY 2-26-07


 SIEVE ANALYSIS
 ==============

 SAMPLE WEIGHT =     48.95

                                          WEIGHT     CUMULATIVE   CUMULATIVE

 SIEVE SIZE   SIEVE SIZE    SIEVE WT     PERCENT      PERCENT      PERCENT
 (MICRONS)      (PHI)        (GRAMS)     RETAINED     THROUGH      RETAINED

 1000.00          .00          .26          .53        99.47          .53
  500.00         1.00          .89         1.82        97.65         2.35
  250.00         2.00        11.58        23.66        73.99        26.01
  125.00         3.00        34.19        69.85         4.15        95.85
   62.50         4.00          .84         1.72         2.43        97.57
```

TEXTURAL CLASSIFICATION AND PHI PERCENTILES — SAMPLE E-1

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	97.57
PERCENT SILT AND CLAY	2.43

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.11	PHI	462.64	MICRONS
PHI(16)	1.58	PHI	335.17	MICRONS
PHI(25)	1.96	PHI	257.48	MICRONS
PHI(50)	2.34	PHI	197.03	MICRONS
PHI(75)	2.70	PHI	153.74	MICRONS
PHI(84)	2.83	PHI	140.60	MICRONS
PHI(95)	2.99	PHI	126.06	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

INSUFFICIENT DATA TO PERFORM EXTRAPOLATION

INTERPOLATED PHI PERCENTILES — SAMPLE E-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.53	99.47
.25	840.90	.8409E+00	.99	99.01
.50	707.11	.7071E+00	1.44	98.56
.75	594.60	.5946E+00	1.89	98.11
1.00	500.00	.5000E+00	2.35	97.65
1.25	420.45	.4204E+00	8.26	91.74
1.50	353.55	.3536E+00	14.18	85.82
1.75	297.30	.2973E+00	20.09	79.91
2.00	250.00	.2500E+00	26.01	73.99
2.25	210.22	.2102E+00	43.47	56.53

2.50	176.78	.1768E+00	60.93	39.07
2.75	148.65	.1487E+00	78.39	21.61
3.00	125.00	.1250E+00	95.85	4.15
3.25	105.11	.1051E+00	96.28	3.72
3.50	88.39	.8839E-01	96.71	3.29
3.75	74.33	.7433E-01	97.14	2.86
4.00	62.50	.6250E-01	97.57	2.43

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STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-1

==========

INMAN'S STATISTICS:

MEDIAN	2.344	PHI	197.029 MICRONS
MEAN	2.204	PHI	217.085 MICRONS
STANDARD DEVIATION	.627	MODERATELY WELL SORTED	
SKEWNESS	-.223	COARSE-SKEWED	
KURTOSIS	.497	VERY PLATYKURTIC	

==========

FOLK'S STATISTICS:

MEAN	2.250	PHI	210.183 MICRONS
STANDARD DEVIATION	.598	MODERATELY WELL SORTED	
SKEWNESS	-.268	COARSE-SKEWED	
KURTOSIS	1.033	MESOKURTIC	

==========

MOMENT MEASURES:

INSUFFICIENT DATA FOR MOMENT MEASURES

==========

ENGINEERING PARAMETERS:

D60	2.200	PHI	217.585 MICRONS
D30	2.630	PHI	161.559 MICRONS
D10	2.916	PHI	132.475 MICRONS
COEF. OF UNIFORMITY	1.642		
COEF. OF CURVATURE	.906		

==========

TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

==========

ANALYSIS OF SAMPLE: E-2

PAN=.05=.1%
BVA- DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 49.98

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.16	.32	99.68	.32
500.00	1.00	2.15	4.30	95.38	4.62
250.00	2.00	13.90	27.81	67.57	32.43
125.00	3.00	32.44	64.91	2.66	97.34
62.50	4.00	1.24	2.48	.18	99.82

==========

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE E-2

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.82
PERCENT SILT AND CLAY .18

==========

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	1.01 PHI	495.31 MICRONS
PHI(16)	1.41 PHI	376.54 MICRONS
PHI(25)	1.73 PHI	300.88 MICRONS
PHI(50)	2.27 PHI	207.24 MICRONS
PHI(75)	2.66 PHI	158.68 MICRONS
PHI(84)	2.79 PHI	144.14 MICRONS
PHI(95)	2.96 PHI	128.16 MICRONS

==========

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.
***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE E-2

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.32	99.68
.25	840.90	.8409E+00	1.40	98.60
.50	707.11	.7071E+00	2.47	97.53
.75	594.60	.5946E+00	3.55	96.45
1.00	500.00	.5000E+00	4.62	95.38
1.25	420.45	.4204E+00	11.57	88.43
1.50	353.55	.3536E+00	18.53	81.47
1.75	297.30	.2973E+00	25.48	74.52
2.00	250.00	.2500E+00	32.43	67.57
2.25	210.22	.2102E+00	48.66	51.34
2.50	176.78	.1768E+00	64.89	35.11
2.75	148.65	.1487E+00	81.11	18.89
3.00	125.00	.1250E+00	97.34	2.66
3.25	105.11	.1051E+00	97.96	2.04
3.50	88.39	.8839E-01	98.58	1.42
3.75	74.33	.7433E-01	99.20	.80
4.00	62.50	.6250E-01	99.82	.18

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-2

INMAN'S STATISTICS:

MEDIAN	2.271 PHI	207.236 MICRONS	
MEAN	2.102 PHI	232.967 MICRONS	
STANDARD DEVIATION	.693	MODERATELY WELL SORTED	
SKEWNESS	-.244	COARSE-SKEWED	
KURTOSIS	.408	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.158 PHI	224.053 MICRONS	
STANDARD DEVIATION	.642	MODERATELY WELL SORTED	
SKEWNESS	-.266	COARSE-SKEWED	
KURTOSIS	.866	PLATYKURTIC	

MOMENT MEASURES:

MEAN	2.147 PHI	225.851 MICRONS	
SECOND MOMENT	.382		
STANDARD DEVIATION	.618	MODERATELY WELL SORTED	
THIRD MOMENT	-.236		
SKEWNESS	-1.002	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.615		
KURTOSIS	1.407	LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.117 PHI	230.592 MICRONS
D30	2.579 PHI	167.381 MICRONS
D10	2.887 PHI	135.191 MICRONS
COEF. OF UNIFORMITY	1.706	
COEF. OF CURVATURE	.899	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: E-3

PAN=.02=.04%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
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SAMPLE WEIGHT = 43.54

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.01	.02	99.98	.02
500.00	1.00	2.86	6.57	93.41	6.59
250.00	2.00	27.82	63.90	29.51	70.49
125.00	3.00	12.44	28.57	.94	99.06
62.50	4.00	.39	.90	.05	99.95

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE E-3

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.95
PERCENT SILT AND CLAY	.05

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.76 PHI	591.44	MICRONS
PHI(16)	1.15 PHI	451.49	MICRONS
PHI(25)	1.29 PHI	409.49	MICRONS
PHI(50)	1.68 PHI	312.22	MICRONS
PHI(75)	2.16 PHI	224.07	MICRONS
PHI(84)	2.47 PHI	180.12	MICRONS
PHI(95)	2.86 PHI	137.93	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE E-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.02	99.98
.25	840.90	.8409E+00	1.67	98.33
.50	707.11	.7071E+00	3.31	96.69
.75	594.60	.5946E+00	4.95	95.05
1.00	500.00	.5000E+00	6.59	93.41
1.25	420.45	.4204E+00	22.57	77.43
1.50	353.55	.3536E+00	38.54	61.46
1.75	297.30	.2973E+00	54.51	45.49
2.00	250.00	.2500E+00	70.49	29.51
2.25	210.22	.2102E+00	77.63	22.37
2.50	176.78	.1768E+00	84.77	15.23
2.75	148.65	.1487E+00	91.92	8.08
3.00	125.00	.1250E+00	99.06	.94
3.25	105.11	.1051E+00	99.28	.72
3.50	88.39	.8839E-01	99.51	.49
3.75	74.33	.7433E-01	99.73	.27
4.00	62.50	.6250E-01	99.95	.05

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-3

INMAN'S STATISTICS:

MEDIAN	1.679 PHI	312.220	MICRONS
MEAN	1.810 PHI	285.171	MICRONS
STANDARD DEVIATION	.663	MODERATELY WELL SORTED	
SKEWNESS	.197	FINE-SKEWED	
KURTOSIS	.584	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	1.767 PHI	293.916 MICRONS	
STANDARD DEVIATION	.650 MODERATELY WELL SORTED		
SKEWNESS	.160 FINE-SKEWED		
KURTOSIS	.990 MESOKURTIC		

==========

MOMENT MEASURES:

MEAN	1.737 PHI	300.036 MICRONS	
SECOND MOMENT	.332		
STANDARD DEVIATION	.576 MODERATELY WELL SORTED		
THIRD MOMENT	.041		
SKEWNESS	.214 FINE-SKEWED		
FOURTH MOMENT	.345		
KURTOSIS	1.045 MESOKURTIC		

==========

ENGINEERING PARAMETERS:

D60	1.523 PHI	347.995 MICRONS
D30	1.992 PHI	251.324 MICRONS
D10	2.683 PHI	155.722 MICRONS
COEF. OF UNIFORMITY	2.235	
COEF. OF CURVATURE	1.166	

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

==========

ANALYSIS OF SAMPLE: E-4

PAN=.02=.04%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 48.72

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.06	.12	99.88	.12
500.00	1.00	2.71	5.56	94.31	5.69
250.00	2.00	27.05	55.52	38.79	61.21
125.00	3.00	18.26	37.48	1.31	98.69
62.50	4.00	.55	1.13	.18	99.82

TEXTURAL CLASSIFICATION AND PHI PERCENTILES — SAMPLE E-4

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.82
PERCENT SILT AND CLAY	.18

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	.88	PHI	544.59 MICRONS
PHI(16)	1.19	PHI	439.59 MICRONS
PHI(25)	1.35	PHI	392.87 MICRONS
PHI(50)	1.80	PHI	287.54 MICRONS
PHI(75)	2.37	PHI	193.71 MICRONS
PHI(84)	2.61	PHI	164.01 MICRONS
PHI(95)	2.90	PHI	133.82 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES — SAMPLE E-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.12	99.88
.25	840.90	.8409E+00	1.51	98.49
.50	707.11	.7071E+00	2.90	97.10
.75	594.60	.5946E+00	4.29	95.71
1.00	500.00	.5000E+00	5.69	94.31
1.25	420.45	.4204E+00	19.57	80.43
1.50	353.55	.3536E+00	33.45	66.55
1.75	297.30	.2973E+00	47.33	52.67
2.00	250.00	.2500E+00	61.21	38.79
2.25	210.22	.2102E+00	70.58	29.42
2.50	176.78	.1768E+00	79.95	20.05
2.75	148.65	.1487E+00	89.32	10.68
3.00	125.00	.1250E+00	98.69	1.31

3.25	105.11	.1051E+00	98.97	1.03
3.50	88.39	.8839E-01	99.25	.75
3.75	74.33	.7433E-01	99.53	.47
4.00	62.50	.6250E-01	99.82	.18

==========

STATISTICS AND ENGINEERING PARAMETERS SAMPLE E-4

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INMAN'S STATISTICS:

MEDIAN	1.798 PHI	287.543 MICRONS	
MEAN	1.897 PHI	268.508 MICRONS	
STANDARD DEVIATION	.711 MODERATELY SORTED		
SKEWNESS	.139 FINE-SKEWED		
KURTOSIS	.424 VERY PLATYKURTIC		

==========

FOLK'S STATISTICS:

MEAN	1.864 PHI	274.709 MICRONS
STANDARD DEVIATION	.662 MODERATELY WELL SORTED	
SKEWNESS	.114 FINE-SKEWED	
KURTOSIS	.813 PLATYKURTIC	

==========

MOMENT MEASURES:

MEAN	1.837 PHI	279.997 MICRONS
SECOND MOMENT	.365	
STANDARD DEVIATION	.604 MODERATELY WELL SORTED	
THIRD MOMENT	-.008	
SKEWNESS	-.037 NEAR-SYMMETRICAL	
FOURTH MOMENT	.380	
KURTOSIS	.951 MESOKURTIC	

==========

ENGINEERING PARAMETERS:

D60	1.618 PHI	325.778 MICRONS
D30	2.235 PHI	212.479 MICRONS
D10	2.768 PHI	146.784 MICRONS
COEF. OF UNIFORMITY	2.219	
COEF. OF CURVATURE	.944	

==========

TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: F-1

PAN=0.10=.2%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS
==========

SAMPLE WEIGHT = 44.93

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.13	.29	99.71	.29
500.00	1.00	2.16	4.81	94.90	5.10
250.00	2.00	14.22	31.65	63.25	36.75
125.00	3.00	27.48	61.16	2.09	97.91
62.50	4.00	.79	1.76	.33	99.67

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-1

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.67

PERCENT SILT AND CLAY .33

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	.98 PHI	507.03 MICRONS
PHI(16)	1.34 PHI	393.79 MICRONS
PHI(25)	1.63 PHI	323.34 MICRONS
PHI(50)	2.22 PHI	215.13 MICRONS
PHI(75)	2.63 PHI	162.05 MICRONS
PHI(84)	2.77 PHI	146.34 MICRONS
PHI(95)	2.95 PHI	129.19 MICRONS

==========

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-1

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.29	99.71
.25	840.90	.8409E+00	1.49	98.51
.50	707.11	.7071E+00	2.69	97.31
.75	594.60	.5946E+00	3.89	96.11
1.00	500.00	.5000E+00	5.10	94.90
1.25	420.45	.4204E+00	13.01	86.99
1.50	353.55	.3536E+00	20.92	79.08
1.75	297.30	.2973E+00	28.83	71.17
2.00	250.00	.2500E+00	36.75	63.25
2.25	210.22	.2102E+00	52.04	47.96
2.50	176.78	.1768E+00	67.33	32.67
2.75	148.65	.1487E+00	82.62	17.38
3.00	125.00	.1250E+00	97.91	2.09
3.25	105.11	.1051E+00	98.35	1.65
3.50	88.39	.8839E-01	98.79	1.21
3.75	74.33	.7433E-01	99.23	.77
4.00	62.50	.6250E-01	99.67	.33

STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-1

INMAN'S STATISTICS:

MEDIAN	2.217 PHI	215.132 MICRONS	
MEAN	2.059 PHI	240.057 MICRONS	
STANDARD DEVIATION	.714	MODERATELY SORTED	
SKEWNESS	-.221	COARSE-SKEWED	
KURTOSIS	.381	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.111 PHI	231.443 MICRONS	
STANDARD DEVIATION	.656	MODERATELY WELL SORTED	
SKEWNESS	-.238	COARSE-SKEWED	
KURTOSIS	.811	PLATYKURTIC	

MOMENT MEASURES:

MEAN	2.088 PHI	235.220 MICRONS	
SECOND MOMENT	.389		
STANDARD DEVIATION	.624	MODERATELY WELL SORTED	
THIRD MOMENT	-.215		
SKEWNESS	-.885	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.561		
KURTOSIS	1.236	LEPTOKURTIC	

ENGINEERING PARAMETERS:

D60	2.053 PHI	240.949 MICRONS
D30	2.544 PHI	171.502 MICRONS
D10	2.871 PHI	136.720 MICRONS
COEF. OF UNIFORMITY	1.762	
COEF. OF CURVATURE	.893	

TIERRA CONSULTING
SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

ANALYSIS OF SAMPLE: F-2

PAN=.05=.11%
BVA DIAL CORDY 2-26-07

SIEVE ANALYSIS

SAMPLE WEIGHT = 44.73

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	9.78	21.86	78.14	21.86
500.00	1.00	19.82	44.31	33.83	66.17
250.00	2.00	9.72	21.73	12.09	87.91
125.00	3.00	5.13	11.47	.63	99.37
62.50	4.00	.18	.40	.22	99.78

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-2

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00 MICRONS
SAND/SILT CUTOFF	62.50 MICRONS
SILT/CLAY CUTOFF	4.00 MICRONS
PERCENT GRAVEL	.00
PERCENT SAND	99.78
PERCENT SILT AND CLAY	.22

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(25)	.07 PHI	952.14 MICRONS
PHI(50)	.63 PHI	643.96 MICRONS
PHI(75)	1.41 PHI	377.32 MICRONS
PHI(84)	1.82 PHI	283.16 MICRONS
PHI(95)	2.62 PHI	162.82 MICRONS

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EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

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INTERPOLATED PHI PERCENTILES SAMPLE F-2

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PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	21.86	78.14
.25	840.90	.8409E+00	32.94	67.06
.50	707.11	.7071E+00	44.02	55.98
.75	594.60	.5946E+00	55.10	44.90
1.00	500.00	.5000E+00	66.17	33.83
1.25	420.45	.4204E+00	71.61	28.39
1.50	353.55	.3536E+00	77.04	22.96
1.75	297.30	.2973E+00	82.47	17.53
2.00	250.00	.2500E+00	87.91	12.09
2.25	210.22	.2102E+00	90.77	9.23
2.50	176.78	.1768E+00	93.64	6.36
2.75	148.65	.1487E+00	96.51	3.49
3.00	125.00	.1250E+00	99.37	.63
3.25	105.11	.1051E+00	99.47	.53
3.50	88.39	.8839E-01	99.58	.42
3.75	74.33	.7433E-01	99.68	.32
4.00	62.50	.6250E-01	99.78	.22

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STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-2

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INMAN'S STATISTICS:

MEDIAN .635 PHI 643.957 MICRONS

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FOLK'S STATISTICS:

INSUFFICIENT DATA FOR FOLK'S STATISTICS

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MOMENT MEASURES:

WARNING ACCURACY OF MOMENT MEASURES MAY BE
ADVERSELY AFFECTED BY THE LARGE AMOUNT OF
MATERIAL RETAINED IN THE FIRST SIEVE **

MEAN	.739	PHI	599.159 MICRONS
SECOND MOMENT	.873		
STANDARD DEVIATION	.934	MODERATELY SORTED	
THIRD MOMENT	.385		
SKEWNESS	.472	STRONGLY FINE-SKEWED	
FOURTH MOMENT	1.926		
KURTOSIS	.842	PLATYKURTIC	

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ENGINEERING PARAMETERS:

D60	.409	PHI	752.997 MICRONS
D30	1.176	PHI	442.568 MICRONS
D10	2.183	PHI	220.271 MICRONS
COEF. OF UNIFORMITY	3.419		
COEF. OF CURVATURE	1.181		

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TIERRA CONSULTING

SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM

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ANALYSIS OF SAMPLE: F-3

PAN=0.04=.08%

SIEVE ANALYSIS

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SAMPLE WEIGHT = 46.34

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.19	.41	99.59	.41
500.00	1.00	1.43	3.09	96.50	3.50
250.00	2.00	8.47	18.28	78.23	21.77
125.00	3.00	34.92	75.36	2.87	97.13
62.50	4.00	1.26	2.72	.15	99.85

TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-3

SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF	2000.00	MICRONS
SAND/SILT CUTOFF	62.50	MICRONS
SILT/CLAY CUTOFF	4.00	MICRONS

PERCENT GRAVEL	.00
PERCENT SAND	99.85
PERCENT SILT AND CLAY	.15

TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

PHI PERCENTILES

PHI(05)	1.08	PHI	472.28	MICRONS
PHI(16)	1.68	PHI	311.20	MICRONS
PHI(25)	2.04	PHI	242.69	MICRONS
PHI(50)	2.37	PHI	192.83	MICRONS
PHI(75)	2.71	PHI	153.22	MICRONS
PHI(84)	2.83	PHI	141.05	MICRONS
PHI(95)	2.97	PHI	127.47	MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-3

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.41	99.59
.25	840.90	.8409E+00	1.18	98.82
.50	707.11	.7071E+00	1.95	98.05
.75	594.60	.5946E+00	2.72	97.28
1.00	500.00	.5000E+00	3.50	96.50
1.25	420.45	.4204E+00	8.07	91.93
1.50	353.55	.3536E+00	12.63	87.37

1.75	297.30	.2973E+00	17.20	82.80
2.00	250.00	.2500E+00	21.77	78.23
2.25	210.22	.2102E+00	40.61	59.39
2.50	176.78	.1768E+00	59.45	40.55
2.75	148.65	.1487E+00	78.29	21.71
3.00	125.00	.1250E+00	97.13	2.87
3.25	105.11	.1051E+00	97.81	2.19
3.50	88.39	.8839E-01	98.49	1.51
3.75	74.33	.7433E-01	99.17	.83
4.00	62.50	.6250E-01	99.85	.15

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                STATISTICS AND ENGINEERING PARAMETERS          SAMPLE F-3
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 INMAN'S STATISTICS:

 MEDIAN                   2.375 PHI        192.834 MICRONS
 MEAN                     2.255 PHI        209.506 MICRONS
 STANDARD DEVIATION        .571 MODERATELY WELL SORTED
 SKEWNESS                 -.210 COARSE-SKEWED
 KURTOSIS                  .655 VERY PLATYKURTIC
================================================================================

 FOLK'S STATISTICS:

 MEAN                     2.295 PHI        203.794 MICRONS
 STANDARD DEVIATION        .572 MODERATELY WELL SORTED
 SKEWNESS                 -.289 COARSE-SKEWED
 KURTOSIS                 1.167 LEPTOKURTIC
================================================================================

 MOMENT MEASURES:

 MEAN                     2.267 PHI        207.817 MICRONS
 SECOND MOMENT             .318
 STANDARD DEVIATION        .563 MODERATELY WELL SORTED
 THIRD MOMENT             -.279
 SKEWNESS                -1.558 STRONGLY COARSE-SKEWED
 FOURTH MOMENT             .669
 KURTOSIS                 2.212 VERY LEPTOKURTIC
================================================================================

 ENGINEERING PARAMETERS:

 D60                      2.242 PHI        211.413 MICRONS
 D30                      2.640 PHI        160.431 MICRONS
 D10                      2.905 PHI        133.473 MICRONS
 COEF. OF UNIFORMITY      1.584
 COEF. OF CURVATURE        .912


================================================================================
                            TIERRA CONSULTING
           SEDPET III: SEDIMENTARY PETROLOGY ANALYSIS PROGRAM
================================================================================
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ANALYSIS OF SAMPLE: F-4

PAN=.03=.06%
BVA-DIAL CORDY 2-26-07

SIEVE ANALYSIS
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SAMPLE WEIGHT = 44.28

SIEVE SIZE (MICRONS)	SIEVE SIZE (PHI)	SIEVE WT (GRAMS)	WEIGHT PERCENT RETAINED	CUMULATIVE PERCENT THROUGH	CUMULATIVE PERCENT RETAINED
1000.00	.00	.13	.29	99.71	.29
500.00	1.00	1.41	3.18	96.52	3.48
250.00	2.00	9.70	21.91	74.62	25.38
125.00	3.00	32.14	72.58	2.03	97.97
62.50	4.00	.86	1.94	.09	99.91

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TEXTURAL CLASSIFICATION AND PHI PERCENTILES SAMPLE F-4

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SIZE CLASSIFICATION USED: STANDARD GEOLOGICAL SOILS CLASSIFICATION

GRAVEL/SAND CUTOFF 2000.00 MICRONS
SAND/SILT CUTOFF 62.50 MICRONS
SILT/CLAY CUTOFF 4.00 MICRONS

PERCENT GRAVEL .00
PERCENT SAND 99.91

PERCENT SILT AND CLAY .09

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TEXTURAL DESCRIPTIONS

FOLK'S: SAND
SHEPARD'S: SAND
TREFETHEN'S: SAND
U.S. ARMY CORPS OF ENGINEERS: SAND
U.S. BUREAU OF SOILS: SAND

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PHI PERCENTILES

PHI(05)	1.07 PHI	476.49 MICRONS
PHI(16)	1.57 PHI	336.43 MICRONS
PHI(25)	1.98 PHI	253.06 MICRONS
PHI(50)	2.34 PHI	197.63 MICRONS
PHI(75)	2.68 PHI	155.66 MICRONS

PHI(84) 2.81 PHI 142.84 MICRONS
PHI(95) 2.96 PHI 128.59 MICRONS

EXTRAPOLATION OF DATA TO CUMULATIVE 99.5% RETAINED.

***OVER 99.5% SAMPLE ACCOUNTED FOR BY INPUT DATA - NO EXTRAPOLATION REQUIRED.

INTERPOLATED PHI PERCENTILES SAMPLE F-4

PHI	MICRONS	MM	PCT. RET	PCT. FINER
.00	1000.00	.1000E+01	.29	99.71
.25	840.90	.8409E+00	1.09	98.91
.50	707.11	.7071E+00	1.89	98.11
.75	594.60	.5946E+00	2.68	97.32
1.00	500.00	.5000E+00	3.48	96.52
1.25	420.45	.4204E+00	8.95	91.05
1.50	353.55	.3536E+00	14.43	85.57
1.75	297.30	.2973E+00	19.91	80.09
2.00	250.00	.2500E+00	25.38	74.62
2.25	210.22	.2102E+00	43.53	56.47
2.50	176.78	.1768E+00	61.68	38.32
2.75	148.65	.1487E+00	79.82	20.18
3.00	125.00	.1250E+00	97.97	2.03
3.25	105.11	.1051E+00	98.45	1.55
3.50	88.39	.8839E-01	98.94	1.06
3.75	74.33	.7433E-01	99.42	.58
4.00	62.50	.6250E-01	99.91	.09

STATISTICS AND ENGINEERING PARAMETERS SAMPLE F-4

INMAN'S STATISTICS:

MEDIAN	2.339 PHI	197.628 MICRONS	
MEAN	2.190 PHI	219.213 MICRONS	
STANDARD DEVIATION	.618	MODERATELY WELL SORTED	
SKEWNESS	-.242	COARSE-SKEWED	
KURTOSIS	.529	VERY PLATYKURTIC	

FOLK'S STATISTICS:

MEAN	2.239 PHI	211.768 MICRONS	
STANDARD DEVIATION	.595	MODERATELY WELL SORTED	
SKEWNESS	-.293	COARSE-SKEWED	
KURTOSIS	1.105	MESOKURTIC	

MOMENT MEASURES:

MEAN	2.226	PHI	213.808 MICRONS
SECOND MOMENT	.318		
STANDARD DEVIATION	.564	MODERATELY WELL SORTED	
THIRD MOMENT	-.252		
SKEWNESS	-1.402	STRONGLY COARSE-SKEWED	
FOURTH MOMENT	.560		
KURTOSIS	1.846	VERY LEPTOKURTIC	

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ENGINEERING PARAMETERS:

D60	2.201	PHI	217.431 MICRONS
D30	2.615	PHI	163.268 MICRONS
D10	2.890	PHI	134.882 MICRONS
COEF. OF UNIFORMITY	1.612		
COEF. OF CURVATURE	.909		

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APPENDIX C

Station Data Summary Report

Station Data Summary Report
Station A1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Oweniida					
Oweniidae					
Owenia fusiformis	1	25	1	14.3	25
Spionida					
Chaetopteridae					
Spiochaetopterus oculatus	1	25	1	14.3	25
Cirratulidae					
Caulleriella sp. J	1	25	1	14.3	25
Magelonidae					
Magelona (LPIL)	2	50	2	28.6	50
Terebellida					
Pectinariidae					
Pectinaria gouldii	1	25	1	14.3	25
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	14.3	25

Note LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	6	6	6	0
Total Individuals	7	7	7	0
Density (nos/sq.m.)		175	175	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	1.75
Species Diversity (Shannon; log base 2)	d	=	2.52
Species Diversity (Shannon; log base 10)	H	=	0.76
Species Diversity (Simpson; 1/S)	1/S	=	21
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	2.57
Equitability Index (Lloyd & Ghelardi)	e	=	1.33

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	5	83.3	6	85.7
Mollusca	1	16.6	1	14.2
TOTALS	**6**		**7**	

Station Data Summary Report
Station A2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Capitellidae (LPIL)	1	25	1	5.9	25
Opheliida					
Opheliidae					
Armandia maculata	1	25	1	5.9	25
Phyllodocida					
Glyceridae					
Glyceridae (LPIL)	2	50	2	11.8	50
Nephtyidae					
Aglaophamus verrilli	1	25	1	5.9	25
Spionida					
Cirratulidae					
Caulleriella sp. J	2	50	2	11.8	50
Magelonidae					
Magelona (LPIL)	1	25	1	5.9	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	2	50	2	11.8	50
Tellinidae					
Tellina (LPIL)	2	50	2	11.8	50
Tellina iris	1	25	1	5.9	25

Station Data Summary Report
Station A2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	4	100	4	23.5	100

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	10	10	10	0
Total Individuals	17	17	17	0
Density (nos/sq.m.)		425	425	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.18
Species Diversity (Shannon; log base 2)	d	=	3.15
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	13.6
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	3.18
Equitability Index (Lloyd & Ghelardi)	e	=	1.25

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	6	60	8	47
Mollusca	4	40	9	52.9
TOTALS	**10**		**17**	

Station Data Summary Report
Station A3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	20	50
Spionidae					
Paraprionospio pinnata	1	25	1	10	25
Spionidae (LPIL)	1	25	1	10	25
Arthropoda					
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella (LPIL)	1	25	1	10	25
Cnidaria					
Hydrozoa					
Hydrozoa (LPIL)	1	25	1	10	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	10	25
Cylichna alba	1	25	1	10	25

Station Data Summary Report

Station A3

Page 1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Phoronida					
Phoronidae					
Phoronis (LPIL)	1	25	1	10	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	10	25

Note:

LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	10	10	10	0
Density (nos/sq.m.)		250	250	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.16
Species Diversity (Shannon; log base 2)	d	=	3.12
Species Diversity (Shannon; log base 10)	H	=	0.94
Species Diversity (Simpson; 1/S)	1/S	=	45
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	3.47
Equitability Index (Lloyd & Ghelardi)	e	=	1.37

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Cnidaria	1	11.1	1	10
Rhynchocoela	1	11.1	1	10
Annelida	3	33.3	4	40
Mollusca	2	22.2	2	20
Arthropoda	1	11.1	1	10
Phoronida	1	11.1	1	10
TOTALS	**9**		**10**	

Station Data Summary Report
Station A4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus californiensis	1	25	1	9.1	25
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	9.1	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	9.1	25
Spionida					
Cirratulidae					
Caulleriella sp. J	1	25	1	9.1	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	1	25	1	9.1	25
Synopiidae					
Synopiidae (LPIL)	2	50	2	18.2	50
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	9.1	25

Station Data Summary Report
Station A4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Veneroida					
Mesodesmatidae					
Ervilia concentrica	1	25	1	9.1	25
Gastropoda					
Neogastropoda					
Olividae					
Oliva sayana	2	50	2	18.2	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	11	11	11	0
Density (nos/sq.m.)		275	275	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.15
Species Diversity (Shannon; log base 2)	d	=	3.1
Species Diversity (Shannon; log base 10)	H	=	0.93
Species Diversity (Simpson; 1/S)	1/S	=	27.5
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	3.34
Equitability Index (Lloyd & Ghelardi)	e	=	1.34

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	4	44.4	4	36.3
Mollusca	3	33.3	4	36.3
Arthropoda	2	22.2	3	27.2
TOTALS	**9**		**11**	

Station Data Summary Report

Station A5

Client: Wilmington District, USACE

Page 1

Station: A5

Project: Topsail Benthic Survey

Sample Type: Macrofauna

Location: Topsail Beach

Replicates: 1

Sample Date: 28-29 Nov 06

Sample Area: 0.0400

TAXON	**Rep 1**		**Station**		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Orbiniida					
Paraonidae					
Aricidea catherinae	1	25	1	9.1	25
Phyllodocida					
Pilargiidae					
Sigambra tentaculata	1	25	1	9.1	25
Spionida					
Magelonidae					
Magelona papillicornis	3	75	3	27.3	75
Arthropoda					
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	9.1	25
Mollusca					
Bivalvia					
Veneroida					
Tellinidae					
Tellina (LPIL)	3	75	3	27.3	75
Gastropoda					
Neogastropoda					
Olividae					
Oliva sayana	1	25	1	9.1	25

Station Data Summary Report
Station A5

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A5
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Pyramidelloida					
Pyramidellidae					
Odostomia weberi	1	25	1	9.1	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station A5

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: A5
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	7	7	7	0
Total Individuals	11	11	11	0
Density (nos/sq.m.)		275	275	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.8
Species Diversity (Shannon; log base 2)	d	=	2.59
Species Diversity (Shannon; log base 10)	H	=	0.78
Species Diversity (Simpson; 1/S)	1/S	=	9.17
Species Evenness (Pielou)	J'	=	0.92
Species Richness (Margalef)	D	=	2.5
Equitability Index (Lloyd & Ghelardi)	e	=	1.2

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	3	42.8	5	45.4
Mollusca	3	42.8	5	45.4
Arthropoda	1	14.2	1	9
TOTALS	**7**		**11**	

Station Data Summary Report
Station B1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B7
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus (LPIL)	3	75	3	12	75
Eunicida					
Dorvilleidae					
Schistomeringos pectinata	1	25	1	4	25
Phyllodocida					
Chrysopetalidae					
Bhawania heteroseta	2	50	2	8	50
Goniadidae					
Goniadides carolinae	2	50	2	8	50
Spionida					
Cirratulidae					
Cirratulidae (LPIL)	1	25	1	4	25
Arthropoda					
Malacostraca					
Amphipoda					
Aoridae					
Rildardanus laminosa	1	25	1	4	25
Melitidae					
Maera caroliniana	2	50	2	8	50
Synopiidae					
Metatiron triocellatus	1	25	1	4	25

Station Data Summary Report
Station B1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B7
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	2	50	2	8	50
Ophiurida					
Amphiuridae					
Amphiuridae (LPIL)	1	25	1	4	25
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella lunulata	4	100	4	16	100
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	4	25
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	2	50	2	8	50
Rhynchocoela					
Rhynchocoela (LPIL)	2	50	2	8	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station B1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B7
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	14	14	14	0
Total Individuals	25	25	25	0
Density (nos/sq.m.)		625	625	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.53
Species Diversity (Shannon; log base 2)	d	=	3.65
Species Diversity (Shannon; log base 10)	H	=	1.1
Species Diversity (Simpson; 1/S)	1/S	=	20
Species Evenness (Pielou)	J'	=	0.96
Species Richness (Margalef)	D	=	4.04
Equitability Index (Lloyd & Ghelardi)	e	=	1.29

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	7.1	2	8
Rhynchocoela	1	7.1	2	8
Annelida	5	35.7	9	36
Mollusca	2	14.2	5	20
Arthropoda	3	21.4	4	16
Echinodermata	2	14.2	3	12
TOTALS	**14**		**25**	

Station Data Summary Report
Station B2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus (LPIL)	1	25	1	11.1	25
Spionida					
Cirratulidae					
Caulleriella sp. J	1	25	1	11.1	25
Arthropoda					
Malacostraca					
Amphipoda					
Synopiidae					
Metatiron (LPIL)	1	25	1	11.1	25
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	11.1	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucina multilineata	1	25	1	11.1	25
Tellinidae					
Tellina (LPIL)	1	25	1	11.1	25

Station Data Summary Report
Station B2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	1	25	1	11.1	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	11.1	25
Sipuncula					
Aspidosiphonidae					
Aspidosiphon albus	1	25	1	11.1	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station B2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	9	9	9	0
Density (nos/sq.m.)		225	225	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	2.2
Species Diversity (Shannon; log base 2)	d	=	3.17
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	
Species Evenness (Pielou)	J'	=	1
Species Richness (Margalef)	D	=	3.64
Equitability Index (Lloyd & Ghelardi)	e	=	1.41

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	11.1	1	11.1
Rhynchocoela	1	11.1	1	11.1
Annelida	2	22.2	2	22.2
Mollusca	2	22.2	2	22.2
Sipuncula	1	11.1	1	11.1
Arthropoda	1	11.1	1	11.1
Echinodermata	1	11.1	1	11.1
TOTALS	**9**		**9**	

Station Data Summary Report
Station B3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: B3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Oligochaeta					
Tubificida					
Enchytraeidae					
Enchytraeidae (LPIL)	2	50	2	3.9	50
Tubificidae					
Tubificidae (LPIL)	1	25	1	2	25
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	2	25
Opheliida					
Opheliidae					
Armandia maculata	1	25	1	2	25
Orbiniida					
Paraonidae					
Aricidea catherinae	1	25	1	2	25
Cirrophorus (LPIL)	1	25	1	2	25
Phyllodocida					
Chrysopetalidae					
Bhawania heteroseta	5	125	5	9.8	125
Glyceridae					
Glyceridae (LPIL)	1	25	1	2	25
Goniadidae					
Goniadides carolinae	7	175	7	13.7	175
Nereidae					
Nereididae (LPIL)	1	25	1	2	25

Station Data Summary Report
Station B3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Phyllodocidae					
Eumida sanguinea	1	25	1	2	25
Pilargiidae					
Ancistrosyllis (LPIL)	1	25	1	2	25
Ancistrosyllis hartmanae	1	25	1	2	25
Spionida					
Cirratulidae					
Cirratulidae (LPIL)	1	25	1	2	25
Spionidae					
Spionidae (LPIL)	4	100	4	7.8	100
Terebellida					
Terebellidae					
Terebellidae (LPIL)	1	25	1	2	25
Arthropoda					
Malacostraca					
Amphipoda					
Aoridae					
Unciola serrata	1	25	1	2	25
Isaeidae					
Microprotopus raneyi	2	50	2	3.9	50
Decapoda					
Paguridae					
Paguridae (LPIL)	1	25	1	2	25
Bryozoa					
Bryozoa (LPIL)	1	25	1	2	25

Station Data Summary Report
Station B3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	5	125	5	9.8	125
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	2	25
Veneroida					
Crassatellidae					
Crassinella lunulata	6	150	6	11.8	150
Semelidae					
Semelidae (LPIL)	1	25	1	2	25
Gastropoda					
Mesogastropoda					
Naticidae					
Tectonatica pusilla	1	25	1	2	25
Phoronida					
Phoronidae					
Phoronis (LPIL)	1	25	1	2	25
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	1	25	1	2	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station B3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: B3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	27	27	27	0
Total Individuals	51	51	51	0
Density (nos/sq.m.)		1275	1275	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.98
Species Diversity (Shannon; log base 2)	d	=	4.29
Species Diversity (Shannon; log base 10)	H	=	1.29
Species Diversity (Simpson; 1/S)	1/S	=	19.92
Species Evenness (Pielou)	J'	=	0.9
Species Richness (Margalef)	D	=	6.61
Equitability Index (Lloyd & Ghelardi)	e	=	1.06

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	3.7	1	1.9
Annelida	16	59.2	30	58.8
Mollusca	4	14.8	9	17.6
Arthropoda	3	11.1	4	7.8
Phoronida	1	3.7	1	1.9
Bryozoa	1	3.7	1	1.9
Echinodermata	1	3.7	5	9.8
TOTALS	**27**		**51**	

Station Data Summary Report
Station C1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Phyllodocida					
Goniadidae					
Goniada littorea	2	50	2	40	50
Arthropoda					
Malacostraca					
Amphipoda					
Phoxocephalidae					
Rhepoxynius hudsoni	2	50	2	40	50
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	1	25	1	20	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	3	3	3	0
Total Individuals	5	5	5	0
Density (nos/sq.m.)		125	125	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.05
Species Diversity (Shannon; log base 2)	d	=	1.52
Species Diversity (Shannon; log base 10)	H	=	0.46
Species Diversity (Simpson; 1/S)	1/S	=	5
Species Evenness (Pielou)	J'	=	0.96
Species Richness (Margalef)	D	=	1.24
Equitability Index (Lloyd & Ghelardi)	e	=	1.29

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	1	33.3	2	40
Mollusca	1	33.3	1	20
Arthropoda	1	33.3	2	40
TOTALS	**3**		**5**	

Station Data Summary Report
Station C2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Phyllodocida					
Goniadidae					
Goniada littorea	3	75	3	17.6	75
Arthropoda					
Malacostraca					
Amphipoda					
Amphipoda (LPIL)	1	25	1	5.9	25
Oedicerotidae					
Oedicerotidae (LPIL)	1	25	1	5.9	25
Platyischnopidae					
Eudevenopus honduranus	3	75	3	17.6	75
Decapoda					
Pasiphaeidae					
Leptochela serratorbita	1	25	1	5.9	25
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	5.9	25
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	2	50	2	11.8	50

Station Data Summary Report
Station C2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Mollusca					
Bivalvia					
Veneroida					
Tellinidae					
Tellina (LPIL)	4	100	4	23.5	100
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	5.9	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	17	17	17	0
Density (nos/sq.m.)		425	425	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.04
Species Diversity (Shannon; log base 2)	d	=	2.94
Species Diversity (Shannon; log base 10)	H	=	0.88
Species Diversity (Simpson; 1/S)	1/S	=	10.46
Species Evenness (Pielou)	J'	=	0.93
Species Richness (Margalef)	D	=	2.82
Equitability Index (Lloyd & Ghelardi)	e	=	1.2

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	1	11.1	3	17.6
Mollusca	2	22.2	5	29.4
Arthropoda	5	55.5	7	41.1
Echinodermata	1	11.1	2	11.7
TOTALS	**9**		**17**	

Station Data Summary Report
Station C3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	6.3	25
Phyllodocida					
Glyceridae					
Glyceridae (LPIL)	1	25	1	6.3	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	3	75	3	18.8	75
Echinodermata					
Echinoidea					
Echinoidea (LPIL)	2	50	2	12.5	50
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	6.3	25
Mollusca					
Bivalvia					
Veneroida					
Tellinidae					
Tellina (LPIL)	5	125	5	31.3	125

Station Data Summary Report
Station C3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	6.3	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	6.3	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	6.3	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	16	16	16	0
Density (nos/sq.m.)		400	400	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.98
Species Diversity (Shannon; log base 2)	d	=	2.85
Species Diversity (Shannon; log base 10)	H	=	0.86
Species Diversity (Simpson; 1/S)	1/S	=	8.57
Species Evenness (Pielou)	J'	=	0.9
Species Richness (Margalef)	D	=	2.89
Equitability Index (Lloyd & Ghelardi)	e	=	1.12

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	11.1	1	6.2
Annelida	2	22.2	2	12.5
Mollusca	3	33.3	7	43.7
Arthropoda	1	11.1	3	18.7
Echinodermata	2	22.2	3	18.7
TOTALS	**9**		**16**	

Station Data Summary Report

Station C4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	5.9	25
Opheliida					
Opheliidae					
Armandia maculata	3	75	3	17.6	75
Spionida					
Chaetopteridae					
Spiochaetopterus oculatus	1	25	1	5.9	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	4	100	4	23.5	100
Decapoda					
Pinnotheridae					
Dissodactylus mellitae	2	50	2	11.8	50
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	5.9	25
Podocopida					
Podocopida (LPIL)	1	25	1	5.9	25

Station Data Summary Report

Station C4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Page 1

Station: C4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Echinodermata					
Echinoidea					
Clypeasteroida					
Mellitidae					
Mellita isometra	1	25	1	5.9	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	1	25	1	5.9	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	2	50	2	11.8	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station C4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: C4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	10	10	10	0
Total Individuals	17	17	17	0
Density (nos/sq.m.)		425	425	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.15
Species Diversity (Shannon; log base 2)	d	=	3.1
Species Diversity (Shannon; log base 10)	H	=	0.93
Species Diversity (Simpson; 1/S)	1/S	=	12.36
Species Evenness (Pielou)	J'	=	0.93
Species Richness (Margalef)	D	=	3.18
Equitability Index (Lloyd & Ghelardi)	e	=	1.21

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	3	30	5	29.4
Mollusca	2	20	3	17.6
Arthropoda	4	40	8	47
Echinodermata	1	10	1	5.8
TOTALS	**10**		**17**	

Station Data Summary Report
Station D1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Oweniida					
Oweniidae					
Owenia fusiformis	1	25	1	25	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	1	25	1	25	25
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	25	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Cylichna alba	1	25	1	25	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	4	4	4	0
Total Individuals	4	4	4	0
Density (nos/sq.m.)		100	100	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.39
Species Diversity (Shannon; log base 2)	d	=	2
Species Diversity (Shannon; log base 10)	H	=	0.6
Species Diversity (Simpson; 1/S)	1/S	=	
Species Evenness (Pielou)	J'	=	1
Species Richness (Margalef)	D	=	2.16
Equitability Index (Lloyd & Ghelardi)	e	=	1.37

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	1	25	1	25
Mollusca	1	25	1	25
Arthropoda	2	50	2	50
TOTALS	**4**		**4**	

Station Data Summary Report
Station D2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	10	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	10	25
Spionida					
Magelonidae					
Magelona papillicornis	3	75	3	30	75
Spionidae					
Spiophanes bombyx	1	25	1	10	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	1	25	1	10	25
Mesodesmatidae					
Ervilia concentrica	1	25	1	10	25
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	10	25

Station Data Summary Report
Station D2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: D2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	10	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	8	8	8	0
Total Individuals	10	10	10	0
Density (nos/sq.m.)		250	250	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	1.97
Species Diversity (Shannon; log base 2)	d	=	2.85
Species Diversity (Shannon; log base 10)	H	=	0.86
Species Diversity (Simpson; 1/S)	1/S	=	15
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	3.04
Equitability Index (Lloyd & Ghelardi)	e	=	1.26

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	12.5	1	10
Annelida	4	50	6	60
Mollusca	3	37.5	3	30
TOTALS	**8**		**10**	

Station Data Summary Report
Station D3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Phyllodocida					
Goniadidae					
Goniada littorea	2	50	2	28.6	50
Spionida					
Spionidae					
Spionidae (LPIL)	1	25	1	14.3	25
Mollusca					
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	14.3	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	3	75	3	42.9	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	4	4	4	0
Total Individuals	7	7	7	0
Density (nos/sq.m.)		175	175	0

FAUNAL INDICES

Species Diversity (Shannon; log base e)	H'	=	1.28
Species Diversity (Shannon; log base 2)	d	=	1.84
Species Diversity (Shannon; log base 10)	H	=	0.55
Species Diversity (Simpson; 1/S)	1/S	=	5.25
Species Evenness (Pielou)	J'	=	0.92
Species Richness (Margalef)	D	=	1.54
Equitability Index (Lloyd & Ghelardi)	e	=	1.22

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	2	50	3	42.8
Mollusca	2	50	4	57.1
TOTALS	**4**		**7**	

Station Data Summary Report
Station D4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Lumbrineridae					
Lumbrineris latreilli	1	25	1	5	25
Orbiniida					
Paraonidae					
Aricidea (LPIL)	1	25	1	5	25
Aricidea wassi	1	25	1	5	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	5	25
Spionida					
Magelonidae					
Magelona papillicornis	1	25	1	5	25
Arthropoda					
Malacostraca					
Amphipoda					
Amphipoda (LPIL)	1	25	1	5	25
Oedicerotidae					
Americhelidium americanum	1	25	1	5	25
Phoxocephalidae					
Rhepoxynius hudsoni	1	25	1	5	25
Platyischnopidae					
Eudevenopus honduranus	3	75	3	15	75

Station Data Summary Report
Station D4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Cumacea					
Diastylidae					
Oxyurostylis (LPIL)	1	25	1	5	25
Ostracoda					
Myodocopina					
Philomedidae					
Harbansus paucichelatus	1	25	1	5	25
Philomedidae (LPIL)	1	25	1	5	25
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	5	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucina (LPIL)	1	25	1	5	25
Tellinidae					
Tellina (LPIL)	1	25	1	5	25
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	3	75	3	15	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station D4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: D4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	16	16	16	0
Total Individuals	20	20	20	0
Density (nos/sq.m.)		500	500	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.67
Species Diversity (Shannon; log base 2)	d	=	3.85
Species Diversity (Shannon; log base 10)	H	=	1.16
Species Diversity (Simpson; 1/S)	1/S	=	31.67
Species Evenness (Pielou)	J'	=	0.96
Species Richness (Margalef)	D	=	5.01
Equitability Index (Lloyd & Ghelardi)	e	=	1.3

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	5	31.2	5	25
Mollusca	3	18.7	5	25
Arthropoda	7	43.7	9	45
Echinodermata	1	6.2	1	5
TOTALS	**16**		**20**	

Station Data Summary Report

Station E1

Client: Wilmington District, USACE

Page 1

Station: E1

Project: Topsail Benthic Survey

Sample Type: Macrofauna

Location: Topsail Beach

Replicates: 1

Sample Date: 28-29 Nov 06

Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Orbiniida					
Paraonidae					
Aricidea wassi	1	25	1	6.7	25
Phyllodocida					
Glyceridae					
Glyceridae (LPIL)	1	25	1	6.7	25
Goniadidae					
Goniada littorea	3	75	3	20	75
Pilargiidae					
Ancistrosyllis (LPIL)	1	25	1	6.7	25
Spionida					
Magelonidae					
Magelona papillicornis	1	25	1	6.7	25
Spionidae					
Spionidae (LPIL)	1	25	1	6.7	25
Arthropoda					
Malacostraca					
Amphipoda					
Oedicerotidae					
Americhelidium americanum	1	25	1	6.7	25
Platyischnopidae					
Eudevenopus honduranus	1	25	1	6.7	25

Station Data Summary Report
Station E1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: E1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Decapoda					
Paguridae					
Pagurus (LPIL)	1	25	1	6.7	25
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	1	25	1	6.7	25
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	3	75	3	20	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	11	11	11	0
Total Individuals	15	15	15	0
Density (nos/sq.m.)		375	375	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.27
Species Diversity (Shannon; log base 2)	d	=	3.27
Species Diversity (Shannon; log base 10)	H	=	0.99
Species Diversity (Simpson; 1/S)	1/S	=	17.5
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	3.69
Equitability Index (Lloyd & Ghelardi)	e	=	1.25

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	6	54.5	8	53.3
Mollusca	2	18.1	4	26.6
Arthropoda	3	27.2	3	20
TOTALS	**11**		**15**	

Station Data Summary Report
Station E2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Capitellidae					
Mediomastus (LPIL)	1	25	1	3.8	25
Opheliida					
Opheliidae					
Opheliidae (LPIL)	1	25	1	3.8	25
Orbiniida					
Paraonidae					
Aricidea (LPIL)	1	25	1	3.8	25
Aricidea wassi	2	50	2	7.7	50
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	7.7	50
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	3	75	3	11.5	75
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	1	25	1	3.8	25

Station Data Summary Report
Station E2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location:
Sample Date: 28-29 Nov 06

Station: E2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	2	50	2	7.7	50
Tellinidae					
Tellina (LPIL)	1	25	1	3.8	25
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	2	50	2	7.7	50
Mesogastropoda					
Caecidae					
Caecum pulchellum	7	175	7	26.9	175
Eulimidae					
Strombiformis bilineatus	1	25	1	3.8	25
Rhynchocoela					
Rhynchocoela (LPIL)	2	50	2	7.7	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	13	13	13	0
Total Individuals	26	26	26	0
Density (nos/sq.m.)		650	650	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.34
Species Diversity (Shannon; log base 2)	d	=	3.38
Species Diversity (Shannon; log base 10)	H	=	1.02
Species Diversity (Simpson; 1/S)	1/S	=	11.21
Species Evenness (Pielou)	J'	=	0.91
Species Richness (Margalef)	D	=	3.68
Equitability Index (Lloyd & Ghelardi)	e	=	1.14

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	7.6	2	7.6
Annelida	5	38.4	7	26.9
Mollusca	5	38.4	13	50
Arthropoda	1	7.6	3	11.5
Echinodermata	1	7.6	1	3.8
TOTALS	**13**		**26**	

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Capitellida					
Maldanidae					
Maldanidae (LPIL)	1	25	1	2.3	25
Opheliida					
Opheliidae					
Armandia (LPIL)	1	25	1	2.3	25
Orbiniida					
Paraonidae					
Aricidea suecica	1	25	1	2.3	25
Cirrophorus (LPIL)	1	25	1	2.3	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	2.3	25
Pilargiidae					
Ancistrosyllis hartmanae	1	25	1	2.3	25
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	4.7	50
Arthropoda					
Malacostraca					
Amphipoda					
Phoxocephalidae					
Metharpinia floridana	1	25	1	2.3	25

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Platyischnopidae					
Eudevenopus honduranus	6	150	6	14	150
Cumacea					
Diastylidae					
Oxyurostylis (LPIL)	1	25	1	2.3	25
Chordata					
Leptocardia					
Amphioxi					
Branchiostomidae					
Branchiostoma (LPIL)	2	50	2	4.7	50
Echinodermata					
Echinodermata (LPIL)	1	25	1	2.3	25
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella dupliniana	3	75	3	7	75
Crassinella lunulata	2	50	2	4.7	50
Montacutidae					
Montacutidae (LPIL)	1	25	1	2.3	25
Tellinidae					
Strigilla mirabilis	1	25	1	2.3	25
Tellina (LPIL)	1	25	1	2.3	25

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	2.3	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	12	300	12	27.9	300
Eulimidae					
Strombiformis bilineatus	1	25	1	2.3	25
Naticidae					
Tectonatica pusilla	1	25	1	2.3	25
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	2.3	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	22	22	22	0
Total Individuals	43	43	43	0
Density (nos/sq.m.)		1075	1075	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.64
Species Diversity (Shannon; log base 2)	d	=	3.82
Species Diversity (Shannon; log base 10)	H	=	1.15
Species Diversity (Simpson; 1/S)	1/S	=	10.38
Species Evenness (Pielou)	J'	=	0.86
Species Richness (Margalef)	D	=	5.58
Equitability Index (Lloyd & Ghelardi)	e	=	0.92

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	4.5	1	2.3
Annelida	7	31.8	8	18.6
Mollusca	9	40.9	23	53.4
Arthropoda	3	13.6	8	18.6
Echinodermata	1	4.5	1	2.3
Chordata	1	4.5	2	4.6
TOTALS	**22**		**43**	

Station Data Summary Report

Station E4

Client: Wilmington District, USACE

Page 1

Station: E4

Project: Topsail Benthic Survey

Sample Type: Macrofauna

Location: Topsail Beach

Replicates: 1

Sample Date: 28-29 Nov 06

Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Oenonidae					
Arabella multidentata	1	25	1	3.6	25
Opheliida					
Opheliidae					
Armandia maculata	2	50	2	7.1	50
Opheliidae (LPIL)	1	25	1	3.6	25
Phyllodocida					
Nereidae					
Ceratocephale oculata	1	25	1	3.6	25
Spionida					
Magelonidae					
Magelona papillicornis	2	50	2	7.1	50
Spionidae					
Paraprionospio pinnata	1	25	1	3.6	25
Arthropoda					
Malacostraca					
Amphipoda					
Phoxocephalidae					
Rhepoxynius hudsoni	1	25	1	3.6	25
Platyischnopidae					
Eudevenopus honduranus	7	175	7	25	175

Station Data Summary Report

Station E4

Client: Wilmington District, USACE

Page 1

Station: E4

Project: Topsail Benthic Survey

Sample Type: Macrofauna

Location: Topsail Beach

Replicates: 1

Sample Date: 28-29 Nov 06

Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	3.6	25
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella dupliniana	1	25	1	3.6	25
Lucinidae					
Lucina multilineata	3	75	3	10.7	75
Tellinidae					
Strigilla mirabilis	1	25	1	3.6	25
Tellina (LPIL)	1	25	1	3.6	25
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	3.6	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	2	50	2	7.1	50
Naticidae					
Tectonatica pusilla	1	25	1	3.6	25

Station Data Summary Report
Station E4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Rhynchocoela					
Rhynchocoela (LPIL)	1	25	1	3.6	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station E4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: E4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	17	17	17	0
Total Individuals	28	28	28	0
Density (nos/sq.m.)		700	700	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.58
Species Diversity (Shannon; log base 2)	d	=	3.72
Species Diversity (Shannon; log base 10)	H	=	1.12
Species Diversity (Simpson; 1/S)	1/S	=	14
Species Evenness (Pielou)	J'	=	0.91
Species Richness (Margalef)	D	=	4.8
Equitability Index (Lloyd & Ghelardi)	e	=	1.12

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	5.8	1	3.5
Annelida	6	35.2	8	28.5
Mollusca	7	41.1	10	35.7
Arthropoda	3	17.6	9	32.1
TOTALS	**17**		**28**	

Station Data Summary Report
Station F1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Opheliida					
Opheliidae					
Opheliidae (LPIL)	1	25	1	11.1	25
Spionida					
Cirratulidae					
Caulleriella sp. J	1	25	1	11.1	25
Magelonidae					
Magelona papillicornis	1	25	1	11.1	25
Magelona pettiboneae	1	25	1	11.1	25
Arthropoda					
Malacostraca					
Cumacea					
Diastylidae					
Oxyurostylis (LPIL)	1	25	1	11.1	25
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella texana	1	25	1	11.1	25
Chordata					
Leptocardia					
Amphioxi					
Branchiostomidae					
Branchiostoma (LPIL)	1	25	1	11.1	25

Station Data Summary Report
Station F1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Mollusca					
Bivalvia					
Veneroida					
Crassatellidae					
Crassinella lunulata	1	25	1	11.1	25
Platyhelminthes					
Turbellaria					
Turbellaria (LPIL)	1	25	1	11.1	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F1

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F1
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	9	9	9	0
Density (nos/sq.m.)		225	225	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.2
Species Diversity (Shannon; log base 2)	d	=	3.17
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	
Species Evenness (Pielou)	J'	=	1
Species Richness (Margalef)	D	=	3.64
Equitability Index (Lloyd & Ghelardi)	e	=	1.41

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Platyhelminthes	1	11.1	1	11.1
Annelida	4	44.4	4	44.4
Mollusca	1	11.1	1	11.1
Arthropoda	2	22.2	2	22.2
Chordata	1	11.1	1	11.1
TOTALS	**9**		**9**	

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Opheliida					
Opheliidae					
Ophelia denticulata	1	25	1	4.2	25
Phyllodocida					
Chrysopetalidae					
Bhawania heteroseta	1	25	1	4.2	25
Goniadidae					
Goniadides carolinae	2	50	2	8.3	50
Hesionidae					
Microphthalmus (LPIL)	1	25	1	4.2	25
Nephtyidae					
Nephtys simoni	1	25	1	4.2	25
Spionida					
Cirratulidae					
Cirratulidae (LPIL)	1	25	1	4.2	25
Arthropoda					
Malacostraca					
Amphipoda					
Melitidae					
Maera caroliniana	1	25	1	4.2	25

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	16	16	16	0
Total Individuals	24	24	24	0
Density (nos/sq.m.)		600	600	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.64
Species Diversity (Shannon; log base 2)	d	=	3.8
Species Diversity (Shannon; log base 10)	H	=	1.14
Species Diversity (Simpson; 1/S)	1/S	=	23
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	4.72
Equitability Index (Lloyd & Ghelardi)	e	=	1.26

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	6.2	3	12.5
Annelida	6	37.5	7	29.1
Mollusca	7	43.7	11	45.8
Arthropoda	1	6.2	1	4.1
Chordata	1	6.2	2	8.3
TOTALS	**16**		**24**	

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Chordata					
Leptocardia					
Amphioxi					
Branchiostomidae					
Branchiostoma (LPIL)	2	50	2	8.3	50
Mollusca					
Bivalvia					
Bivalvia (LPIL)	1	25	1	4.2	25
Ostreoida					
Anomiidae					
Anomia simplex	1	25	1	4.2	25
Veneroida					
Crassatellidae					
Crassinella dupliniana	4	100	4	16.7	100
Crassinella lunulata	2	50	2	8.3	50
Gastropoda					
Cephalaspidea					
Scaphandridae					
Acteocina canaliculata	1	25	1	4.2	25
Mesogastropoda					
Caecidae					
Caecum pulchellum	1	25	1	4.2	25
Pyramidelloida					
Pyramidellidae					
Turbonilla (LPIL)	1	25	1	4.2	25

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Rhynchocoela					
Rhynchocoela (LPIL)	3	75	3	12.5	75

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F2

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F2
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	16	16	16	0
Total Individuals	24	24	24	0
Density (nos/sq.m.)		600	600	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.64
Species Diversity (Shannon; log base 2)	d	=	3.8
Species Diversity (Shannon; log base 10)	H	=	1.14
Species Diversity (Simpson; 1/S)	1/S	=	23
Species Evenness (Pielou)	J'	=	0.95
Species Richness (Margalef)	D	=	4.72
Equitability Index (Lloyd & Ghelardi)	e	=	1.26

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Rhynchocoela	1	6.2	3	12.5
Annelida	6	37.5	7	29.1
Mollusca	7	43.7	11	45.8
Arthropoda	1	6.2	1	4.1
Chordata	1	6.2	2	8.3
TOTALS	**16**		**24**	

Station Data Summary Report
Station F3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Onuphidae					
Onuphidae (LPIL)	1	25	1	7.1	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	7.1	25
Nereidae					
Ceratocephale oculata	1	25	1	7.1	25
Spionida					
Spionidae					
Paraprionospio pinnata	1	25	1	7.1	25
Arthropoda					
Malacostraca					
Amphipoda					
Platyischnopidae					
Eudevenopus honduranus	2	50	2	14.3	50
Echinodermata					
Ophiuroidea					
Ophiuroidea (LPIL)	2	50	2	14.3	50

Station Data Summary Report
Station F3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	2	50	2	14.3	50
Gastropoda					
Mesogastropoda					
Caecidae					
Caecum pulchellum	2	50	2	14.3	50
Neogastropoda					
Olividae					
Olivella dealbata	2	50	2	14.3	50

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F3

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F3
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	9	9	9	0
Total Individuals	14	14	14	0
Density (nos/sq.m.)		350	350	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.14
Species Diversity (Shannon; log base 2)	d	=	3.09
Species Diversity (Shannon; log base 10)	H	=	0.93
Species Diversity (Simpson; 1/S)	1/S	=	18.2
Species Evenness (Pielou)	J'	=	0.98
Species Richness (Margalef)	D	=	3.03
Equitability Index (Lloyd & Ghelardi)	e	=	1.34

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	4	44.4	4	28.5
Mollusca	3	33.3	6	42.8
Arthropoda	1	11.1	2	14.2
Echinodermata	1	11.1	2	14.2
TOTALS	**9**		**14**	

Station Data Summary Report
Station F4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Annelida					
Polychaeta					
Eunicida					
Lumbrineridae					
Lumbrineris latreilli	1	25	1	3.4	25
Oenonidae					
Arabella multidentata	1	25	1	3.4	25
Phyllodocida					
Goniadidae					
Goniada littorea	1	25	1	3.4	25
Nephtyidae					
Nephtys picta	2	50	2	6.9	50
Nereidae					
Ceratocephale oculata	1	25	1	3.4	25
Spionida					
Magelonidae					
Magelona papillicornis	1	25	1	3.4	25
Spionidae					
Spionidae (LPIL)	1	25	1	3.4	25
Arthropoda					
Malacostraca					
Amphipoda					
Haustoriidae					
Acanthohaustorius intermedius	2	50	2	6.9	50

Station Data Summary Report
Station F4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

TAXON	Rep 1		Station		
	Count	Density	Total	Percent	Mean Density
Phoxocephalidae					
Rhepoxynius hudsoni	1	25	1	3.4	25
Platyischnopidae					
Eudevenopus honduranus	12	300	12	41.4	300
Ostracoda					
Myodocopina					
Sarsiellidae					
Eusarsiella radiicosta	1	25	1	3.4	25
Echinodermata					
Echinoidea					
Clypeasteroida					
Mellitidae					
Mellitidae (LPIL)	2	50	2	6.9	50
Mollusca					
Bivalvia					
Veneroida					
Lucinidae					
Lucinidae (LPIL)	1	25	1	3.4	25
Mesodesmatidae					
Ervilia concentrica	1	25	1	3.4	25
Gastropoda					
Neogastropoda					
Turridae					
Kurtziella atrostyla	1	25	1	3.4	25

Note: LPIL designates the LOWEST PRACTICAL IDENTIFICATION LEVEL

Station Data Summary Report
Station F4

Client: Wilmington District, USACE
Project: Topsail Benthic Survey
Location: Topsail Beach
Sample Date: 28-29 Nov 06

Station: F4
Sample Type: Macrofauna
Replicates: 1
Sample Area: 0.0400

DATA SUMMARY

FAUNAL PARAMETERS	Station	Rep 1	Mean	Std Dev
Total Taxa	15	15	15	0
Total Individuals	29	29	29	0
Density (nos/sq.m.)		725	725	0

FAUNAL INDICES			
Species Diversity (Shannon; log base e)	H'	=	2.2
Species Diversity (Shannon; log base 2)	d	=	3.17
Species Diversity (Shannon; log base 10)	H	=	0.95
Species Diversity (Simpson; 1/S)	1/S	=	5.88
Species Evenness (Pielou)	J'	=	0.81
Species Richness (Margalef)	D	=	4.16
Equitability Index (Lloyd & Ghelardi)	e	=	0.85

MAJOR TAXONOMIC GROUPS	Total No. Taxa	Taxa % Total	Total No. Individuals	Individuals % Total
Annelida	7	46.6	8	27.5
Mollusca	3	20	3	10.3
Arthropoda	4	26.6	16	55.1
Echinodermata	1	6.6	2	6.8
TOTALS	**15**		**29**	

APPENDIX D

Supporting Data Tables

Table D-1. Species abundance and density at sampling stations within borrow sites A, B, and C off Topsail Beach, NC.

											Mean								Mean										Mean	
	A1		A2		A3		A4		A5		A		B1		B2		B3		B		C1		C2		C3		C4		C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
ANNELIDA																														
CLASS OLIGOCHAETA																														
Order TUBIFICIDA																														
FAMILY ENCHYTRAEIDAE																														
Enchytraeidae (LPIL)																	2	50	.67	16.67										
FAMILY TUBIFICIDAE																														
Tubificidae (LPIL)																	1	25	.33	8.33										
CLASS POLYCHAETA																														
Order CAPITELLIDA																														
FAMILY CAPITELLIDAE																														
Capitellidae (LPIL)			1	25							.20	5.00																		
Mediomastus (LPIL)													3	75	1	25			1.33	33.33										
Mediomastus californiensis							1	25			.20	5																		
FAMILY MALDANIDAE																														
Maldanidae (LPIL)																														
Order EUNICIDA																														
FAMILY DORVILLEIDAE																														
Schistomeringos pectinata													1	25					.33	8.33										
FAMILY LUMBRINERIDAE																														
Lumbrineris latreilli																														
FAMILY OENONIDAE																														
Arabella multidentata																														
FAMILY ONUPHIDAE																														
Onuphidae (LPIL)							1	25			.20	5.00					1	25	.33	8.33					1	25	1	25	.50	12.50
Order OPHELIIDA																														
FAMILY OPHELIIDAE																														
Opheliidae (LPIL)																														
Armandia (LPIL)																														
Armandia maculata			1	25							.20	5.00					1	25	.33	8.33							3	75	.75	18.75
Ophelia denticulata																														
Order ORBINIIDA																														
FAMILY PARAONIDAE																														
Aricidea (LPIL)																														
Aricidea catherinae									1	25	.20	5.00					1	25	.33	8.33										
Aricidea suecica																														
Aricidea wassi																														
Cirrophorus (LPIL)																	1	25	.33	8.33										

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order OWENIIDA																														
FAMILY OWENIIDAE																														
Owenia fusiformis	1	25									.20	5.00																		
Order PHYLLODOCIDA																														
FAMILY CHRYSOPETALIDAE																														
Bhawania heteroseta													2	50			5	125	2.33	58.33										
FAMILY GLYCERIDAE																														
Glyceridae (LPIL)			2	50							.40	10.00					1	25	.33	8.33					1	25			.25	6.25
FAMILY GONIADIDAE																														
Goniada littorea							1	25			.20	5.00									2	50	3	75					1.25	31.25
Goniadides carolinae													2	50			7	175	3	75.00										
FAMILY HESIONIDAE																														
Microphthalmus (LPIL)																														
FAMILY NEPHTYIDAE																														
Aglaophamus verrilli			1	25							.20	5.00																		
Nephtys picta																														
Nephtys simoni																														
FAMILY NEREIDAE																														
Nereididae (LPIL)																	1	25	.33	8.33										
Ceratocephale oculata																														
FAMILY PHYLLODOCIDAE																														
Eumida sanguinea																	1	25	.33	8.33										
FAMILY PILARGIIDAE																														
Ancistrosyllis (LPIL)																	1	25	.33	8.33										
Ancistrosyllis hartmanae																	1	25	.33	8.33										
Sigambra tentaculata									1	25	.20	5.00																		
Order SPIONIDA																														
FAMILY CHAETOPTERIDAE																														
Spiochaetopterus oculatus	1	25									.20	5.00															1	25	.25	6.25
FAMILY CIRRATULIDAE																														
Cirratulidae (LPIL)													1	25			1	25	.67	16.67										
Caulleriella sp. J	1	25	2	50			1	25			.80	20.00			1	25			.33	8.33										
FAMILY MAGELONIDAE																														
Magelona (LPIL)	2	50	1	25							.60	15.00																		
Magelona papillicornis					2	50			3	75	1.00	25.00																		
Magelona pettiboneae																														
FAMILY SPIONIDAE																														
Spionidae (LPIL)					1	25					.20	5.00					4	100	1.33	33.33										
Paraprionospio pinnata					1	25					.20	5.00																		
Spiophanes bombyx																														

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order TEREBELLIDA																														
FAMILY PECTINARIIDAE																														
Pectinaria gouldii	1	25									.20	5.00																		
FAMILY TEREBELLIDAE																														
Terebellidae (LPIL)																	1	25	.33	8.33										
ARTHROPODA																														
CLASS MALACOSTRACA																														
Order AMPHIPODA																														
Amphipoda (LPIL)																							1	25					.25	6.25
FAMILY AORIDAE																														
Rildardanus laminosa													1	25					.33	8.33										
Unciola serrata																	1	25	.33	8.33										
FAMILY HAUSTORIIDAE																														
Acanthohaustorius intermedius																														
FAMILY ISAEIDAE																														
Microprotopus raneyi																	2	50	.67	16.67										
FAMILY MELITIDAE																														
Maera caroliniana													2	50					.67	16.67										
FAMILY OEDICEROTIDAE																														
Oedicerotidae (LPIL)																							1	25					.25	6.25
Americhelidium americanum																														
FAMILY PHOXOCEPHALIDAE																														
Metharpinia floridana																														
Rhepoxynius hudsoni																					2	50							.50	12.50
FAMILY PLATYISCHNOPIDAE																														
Eudevenopus honduranus																							3	75	3	75	4	100	2.50	62.50
FAMILY SYNOPIIDAE																														
Metatiron (LPIL)															1	25			.33	8.33										
Metatiron triocellatus													1	25					.33	8.33										
Order CUMACEA																														
FAMILY DIASTYLIDAE																														
Oxyurostylis (LPIL)																														
Order DECAPODA																														
FAMILY PAGURIDAE																														
Pagurus (LPIL)																	1	25	.33	8.33										
FAMILY PASIPHAEIDAE																														
Leptochela serratorbita																														
FAMILY PINNOTHERIDAE																														
Dissodactylus mellitae																											2	50	.50	12.50

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
CLASS OSTRACODA																														
Order MYODOCOPINA																														
FAMILY PHILOMEDIDAE																														
Philomedidae (LPIL)																														
Harbansus paucichelatus																														
FAMILY SARSIELLIDAE																														
Eusarsiella (LPIL)					1	25					.20	5.00																		
Eusarsiella radiicosta																														
Eusarsiella texana									1	25	.20	5.00											1	25			1	25	.50	12.50
Order PODOCOPIDA																														
Podocopida (LPIL)																											1	25	.25	6.25
BRYOZOA																														
Bryozoa (LPIL)																	1	25	.33	8.33										
CHORDATA																														
CLASS LEPTOCARDIA																														
Order AMPHIOXI																														
FAMILY BRANCHIOSTOMIDAE																														
Branchiostoma (LPIL)																														
CNIDARIA																														
CLASS HYDROZOA																														
Hydrozoa (LPIL)					1	25					.20	5.00																		
ECHINODERMATA																														
Echinodermata (LPIL)																														
CLASS ECHINOIDEA																														
Echinoidea (LPIL)																									2	50			.50	12.50
Order CLYPEASTEROIDA																														
FAMILY MELLITIDAE																														
Mellitidae (LPIL)																														
Mellita isometra																											1	25	.25	6.25
CLASS OPHIUROIDEA																														
Ophiuroidea (LPIL)													2	50	1	25	5	125					2	50	1	25			.75	18.75
Order OPHIURIDA																														
FAMILY AMPHIURIDAE																														
Amphiuridae (LPIL)													1	25					.33	8.33										
MOLLUSCA																														
CLASS BIVALVIA																														
Bivalvia (LPIL)	1	25					1	25			.40	10.00					1	25	.33	8.33										
Order OSTREOIDA																														
FAMILY ANOMIIDAE																														
Anomia simplex																														

Table D-1. (continued)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order VENEROIDA																														
FAMILY CRASSATELLIDAE																														
Crassinella dupliniana																														
Crassinella lunulata													4	100			6	150	3.33	83.33										
FAMILY LUCINIDAE																														
Lucinidae (LPIL)			2	50							.40	10.00																		
Lucina (LPIL)																														
Lucina multilineata															1	25			.33	8.33										
FAMILY MESODESMATIDAE																														
Ervilia concentrica							1	25			.20	5.00																		
FAMILY MONTACUTIDAE																														
Montacutidae (LPIL)																														
FAMILY SEMELIDAE																														
Semelidae (LPIL)																	1	25	.33	8.33										
FAMILY TELLINIDAE																														
Strigilla mirabilis																														
Tellina (LPIL)			2	50					3	75	1.0	25.00			1	25			.33	8.33			4	100	5	125			2.25	56.25
Tellina iris			1	25							.20	5.00																		
CLASS GASTROPODA																														
Order CEPHALASPIDEA																														
FAMILY SCAPHANDRIDAE																														
Acteocina canaliculata					1	25					.20	5.00													1	25			.25	6.25
Cylichna alba			4	100	1	25					1.0	25.00									1	25					1	25	.50	12.50
Order MESOGASTROPODA																														
FAMILY CAECIDAE																														
Caecum pulchellum													1	25					.33	8.33			1	25	1	25	2	50	1.00	25.00
FAMILY EULIMIDAE																														
Strombiformis bilineatus																														
FAMILY NATICIDAE																														
Tectonatica pusilla																	1	25	.33	8.33										
Order NEOGASTROPODA																														
FAMILY OLIVIDAE																														
Oliva sayana							2	50	1	75	.60	25.00																		
Olivella dealbata																														
FAMILY TURRIDAE																														
Kurtziella atrostyla																														
Order PYRAMIDELLOIDA																														
FAMILY PYRAMIDELLIDAE																														
Odostomia weberi									1	25	.20	5.00																		
Turbonilla (LPIL)																														

Table D-1. (concluded)

	A1		A2		A3		A4		A5		Mean A		B1		B2		B3		Mean B		C1		C2		C3		C4		Mean C	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
PHORONIDA																														
FAMILY PHORONIDAE																														
Phoronis (LPIL)					1	25					.20	5.00					1	25	.33	8.33										
PLATYHELMINTHES																														
CLASS TURBELLARIA																														
Turbellaria (LPIL)													2	50	1	25	1	25	1.33	33.33										
RHYNCHOCOELA																														
Rhynchocoela (LPIL)					1	25					.20	5.00	2	50	1	25			1.00	25.00					1	25			.25	6.25
SIPUNCULA																														
FAMILY ASPIDOSIPHONIDAE																														
Aspidosiphon albus															1	25			.33	8.33										

Table D-2. Species abundance and density at sampling stations within borrow sites D, E, and F off Topsail Beach, NC.

	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
ANNELIDA																														
CLASS OLIGOCHAETA																														
Order TUBIFICIDA																														
FAMILY ENCHYTRAEIDAE																														
Enchytraeidae (LPIL)																														
FAMILY TUBIFICIDAE																														
Tubificidae (LPIL)																														
CLASS POLYCHAETA																														
Order CAPITELLIDA																														
FAMILY CAPITELLIDAE																														
Capitellidae (LPIL)																														
Mediomastus (LPIL)													1	25					.25	6.25										
Mediomastus californiensis																														
FAMILY MALDANIDAE																														
Maldanidae (LPIL)															1	25			.25	6.25										
Order EUNICIDA																														
FAMILY DORVILLEIDAE																														
Schistomeringos pectinata																														
FAMILY LUMBRINERIDAE																														
Lumbrineris latreilli							1	25	.25	6.25																	1	25	.25	6.25
FAMILY OENONIDAE																														
Arabella multidentata																	1	25	.25	6.25										
FAMILY ONUPHIDAE																														
Onuphidae (LPIL)			1	25					.25	6.25															1	25	1	25	.50	12.50
Order OPHELIIDA																														
FAMILY OPHELIIDAE																														
Opheliidae (LPIL)													1	25			1	25	.50	12.50	1	25							.25	6.25
Armandia (LPIL)															1	25			.25	6.25										
Armandia maculata																	2	50	.50	12.50										
Ophelia denticulata																							1	25					.25	6.25
Order ORBINIIDA																														
FAMILY PARAONIDAE																														
Aricidea (LPIL)							1	25	.25	6.25			1	25					.25	6.25										
Aricidea catherinae																														
Aricidea suecica															1	25			.25	6.25										
Aricidea wassi							1	25	.25	6.25	1	25	2	50																
Cirrophorus (LPIL)															1	25			.25	6.25										
Order OWENIIDA																														
FAMILY OWENIIDAE																														
Owenia fusiformis	1	25																												

Table D-2. (continued)

	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order PHYLLODOCIDA																														
FAMILY CHRYSOPETALIDAE																														
Bhawania heteroseta																							1	25					.25	6.25
FAMILY GLYCERIDAE																														
Glyceridae (LPIL)											1	25							.25	6.25										
FAMILY GONIADIDAE																														
Goniada littorea			1	25	2	50	1	25	1.00	25.00	3	75			1	25			1.00	25.00					1	25	1	25	.50	12.50
Goniadides carolinae																							2	50					.50	12.50
FAMILY HESIONIDAE																														
Microphthalmus (LPIL)																							1	25					.25	6.25
FAMILY NEPHTYIDAE																														
Aglaophamus verrilli																														
Nephtys picta																											2	50	.50	12.50
Nephtys simoni																							1	25					.25	6.25
FAMILY NEREIDAE																														
Nereididae (LPIL)																														
Ceratocephale oculata																	1	25	.25	6.25					1	25	1	25	.50	12.50
FAMILY PHYLLODOCIDAE																														
Eumida sanguinea																														
FAMILY PILARGIIDAE																														
Ancistrosyllis (LPIL)											1	25							.25	6.25										
Ancistrosyllis hartmanae															1	25			.25	6.25										
Sigambra tentaculata																														
Order SPIONIDA																														
FAMILY CHAETOPTERIDAE																														
Spiochaetopterus oculatus																														
FAMILY CIRRATULIDAE																														
Cirratulidae (LPIL)																							1	25					.25	6.25
Caulleriella sp. J																					1	25							.25	6.25
FAMILY MAGELONIDAE																														
Magelona (LPIL)																														
Magelona papillicornis			3	75			1	25	1.00	25.00	1	25	2	50	2	50	2	50	1.75	43.75	1	25					1	25	.50	12.50
Magelona pettiboneae																					1	25							.25	6.25
FAMILY SPIONIDAE																														
Spionidae (LPIL)					1	25			.25	6.25	1	25							.25	6.25							1	25	.25	6.25
Paraprionospio pinnata																	1	25	.25	6.25					1	25			.25	6.25
Spiophanes bombyx			1	25					.25	6.25																				
Order TEREBELLIDA																														
FAMILY PECTINARIIDAE																														
Pectinaria gouldii																														
FAMILY TEREBELLIDAE																														
Terebellidae (LPIL)																														

Table D-2. (continued)

	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
ARTHROPODA																														
CLASS MALACOSTRACA																														
Order AMPHIPODA																														
Amphipoda (LPIL)							1	25	.25	6.25																				
FAMILY AORIDAE																														
Rildardanus laminosa																														
Unciola serrata																														
FAMILY HAUSTORIIDAE																														
Acanthohaustorius intermedius																											2	50	.50	12.50
FAMILY ISAEIDAE																														
Microprotopus raneyi																														
FAMILY MELITIDAE																														
Maera caroliniana																							1	25					.25	6.25
FAMILY OEDICEROTIDAE																														
Oedicerotidae (LPIL)																														
Americhelidium americanum							1	25	.25	6.25	1	25							.25	6.25										
FAMILY PHOXOCEPHALIDAE																														
Metharpinia floridana															1	25			.25	6.25										
Rhepoxynius hudsoni							1	25	.25	6.25							1	25	.25	6.25							1	25	.25	6.25
FAMILY PLATYISCHNOPIDAE																														
Eudevenopus honduranus	1	25					3	75	.75	18.75	1	25	3	75	6	150	7	175	4.25	106.25					2	50	12	300	3.50	87.50
FAMILY SYNOPIIDAE																														
Metatiron (LPIL)																														
Metatiron triocellatus																														
Order CUMACEA																														
FAMILY DIASTYLIDAE																														
Oxyurostylis (LPIL)							1	25	.25	6.25					1	25			.25	6.25	1	25							.25	6.25
Order DECAPODA																														
FAMILY PAGURIDAE																														
Pagurus (LPIL)											1	25							.25	6.25										
FAMILY PASIPHAEIDAE																														
Leptochela serratorbita																														
FAMILY PINNOTHERIDAE																														
Dissodactylus mellitae																														
CLASS OSTRACODA																														
Order MYODOCOPINA																														
FAMILY PHILOMEDIDAE																														
Philomedidae (LPIL)							1	25	.25	6.25																				
Harbansus paucichelatus							1	25	.25	6.25																				
FAMILY SARSIELLIDAE																														
Eusarsiella (LPIL)																														
Eusarsiella radiicosta																											1	25	.25	6.25
Eusarsiella texana	1	25															1	25	.25	6.25	1	25							.25	6.25

Table D-2. (continued)

	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
Order PODOCOPIDA																														
Podocopida (LPIL)																														
BRYOZOA																														
Bryozoa (LPIL)																														
CHORDATA																														
CLASS LEPTOCARDIA																														
Order AMPHIOXI																														
FAMILY BRANCHIOSTOMIDAE																														
Branchiostoma (LPIL)															2	50			.50	12.50	1	25	2	50					.75	18.75
CNIDARIA																														
CLASS HYDROZOA																														
Hydrozoa (LPIL)																														
ECHINODERMATA																														
Echinodermata (LPIL)															1	25			.25	6.25										
CLASS ECHINOIDEA																														
Echinoidea (LPIL)																														
Order CLYPEASTEROIDA																														
FAMILY MELLITIDAE																														
Mellitidae (LPIL)																											2	50	.50	12.50
Mellita isometra																														
CLASS OPHIUROIDEA																														
Ophiuroidea (LPIL)							1	25	.25	6.25			1	25					.25	6.25					2	50			.50	12.50
Order OPHIURIDA																														
FAMILY AMPHIURIDAE																														
Amphiuridae (LPIL)																														
MOLLUSCA																														
CLASS BIVALVIA																														
Bivalvia (LPIL)																														
Order OSTREOIDA																														
FAMILY ANOMIIDAE																														
Anomia simplex																							1	25					.25	6.25
Order VENEROIDA																														
FAMILY CRASSATELLIDAE																														
Crassinella dupliniana															3	75	1	25	1.00	25.00			4	100					1.00	25.00
Crassinella lunulata															2	50			.50	12.50	1	25	2	50					.75	18.75
FAMILY LUCINIDAE																														
Lucinidae (LPIL)			1	25					.25	6.25	1	25	2	50					.75	18.75					2	50	1	25	.75	18.75
Lucina (LPIL)							1	25	.25	6.25																				
Lucina multilineata																	3	75	.75	18.75										
FAMILY MESODESMATIDAE																														
Ervilia concentrica			1	25					.25	6.25																	1	25	.25	6.25

Table D-2. (concluded)

	D1		D2		D3		D4		Mean D		E1		E2		E3		E4		Mean E		F1		F2		F3		F4		Mean F	
Species List	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density	Count	Density
FAMILY MONTACUTIDAE																														
Montacutidae (LPIL)															1	25			.25	6.25										
FAMILY SEMELIDAE																														
Semelidae (LPIL)																														
FAMILY TELLINIDAE																														
Strigilla mirabilis															1	25	1	25	.50	12.50										
Tellina (LPIL)							1	25	.25	6.25			1	25	1	25	1	25	.75	18.75										
Tellina iris																														
CLASS GASTROPODA																														
Order CEPHALASPIDEA																														
FAMILY SCAPHANDRIDAE																														
Acteocina canaliculata					1	25			.25	6.25			2	50	1	25	1	25	1.00	25.00			1	25					.25	6.25
Cylichna alba	1	25																												
Order MESOGASTROPODA																														
FAMILY CAECIDAE																														
Caecum pulchellum			1	25	3	75	3	75	1.75	43.75	3	75	7	175	12	300	2	50	6.00	150.00			1	25	2	50			.75	18.75
FAMILY EULIMIDAE																														
Strombiformis bilineatus													1	25	1	25			.50	12.50										
FAMILY NATICIDAE																														
Tectonatica pusilla															1	25	1	25	.50	12.50										
Order NEOGASTROPODA																														
FAMILY OLIVIDAE																														
Oliva sayana																														
Olivella dealbata																									2	50			.50	12.50
FAMILY TURRIDAE																														
Kurtziella atrostyla																											1	25	.25	6.25
Order PYRAMIDELLOIDA																														
FAMILY PYRAMIDELLIDAE																														
Odostomia weberi																														
Turbonilla (LPIL)																							1	25					.25	6.25
PHORONIDA																														
FAMILY PHORONIDAE																														
Phoronis (LPIL)																														
PLATYHELMINTHES																														
CLASS TURBELLARIA																														
Turbellaria (LPIL)																					1	25							.25	6.25
RHYNCHOCOELA																														
Rhynchocoela (LPIL)			1	25					.25	6.25			2	50	1	25	1	25	1.00	25.00			3	75					.75	18.75
SIPUNCULA																														
FAMILY ASPIDOSIPHONIDAE																														
Aspidosiphon albus																														

Table D-3. Biomass for major taxa groups from Topsail Beach, NC, benthic sampling stations.

Station: A1	gm/04 m²	gm/m²
Annelida	0.5556	13.89
Mollusca	0.5544	13.86
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.1100	27.75

Station: A2	gm/04 m²	gm/m²
Annelida	0.6517	16.2925
Mollusca	0.5792	14.48
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.2309	30.7725

Station: A3	gm/04 m²	gm/m²
Annelida	0.5557	13.8925
Mollusca	0.5512	13.78
Arthropoda	0.5484	13.71
Echinodermata	0.0000	0
Other Taxa	0.5490	13.725
Total	2.2043	55.1075

Station: A4	gm/04 m²	gm/m²
Annelida	0.5620	14.05
Mollusca	0.5712	14.28
Arthropoda	0.5563	13.9075
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6895	42.2375

Station: A5	gm/04 m²	gm/m²
Annelida	0.5517	13.7925
Mollusca	0.5522	13.805
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.1039	27.5975

Station: B1	gm/04 m²	gm/m²
Annelida	0.5519	13.7975
Mollusca	0.5513	13.7825
Arthropoda	0.5711	14.2775
Echinodermata	0.5760	14.4
Other Taxa	0.5654	14.135
Total	2.8157	70.3925

Station: B2	gm/04 m²	gm/m²
Annelida	0.5520	13.8
Mollusca	0.5520	13.8
Arthropoda	0.5481	13.7025
Echinodermata	0.5492	13.73
Other Taxa	0.5491	13.7275
Total	2.7504	68.76

Station: B3	gm/04 m²	gm/m²
Annelida	0.5665	14.1625
Mollusca	0.5511	13.7775
Arthropoda	0.5513	13.7825
Echinodermata	0.5490	13.725
Other Taxa	0.5595	13.9875
Total	2.7774	69.435

Station: C1	gm/04 m²	gm/m²
Annelida	0.5526	13.815
Mollusca	0.5490	13.725
Arthropoda	0.5520	13.8
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6536	41.34

Station: C2	gm/04 m²	gm/m²
Annelida	0.5526	13.815
Mollusca	0.5490	13.725
Arthropoda	0.5520	13.8
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6536	41.34

Station: C3	gm/04 m²	gm/m²
Annelida	0.5556	13.89
Mollusca	0.5555	13.8875
Arthropoda	0.5564	13.91
Echinodermata	0.5491	13.7275
Other Taxa	0.5496	13.74
Total	2.7662	69.155

Station: C4	gm/04 m²	gm/m²
Annelida	0.5539	13.8475
Mollusca	0.5496	13.74
Arthropoda	0.5533	13.8325
Echinodermata	21.4873	537.1825
Other Taxa	0.0000	0
Total	23.1441	578.6025

Table D-3. (concluded)

Station: D1	gm/04 m²	gm/m²
Annelida	0.5556	13.89
Mollusca	0.5494	13.735
Arthropoda	0.5483	13.7075
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.6533	41.3325

Station: D2	gm/04 m²	gm/m²
Annelida	0.5659	14.1475
Mollusca	0.5491	13.7275
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.5492	13.73
Total	1.6642	41.605

Station: D3	gm/04 m²	gm/m²
Annelida	0.5658	14.145
Mollusca	0.5493	13.7325
Arthropoda	0.0000	0
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.1151	27.8775

Station: D4	gm/04 m²	gm/m²
Annelida	0.5743	14.3575
Mollusca	0.5495	13.7375
Arthropoda	0.5485	13.7125
Echinodermata	0.5492	13.73
Other Taxa	0.0000	0
Total	2.2215	55.5375

Station: E1	gm/04 m²	gm/m²
Annelida	0.5722	14.305
Mollusca	0.5526	13.815
Arthropoda	0.5766	14.415
Echinodermata	0.0000	0
Other Taxa	0.0000	0
Total	1.7014	42.535

Station: F1	gm/04 m²	gm/m²
Annelida	0.5520	13.8
Mollusca	0.5513	13.7825
Arthropoda	0.5520	13.8
Echinodermata	0.0000	0
Other Taxa	0.5491	13.7275
Total	2.2044	55.11

Station: E2	gm/04 m²	gm/m²
Annelida	0.5546	13.865
Mollusca	0.5545	13.8625
Arthropoda	0.5563	13.9075
Echinodermata	0.5492	13.73
Other Taxa	0.5490	13.725
Total	2.7636	69.09

Station: E3	gm/04 m²	gm/m²
Annelida	0.5622	14.055
Mollusca	0.5522	13.805
Arthropoda	0.5563	13.9075
Echinodermata	0.5491	13.7275
Other Taxa	0.5490	13.725
Total	2.7688	69.22

Station: E4	gm/04 m²	gm/m²
Annelida	0.5623	14.0575
Mollusca	0.5543	13.8575
Arthropoda	0.5524	13.81
Echinodermata	0.0000	0
Other Taxa	0.5492	13.73
Total	2.2182	55.455

Station: F2	gm/04 m²	gm/m²
Annelida	0.6508	16.27
Mollusca	0.5512	13.78
Arthropoda	0.5561	13.9025
Echinodermata	0.0000	0
Other Taxa	0.6559	16.3975
Total	2.4140	60.35

Station: F3	gm/04 m²	gm/m²
Annelida	0.6508	16.27
Mollusca	0.5512	13.78
Arthropoda	0.5561	13.9025
Echinodermata	0.0000	0
Other Taxa	0.6559	16.3975
Total	2.4140	60.35

Station: F4	gm/04 m²	gm/m²
Annelida	0.5513	13.7825
Mollusca	0.5740	14.35
Arthropoda	0.5490	13.725
Echinodermata	0.5496	13.74
Other Taxa	0.0000	0
Total	2.2239	55.5975