NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT NC0801C

Kitty Hawk to Rodanthe, North Carolina

Introduction

Coastal Mapping Program (CMP) project NC0801C, located along the Outer Banks of eastern North Carolina, extends from Kitty Hawk in the north to Rodanthe to the South. The project includes Oregon Inlet, the eastern portion of Roanoke Island and the marinas of Oregon Inlet, Wanchese and Manteo. The approximate bounding coordinates are 36°03' to 35°36' latitude, and 75°45' to 75°27' longitude. The project is part of the larger NC0801 acquisition project that extends from Cape Henry, Virginia to Ocracoke Island, North Carolina.

Successful completion of this project resulted in a densification of the National Spatial Reference System (NSRS), a set of controlled metric-quality aerial photographs, airborne topographic LIDAR data, and digital feature data of the coastal zone which complements the Nautical Charting Program (NCP) as well as geographic information systems (GIS) for a variety of coastal zone management applications.

Project Design

The Requirements Branch (RB) of the Remote Sensing Division (RSD) formulated the photographic mission instructions for this project supplementary to the Photo Mission Standard Operating Procedure Version II (7/1/1993), the GPS Controlled Photogrammetry Field Operations Manual (1/2/1996), and the Light Detection And Ranging (LIDAR) Requirements Version 5 (7/3/2003). The instructions discussed the project's purpose, geographic area of coverage, scope and priority; photographic and LIDAR requirements; flight line priority; Global Positioning System (GPS) data collection procedures and guidelines for both kinematic and static surveys; data recording and handling instructions; and contact and communication information. RB created a Project Layout Diagram, flight maps and input files for the aircraft flight management system.

Field Operations

The field operations consisted of acquisition of aerial LIDAR data, digital aerial imagery, static and kinematic Global Positioning System (GPS) data, and Inertial Measurement Unit (IMU) data. Static GPS data were collected to support aerial data collection and processing operations as well as to assess the accuracy of post-processed imagery and LIDAR products.

The airborne survey operations were conducted March 17-26, 2008 with the NOAA Cessna Citation (N52RF) aircraft. Ten strips of natural color digital images were acquired at a flying height of 1,500 meters, for a nominal ground sample distance (GSD) of 0.17 meters with an Applanix Digital Sensor System (DSS-439) DualCam. Additionally, tandem strips of LIDAR data were collected, using an Optech ALTM 3100 Topographic LIDAR sensor, for those areas

corresponding to the outer coastline. LIDAR postings were collected at a nominal density of 1 posting per square meter.

Airborne GPS/IMU Data Processing

GPS and IMU data were processed by RSD personnel to yield precise camera positions and orientations in order to provide a control network necessary for aerotriangulation. A local fixed base station at Newport News International Airport (PHF1) and a CORS station (NCPI, Pea Island) were used as base data for the GPS/IMU post-processing. The airborne kinematic data was processed using Applanix POSPAC (ver. 4.4) software in March-April of 2008. An Airborne Positioning and Orientation Report was written and is on file with other project data within the RSD Applications Branch (AB) Project Archive.

Ortho-image Processing

Ortho-images were created with the natural color (RGB) DSS-439 imagery and associated image Exterior Orientation (EO) data using Applanix RapidOrtho software. United States Geological Survey (USGS) National Elevation Data (NED) models were utilized to rectify the data.

Multiple field-surveyed check points were established using static GPS positioning methods, to assess the accuracy of the ortho-image data. Fifty (50) check points were surveyed in the Virginia Beach, VA area and twelve (12) check points were surveyed in the Frisco, NC area. Using these check points, the accuracy of the ortho-images was computed to be 2.0 meters circular error at the 95% confidence level (CE95).

LIDAR Data Processing

LIDAR point cloud data were processed using the combined chain of:

1) Optech's *Project Dashboard* pre-processing software to place the LIDAR point cloud into a mapping projection,
2) Terrasolid's suite of LIDAR calibration and editing software to correct alignment, remove erroneous returns, and classify bare earth points,
3) NOAA's VDatum software to convert the vertical datum of the bare earth points from NAVD88 to local MHW, and
4) GeoCue LIDAR processing software to produce MHW digital elevation models (DEM) at 1 meter pixel resolution.

The journal article "Lidar-Derived National Shoreline: Empirical and Stochastic Uncertainty Analyses" (2010), published in the *Journal of Coastal Research*, contains more detailed information, and is on file in the RSD Project Archive.

Aerotriangulation

The aerotriangulation (AT) task was initiated by RSD personnel in April of 2011 utilizing a Digital Photogrammetric Workstation (DPW). Image measurements and block adjustments were performed using BAE Systems' SOCET SET (SS, version 5.4.1) photogrammetric software. AT procedures were accomplished using the Multi-Sensor Triangulation (MST) module of SS. The Automatic Point Measurement (APM) algorithm, within MST, was used to collect tie points, and a simultaneous solve adjustment was then performed. The predicted horizontal circular error,

using all measured image points, was computed to be 0.32 meters at the 95% confidence level (CE95). Positional data for this project is referenced to the North American Datum of 1983 (NAD 83). An Aerotriangulation Report was written and is on file with other project data within the RSD Project Archive.

Compilation

The data compilation phase of this project was completed between September 2011 and December 2011 and was performed in the following three distinct technical phases:

1) *LIDAR MHW Shoreline approach* – A MHW shoreline vector (in shapefile format) for the outer coastline, from Kitty Hawk to Rodanthe, was delineated using the MHW DEM discussed above and a Raster-to-Vector (R2V) script implemented within ESRI's ArcGIS 9.3 software. The shapefile table was then edited to create attribute fields compatible with the RSD interim shapefile format. Subsequently, the ortho-images were used to review/edit/attribute the LIDAR shoreline vector. The LIDAR-derived shoreline included natural MHW shoreline features along the entire outer Atlantic Ocean coastline and back-bay (mostly marsh) shoreline in southern Roanoke Sound and northern Pamlico Sound. LIDAR was not utilized to delineate engineered features such as bulkheads, piers, bridges, or the back-bay shorelines of northern Roanoke and Albemarle Sounds.

   The LIDAR shoreline was compared to higher accuracy field transects, acquired at three sample sites in the larger NC0801 project area. Based on this comparison, the LIDAR derived shoreline vectors meet a horizontal accuracy of 4.5 meters at the 95% confidence level. This procedure is described in fuller detail in the journal article referenced above.

2) *Semi-Automated Feature Extraction (AFE) approach* – For compilation of shoreline in the northern back-bay areas, an AFE method was performed using the ortho-images discussed above in combination with an object-based image analysis approach from within the ENVI Feature Extraction (Fx) software. ENVI Fx allows the user to interactively create and classify objects, based on image rules that meet in-situ criteria, and then run a R2V algorithm to convert the classified objects to an ArcGIS polygon shapefile. Upon completion of the AFE process, the polygon shapefile was imported into ArcGIS and 1) *aggregated* to merge polygons separated by less than the standard minimum distance, 2) *converted* to a polyline format, 3) *smoothed* and *simplified*, and 4) *edited* to create attribute fields (within the table) compatible with the RSD interim shapefile format. As in the LIDAR phase, the ortho-images were used to review, edit, and attribute the AFE shoreline vectors.

At this point the shape files, created in phases 1 and 2 above, were *merged* within ArcGIS to create a single "Shoreline" shapefile in the RSD interim format. This *merged* file was then imported into SS and a Feature Database (FDB) was created. The FDB, consisting solely of shoreline features, was then reviewed and edited within the SS Feature Extraction module, by the original compiler, using stereo-models derived from the AT solution. As a result of this review and edit process the features derived using the AFE method (2 above) were assigned a horizontal accuracy equal to the accuracy calculated for the stereo-models, which was derived from the AT solution results (see method 3 below).

3) *Stereo-Models and Manual Compilation approach* – The FDB, created above, was subsequently populated with additional features compiled using the SS Feature Extraction software module in combination with stereo-models. This served to integrate all coastal features within a single FDB. This manual data compilation phase utilized the *traditional* RSD digital mapping approach of stereoscopic interpretation integrated with "heads-up" digitizing.

   Features digitized manually (or reviewed and edited) using the stereo-models were compiled to meet a horizontal accuracy of 0.6 meters at the 95% confidence level (CE95), calculated by doubling the circular error derived from AT statistics.

Feature attribution, for all three phases above, was assigned in compliance with the Coastal Cartographic Object Attribute Source Table (C-COAST), which provides the definition and attribution scheme for the full range of cartographic features pertinent to the CMP. Selected features were further modified with additional descriptive information to refine general classification.

The following table provides information on aerial photographs used in the project completion:

Date	Time (UTC)	Roll Id	Strip	Frames	GSD	Tide Level*
3/17/2008	16:31 – 16:42	08NC86	25-072	18309 – 18476	0.17 m	0.0 m
3/17/2008	17:27 – 17:38	08NC86	25-073	18813 – 18980	0.17 m	0.0 m
3/18/2008	16:29 – 16:35	08NC87	25-080	20012 – 20098	0.17 m	0.0 m
3/18/2008	16:35 – 16:39	08NC87	25-080	20099 – 20163	0.17 m	0.2 m
3/20/2008	17:41 – 17:47	08NC88	25-079	20623 – 20704	0.17 m	0.3 m
3/20/2008	17:47 – 17:52	08NC88	25-079	20705 – 20790	0.17 m	0.1 m
3/20/2008	18:01 – 18:04	08NC88	25-078	20827 – 20880	0.17 m	0.1 m
3/20/2008	18:05 – 18:06	08NC88	25-078	20881 – 20908	0.17 m	0.2 m
3/20/2008	18:06 – 18:09	08NC88	25-078	20909 – 20946	0.17 m	0.0 m
3/20/2008	18:09 – 18:12	08NC88	25-078	20947 – 20994	0.17 m	0.3 m
3/21/2008	14:04 – 14:08	08NC89	25-071	21373 – 21435	0.17 m	0.1 m
3/21/2008	14:08 – 14:12	08NC89	25-071	21436 – 21487	0.17 m	0.2 m
3/21/2008	14:12 – 14:15	08NC89	25-071	21488 – 21540	0.17 m	0.3 m
3/21/2008	14:54 – 14:55	08NC89	25-074	21865 – 21888	0.17 m	0.3 m
3/21/2008	14:55 – 15:01	08NC89	25-074	21889 – 21971	0.17 m	0.2 m
3/21/2008	15:01 – 15:05	08NC89	25-074	21972 – 22032	0.17 m	0.1 m
3/25/2008	19:41 – 19:43	08NC90	25-076	22253 – 22278	0.17 m	0.1 m
3/25/2008	19:43 – 19:52	08NC90	25-076	22279 – 22420	0.17 m	0.0 m
3/25/2008	20:36 – 20:38	08NC90	25-077	22802 – 22833	0.17 m	0.2 m

3/25/2008	20:34 – 20:47	08NC90	25-077	22834 – 22969	0.17 m	0.0 m
3/26/2008	13:55 – 14:02	08NC91	25-075	23055 – 23154	0.17 m	0.1 m
3/26/2008	14:02 – 14:03	08NC91	25-075	23155 – 23163	0.17 m	0.4 m
3/26/2008	14:03 – 14:05	08NC91	25-075	23164 – 23210	0.17 m	0.2 m
3/26/2008	14:22 – 14:23	08NC91	25-075	23243 – 23262	0.17 m	0.2 m

* Tide levels are given in meters above MLLW and are based on actual observations recorded by the NOS reference gages at Oregon Inlet Marina and at Duck Pier with offsets applied to substations within the project area. The height of the MHW tidal datum in the project area varies between 0.1 - 1.1 meters above MLLW.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by a senior member of AB. The final QC review was completed in February 2012, including analysis of the aerotriangulation results, assessment of the spatial placement of the LIDAR and AFE derived shorelines from within the stereo viewing environment, and assessment of the identification and attribution of digital feature data within the GC according to image analysis and criteria defined in C-COAST. The quality control process concluded with an inspection of topological connectivity within the GC using ArcGIS 9.3 software. All project data was evaluated for compliance to CMP requirements.

Comparisons of the largest scale NOAA nautical charts with color imagery and compiled project data resulted in creation of the Chart Evaluation File (CEF). The following nautical charts were used in the comparison process:

12205, Cape Henry to Pamlico Sound (various scales), 31st ed., Dec. /07
12204, Currituck Beach Light to Wimble Shoals, 1: 80,000 scale, 37th ed., Sep. /07

End Products and Deliverables

The following specifies the location and identification of the products generated during the completion of this project:

RSD Applications Branch Archive

- Hardcopy of the Airborne Positioning and Orientation Report (APOR)
- Hardcopy of the Aerotriangulation (AT) Report
- Hardcopy of the Project Completion Report (PCR)
- Page-size graphic plot of GC10845 file contents, attached to PCR
- Hardcopy of journal article, “Lidar-Derived National Shoreline: Empirical and Stochastic Uncertainty Analyses” by White et al

Remote Sensing Division Electronic Data Library

- Project database
- GC10845 in shapefile format
- Digital copy of the PCR in Adobe PDF format
- CEF in shapefile format

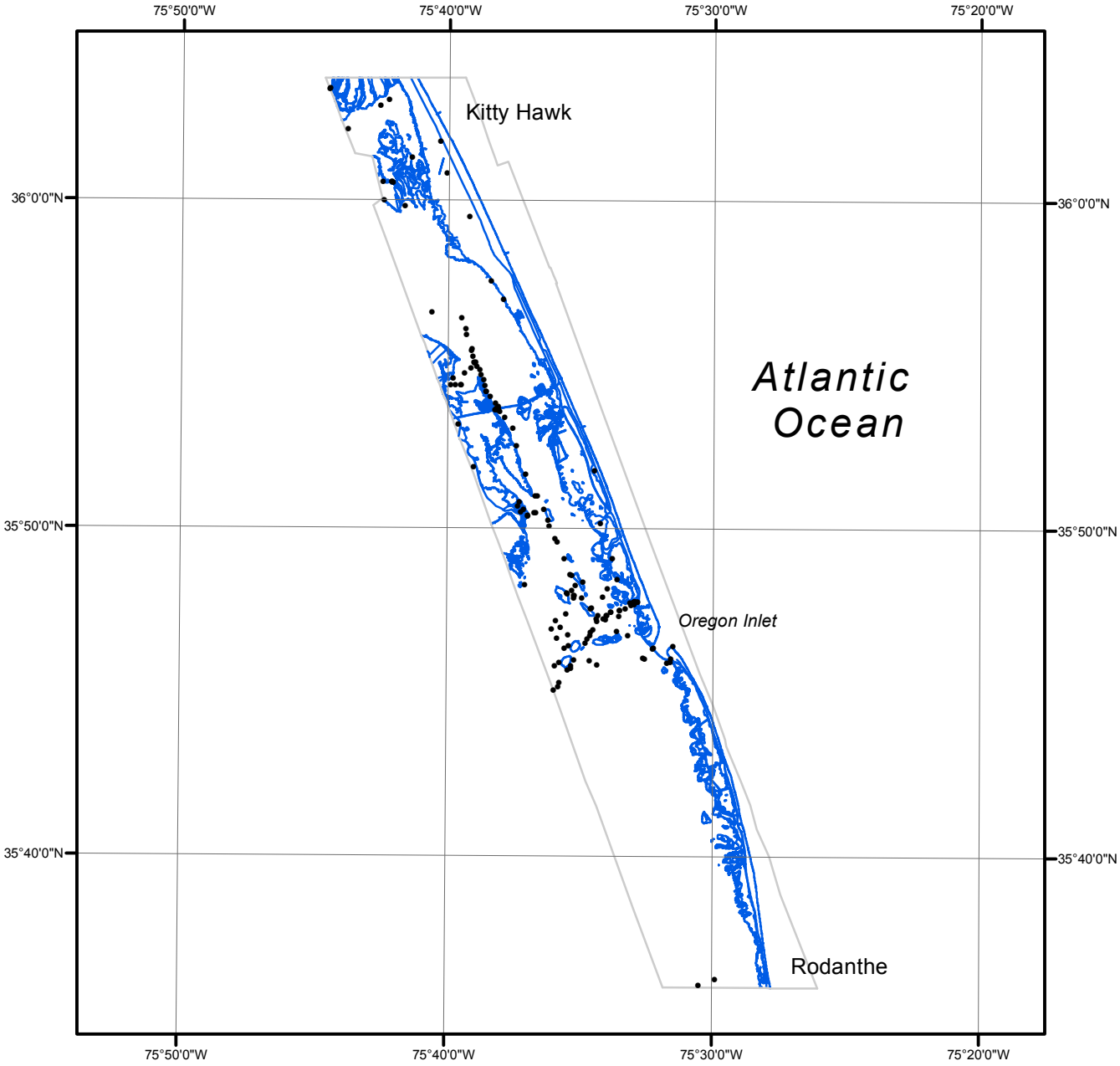
NOAA Shoreline Data Explorer

- GC10845 in shapefile format
- Metadata file for GC10845.
- Digital copy of the PCR in Adobe PDF format

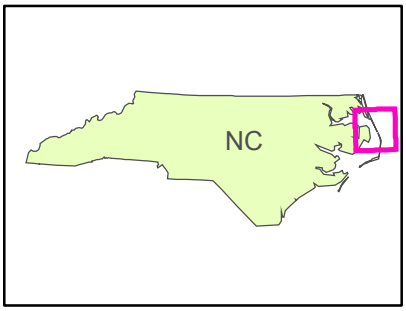
End of Report

KITTY HAWK TO RODANTHE

NORTH CAROLINA



Overview



NC0801C

GC10845