NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT NC1408-TB-C

Winyah Bay, South Carolina to Norfolk, Virginia

Introduction

NOAA Coastal Mapping Program (CMP) Project NC1408-TB-C provides a highly accurate database of new digital shoreline data for a portion of the Eastern Coastline of the United States extending from Winyah Bay, South Carolina northward to Norfolk, Virginia. The approximate bounding coordinates of the project are 33°08'N to 37°00'N latitude, and 75°26'W to 79°15'W longitude and includes Cape Fear, Cape Lookout, Cape Hatteras and Cape Henry. NC1408-TB-C is the southernmost part of a topographic/bathymetric lidar mapping initiative to provide updated shoreline data in the wake of Hurricane Sandy.

Successful completion of this project resulted in a densification of the National Spatial Reference System (NSRS), a set of controlled metric-quality aerial photographs, lidar point cloud 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.

The project database consists of information measured and extracted from aerial lidar data and digital imagery, and metadata related to shoreline extraction and derivation. Base mapping was conducted within both digital GIS and stereo softcopy photogrammetric environments using associated cartographic practices supplemented with lidar derived Mean High Water (MHW) and Mean Lower Low Water (MLLW) contour data.

Project Design

NC1408-TB-C was designed to support:

1) Application of topographic/bathymetric (topobathy) data acquired under the Sandy Supplemental Topo-Bathy project at the National Geodetic Survey (NGS),
2) Chart update activity of the Marine Chart Division (MCD),
3) Bathymetric data assessment by the Hydrographic Surveys Division (HSD).

The NOAA National Geodetic Survey (NGS) formulated the Project Instructions for this project following the guidelines of the "Scope of Work, Shoreline Mapping for the Coastal Mapping Program" (SOW), Version 14A, dated October 24, 2012. The instructions discussed the project's purpose, geographic area of coverage, scope and priority; data acquisition, processing, accuracy, and compilation requirements; product delivery and reporting instructions; and contact and communication information.

Field Operations

The field operations for NC1408-TB-C consisted of acquisition of topobathy lidar data, digital aerial imagery, static and kinematic GPS data, and Inertial Measurement Unit (IMU) data. Static GPS data were collected to support aerial data acquisition and processing operations, as well as to assess the accuracy of post-processed lidar data.

Lidar Data Acquisition

The topobathy lidar acquisition was conducted from November 11, 2013 through July 27, 2014 and consisted of a total of 262 lidar acquisition missions for airborne laser point cloud data. Lidar was captured with an approximate nominal point density of ≥ 4 pulses per square meter through the use of the Riegl VQ-820G sensor. The data were collected within a +/- 2 hour time window of the Mean Lower Low Water (MLLW) tide stage at a nominal altitude of 1,000 feet with a 50% swath overlap.

Digital Aerial Imagery Acquisition

The digital imagery acquisition for NC1408 was conducted from January 17, 2014 through February 28, 2014 and consisted of a total of forty-six (46) flight lines of natural color (NC) imagery - tide coordinated within 25% of the Mean Range. Imagery was captured at a nominal altitude of 10,000 feet with a ground sample distance (GSD) of 0.3m through the use of Intergraph Z/I Digital large format mapping cameras (DMC) with a focal length of 120 mm

Ground Control

A total of seventy-nine (79) GCPs were established in the NC1408-TB-C project area using a combination of traditional static, fast-static (FS), rapid-static (RS), real-time kinematic (RTK), and post processed kinematic (PPK) GPS techniques. Survey field work was performed between November 23, 2013 and June 03, 2014. A Ground Survey (GS) Report is on file with other project data within the NGS Remote Sensing Division (RSD) Applications Branch (AB) Project Archive.

GPS Data Processing

Acquisition aircraft were equipped with either a POSAV Applanix Model 510 IMU and/or a dual frequency Trimble BD960 to collect the ABGPS and IMU data. NGS CORS, and several Cooperative CORS stations, were used for base stations on the project, with at least two of these CORS stations being used to process each POSAV dataset to achieve the final photo center locations. For further information refer to the Airborne Positioning and Orientation Report (APOR) on file with other project data within the AB Project Archive.

Lidar Data Processing

LIDAR point cloud data for all of the areas acquired under the Sandy Supplemental Topo-Bathy project were processed from January 2014 to September 2015 using the following steps:

1) Riegl RiProcess software was utilized to transform the lidar point cloud into a mapping projection and check the calibration stability.
2) Terrasolid software was utilized for assessing relative and absolute accuracies between overlapping lifts and relative with each lift, initial point cloud classification, editing of

the lidar point cloud, and for classification of water surface, erroneous returns, bathymetric surface and bare earth points.

3) Refraction correction was performed through Dewberry's Lidar Processor
4) Additional QC, point classification, and formatting were performed with GeoCue, Terrasolid, and Global Mapper Software.
5) NOAA VDatum software was used to convert the vertical datum of the lidar points from NAD83 ellipsoid to local MHW and MLLW tidal datums.
6) QTModeler and custom ArcGIS Scripts were used to produce bare earth MHW and MLLW digital elevation models (DEMs) at a 1 meter grid resolution and the extraction and formatting of MHW and MLLW Shoreline Shapefiles
7) Accuracy Assessment: the lidar point cloud was compared to higher accuracy ground control points to determine vertical uncertainties of the data set, and then compared to the morphologic slope around the derived shoreline at 91,460 sample sites in the project area (63,748 MHW and 27,712 MLLW sites) to determine the uncertainty of the vectors. Based on this assessment:
    a. MHW lidar derived shoreline vectors meet a horizontal accuracy ranging from 1.06 to 2.77 meters at 95% CE,
    b. MLLW lidar derived shoreline vectors meet a horizontal accuracy ranging from 1.28 to 4.20 meters at 95% CE.

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) phase of the project (Sandy Supplemental Topo/Bathy – Southern Section) was performed using digital AT methods to establish the network of photogrammetric control required for the compilation phase. The Intergraph ImageStation Automatic Triangulation (ISAT) software (ver. 6.1) was used to perform automatic point measurements and interactive point measurements of tie points. The spatial extent of the AT consisted of three (3) sub-blocks: NC1408, VA1408 and NJ1403 (south), see Figure 1 in the AT report.

The Root Mean Square (RMS) of the standard deviations in both X and Y directions were calculated and used to determine a predicted horizontal circular error at the 95% confidence level (95% CE) of 0.18 meters. An AT Report is on file with other project data within the Applications Branch Project Archive. The project database consists of project parameters and options, camera calibration data, interior orientation parameters, ground control parameters, adjusted exterior orientation parameters, and positional listing of all measured points. Positional data is referenced to the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD88). Stereo-models were examined and found to have acceptable levels of parallax for mapping purposes.

Compilation

The data compilation phase of this project was completed in August 2015 and accomplished in two phases: 1) Automated extraction from topo-bathy lidar, and 2) manual extraction using digital stereo imagery.

1) Lidar Shoreline approach: MHW and MLLW shoreline vectors (in shapefile format) for the outer coastline were delineated using the DEMs discussed above (LiDAR processing section) along with a Raster-to-Vector (R2V) script implemented within ESRI ArcGIS 10.2 software. Subsequently, digital orthoimagery and/or stereoscopic imagery were used to review, edit, and attribute the lidar shoreline vectors. The lidar derived shoreline data were limited to terrain features at the land/water interface and did not include engineered, elevated features such as bulkheads, piers, bridges, Landmarks, etc. The MHW ("Shoreline") and MLLW ("Contour") shape files were then imported into BAE Systems SOCET SET (SS) software (version 5.6.0), and a Feature Database (FDB) was created.

2) Manual Compilation approach: The manual data compilation phase was accomplished using a Digital Photogrammetric Workstation (DPW), which consists of a stereo-enabled PC-based graphics workstation running the Windows 2007 operating system and SOCET SET suite of digital photogrammetric software (version 5.6.0). The FDB, created above, was populated with additional features compiled using the SS Feature Extraction software module based on imagery analysis of the processed digital images and information extracted from the appropriate NOAA Nautical Charts, the U.S. Coast Guard Light List and other ancillary sources. Feature attribution 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. Features compiled using this method meet a horizontal accuracy of 0.36 meters at the 95% confidence level. This accuracy is derived by doubling the 95% CE computed from the AT.

The following table provides information on the imagery used to complete this project:

Date	Time (UTC)	Flight Line	Photo ID	Tide Level*
01/17/2014	17:15:20 – 17:24:26	308	0001 – 0040	0.5
01/17/2014	17:29:36 – 17:31:24	309	0001 – 0013	0.4
01/17/2014	17:36:29 – 17:38:33	310	0001 – 0010	0.4
01/17/2014	17:42:52 – 17:50:02	311	0001 – 0046	0.2
01/17/2014	17:55:07 – 18:05:43	314	0001 – 0072	0.1
01/17/2014	18:11:19 – 18:26:59	313	0001 – 0068	0.1
01/17/2014	18:31:26 – 18:40:48	312	0001 – 0044	0.1
01/26/2014	14:42:27 – 14:52:14	305	0001 – 0049	-0.1
01/26/2014	15:03:27 – 15:10:34	306	0001 – 0048	-0.1
02/14/2014	17:26:19 – 17:37:15	303	0001 – 0051	0.5
02/14/2014	17:40:14 – 17:43:19	300	0001 – 0017	0.4
02/14/2014	17:46:39 – 17:52:06	302	0001 – 0031	0.4
02/14/2014	17:56:42 – 18:01:59	301	0001 – 0028	0.3

02/14/2014	18:08:32 – 18:17:07	304	0001 – 0055	0.2
02/14/2014	18:23:55 – 18:30:13	307	0001 – 0042	0.1
02/16/2014	18:25:58 – 18:35:48	315	0001 – 0013	0.1
02/16/2014	18:39:16 – 18:45:25	316	0001 – 0042	0.1
02/16/2014	18:51:07 – 19:05:33	317	0001 – 0058	0.0
02/16/2014	19:11:29 – 19:14:54	318	0001 – 0024	0.0
02/16/2014	19:17:37 – 19:20:39	319	0001 – 0021	0.0
02/16/2014	19:25:50 – 19:28:23	320	0001 – 0011	0.0
02/16/2014	19:32:56 – 19:34:00	321	0001 – 0008	0.0
02/16/2014	19:38:53 – 19:40:11	322	0001 – 0006	0.0
02/18/2014	18:17:07 – 18:26:55	329	0001 – 0017	0.2
02/18/2014	18:31:09 – 18:38:02	330	0001 – 0036	0.2
02/18/2014	18:40:30 – 18:43:59	331	0001 – 0019	0.2
02/18/2014	18:47:47 – 18:57:25	332	0001 – 0053	0.2
02/18/2014	19:03:29 – 19:07:48	333	0001 – 0023	0.2
02/18/2014	19:13:31 – 19:22:43	338	0001 – 0044	-0.1
02/18/2014	19:26:53 – 19:36:55	337	0001 – 0062	-0.2
02/18/2014	19:41:55 – 19:56:06	336	0001 – 0067	-0.2
02/18/2014	20:00:35 – 20:02:13	335	0001 – 0011	-0.2
02/18/2014	20:05:28 – 20:07:17	334	0001 – 0012	0.1
02/24/2014	14:08:48 – 14:18:39	323	0001 – 0060	0.0

* Tide levels are given in meters above MLLW and are based on verified observations recorded by the NOS tide gauges at: Oyster Landing (N Inlet Estuary) (ID# 8662245) and Springmaid Pier (ID# 8661070) in South Carolina; Wrightsville Beach (ID# 8658163), Beaufort (ID# 8656483), USCG Station Hatteras (ID# 8654467), Oregon Inlet Marina (ID# 8652587), and Duck (ID# 8651370) in North Carolina; and Chesapeake Bay Bridge Tunnel (ID# 8638863), and Sewells Point (ID# 8638863) in Virginia. The elevation of the MHW tidal datum along the outer coast in the area covered by this project varies between 0.8 – 1.6 m. above MLLW.

Quality Control / Final Review

Quality control tasks were conducted by RSD personnel and the final QC review was completed in December, 2015. The review process included analysis of AT results and assessment of the identification and attribution of digital feature data within the GC according to image analysis, using Stereo and Ortho-image data, and criteria defined in C-COAST. The quality control process concluded with an inspection of topological connectivity within the GC using ArcGIS 10.2 software. All project data was evaluated for compliance to CMP requirements.

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

- 11532, Winyah Bay, SC, 1:40,000 scale, 22nd Ed., Oct./12
- 11534, ICW, Myrtle Grove Snd/Cape Fear R. to Casino Cr, 1:40,000 scale, 38th Ed., Sep./13
- 11535, Little River Inlet to Winyah Bay Entrance, SC, 1:80,000 scale, 13th Ed., Feb./12
- 11537, Cape Fear River, Cape Fear to Wilmington, NC, 1:40,000 scale, 39th Ed., Apr./13
- 11541, ICW, Neuse River to Myrtle Grove Sound, NC, 1:40,000 scale, 40th Ed., Feb./13
- 11542, New River, NC, 1:40,000 scale, 19th Ed., Apr./14
- 11543, Cape Lookout to New River, NC, 1:80,000 scale, 25th Ed., Apr./15
- 11545, Beaufort Inlet and Part of Core Sound, NC, 1:40,000 scale, 65th Ed., May/13
- 11547, Morehead City Harbor, NC, 1:15,000 scale, 39th Ed., Dec./13
- 11550, Ocracoke Inlet and Part of Core Sound, NC, 1:40,000 scale, 30th Ed., Oct./12
- 11555, Cape Hatteras, Wimble Shoals to Ocracoke, NC, 1:80,000 scale, 42nd Ed., Apr./15
- 12204, Currituck Beach Light to Wimble Shoals, NC, 1:80,000 scale, 38th Ed., Dec./12
- 12205, Cape Henry, VA to Pamlico Sound, NC, 1:80,000 scale, 34th Ed., Apr./14
- 12206, ICW, Norfolk, VA to Albemarle Sound, NC 1:40,000 scale, 34th Ed., Jan./13
- 12208, Approaches to Chesapeake Bay, VA, 1:50,000 scale, 16th Ed., Jul./13
- 12222, Chesapeake Bay, Cape Charles to Norfolk Harbor, 1:40,000 scale, 55th Ed., Feb./15
- 12245, Hampton Roads, VA, 1:20,000 scale, 68th Ed., May/13
- 12254, Chesapeake Bay, Cape Henry to Thimble Shoal Lt, 1:20,000 scale, 49th Ed., Aug./11
- 12255, Naval Amphibious Base Little Creek, VA, 1:5,000 scale, 18th Ed., Sep./14
- 12256, Chesapeake Bay, Thimble Shoal Channel, VA, 1:20,000 scale, 18th Ed., Jan./14

End Products and Deliverables

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

Remote Sensing Division Electronic Data Library

- Ground Control Report
- Airborne Positioning and Orientation Reports (APOR)
- Aerotriangulation Report
- Project Completion Report (PCR)
- Project database
- GC11173 in shapefile format
- Chart Evaluation File (CEF) in shapefile format

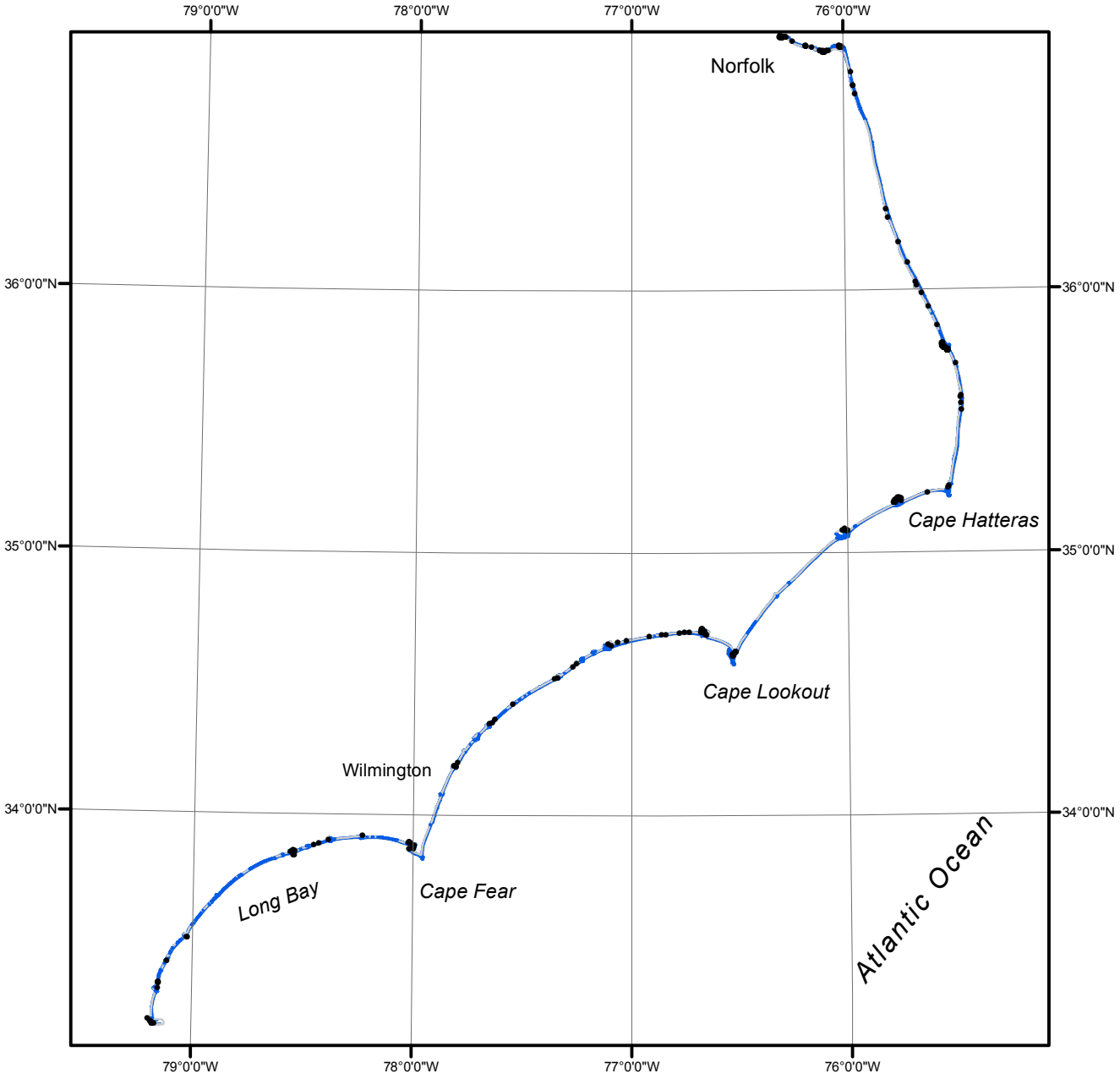
NOAA Shoreline Data Explorer

- GC11173 in shapefile format
- Metadata file for GC11173
- Digital copy of the PCR in Adobe PDF format

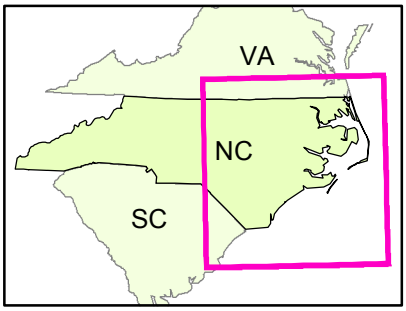
End of Report

WINYAH BAY TO NORFOLK

SOUTH CAROLINA, NORTH CAROLINA, AND VIRGINIA



Overview



NC1408-TB-C

GC11173