NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT PR1401B-TB-N

Southern Puerto Rico, Punta Verraco to Cabo Mala Pascua, Puerto Rico

Introduction

NOAA Coastal Mapping Program (CMP) Project PR1401B-TB-N provides a highly accurate database of new digital shoreline data for a portion of the southern shore of Puerto Rico, extending from Punta Verraco to Cabo Mala Pascua. Project PR1401B-TB-N is a subproject of a larger project, PR1401-TB-N, which covers Puerto Rico nearly in its entirety. Project PR1401B-TB-N was conducted using stereo softcopy photogrammetry supplemented with Mean High Water (MHW) and Mean Lower Low Water (MLLW) data derived from topographic-bathymetric (topobathy) lidar sensor technology. The Geographic Cell (GC) may be used in support of the NOAA Nautical Charting Program (NCP) as well as geographic information systems (GIS) for a variety of coastal zone management applications.

Project Design

Project PR1401-TB-N was designed by personnel of NOAA's National Geodetic Survey (NGS) within the Requirements Branch (RB) of the Remote Sensing Division (RSD). RB 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.

NGS was responsible for the planning, acquisition, and processing of all aerial data in order to support photogrammetric and lidar processing for feature compilation. This includes the establishment of ground control, and the post-processing of airborne Global Positioning System (GPS) data. In addition, NGS provided shapefiles of the flight lines and exposure centers of the imagery to be used for compilation. Subsequent to the completion of project planning and data collection, Dewberry was contracted for additional processing and compilation activities.

Field Operations

NGS performed all field operations, which included the acquisition of aerial photographs and topobathy lidar, as well as the surveying of ground control points (GCPs) and accuracy assessment checkpoints (CPs), and the establishment of base stations to support aerial collection and survey operations.

Ground survey operations were conducted by NGS from October 2014 to May 2015 to support aerial imagery and lidar collections. Two aerial base stations per flight mission and 477 lidar GCPs were surveyed using a combination of traditional static, real-time kinematic, and post processed kinematic GPS techniques. From the above GCPs, a subset of 27 were utilized in an

accuracy assessment to compute a 95% confidence circle for PR1401-TB-N orthoimagery which was used for feature compilation in other subprojects.

Aerial survey operations for Project PR1401-TB-N were conducted by NGS in two phases. The first phase, from October 2014 to May 2015, included concurrent acquisition of lidar and imagery, utilizing a total of 630 passes with NOAA's DeHavilland Twin Otter aircraft at an altitude of 400 meters above ground level (AGL) to cover a 491 square mile area within the project. Topobathy lidar data was collected with a Riegl VQ-820-G system at an aggregate nominal point density of 18 pulses per square meter, with a nominal swath width of 234 meters and a 50% swath overlap. Additionally a total of 1,340 flight lines of color (RGB) imagery were acquired. Imagery was captured with an approximate nominal ground sample distance (GSD) of 0.035 meters through the use of an Applanix Digital Sensor System (DSS) 539 aerial camera. Imagery was collected in this phase of acquisition for the purpose of creating orthoimages.

The second phase of aerial survey operations was conducted from February through March 2016. Lidar acquisition consisted of a total of 163 passes using NOAA's DeHavilland Twin Otter aircraft at an altitude of 400 meters AGL to complete a 107 square mile area. Topobathy lidar data was collected with a Riegl VQ-880-G lidar system at an aggregate nominal point density of 18 pulses per square meter with a nominal swath width of 287 meters and a 50% swath overlap. Imagery was acquired separately from the lidar in this phase, using the NOAA King Air aircraft and an Applanix DSS 580/560 dual aerial camera system. A total of 49 flight lines of RGB and near-infrared (NIR) imagery were acquired over the second phase area at altitudes of 1,400 meters (34 lines) and 2,400 meters (15 lines), resulting in nominal GSDs of 0.14 meters and 0.24 meters respectively. Imagery collected in the second phase of acquisition was planned with 60% endlap specifically to support stereo photogrammetric feature compilation.

GPS Data Processing

For both the lidar and image data acquisitions for PR1401-TB-N, airborne GPS data was collected using an Applanix POSAV IMU unit with a dual-frequency Trimble BD960 receiver. Airborne GPS data was processed using the Applanix POSPac MMS software with tightly coupled processing (IN-Fusion Single Base) to achieve the final image center locations and orientations. Base data, for all kinematic processing, consisted of GPS stations set-up in the survey area collecting at least four hours of static data with positions derived via the NGS Online Positioning Users Service (OPUS). Two base stations were utilized for the lidar acquisition for redundancy purposes. For further information refer to the Airborne Positioning and Orientation Reports (APOR) on file with other project data within the RSD Electronic Data Library.

Lidar Data Processing

Lidar point cloud data for both phases of acquisition was processed by October 2017. NGS personnel performed initial processing and quality control, including calibration, checks for data voids, relative swath accuracy, refraction correction, and preliminary vertical accuracy assessment before delivering calibrated lidar swath data to Dewberry for further processing.

Dewberry utilized a variety of software for lidar data processing, including Leica LP360, TerraScan, Esri ArcGIS, QT Modeler, GeoCue, Global Mapper, and Dewberry's proprietary LIDAR Processor tool. Data processing included additional quality checks and accuracy assessments of the preliminary swath data, breakline creation to define the land/water interface, point classification, automated and manual editing of the lidar tiles, QA/QC, and final formatting

of the LAS tiles. Final processed lidar products delivered to NOAA included raw point cloud data (swaths), breaklines, classified LAS tiles, topobathy DEM tiles, void polygon layer, intensity image tiles, confidence maps, and FGDC compliant metadata files.

NGS used NOAA VDatum software to convert the vertical datum of the classified lidar points from NAD83 ellipsoid to local MHW and MLLW tidal datums. 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 to create and format the MHW and MLLW vectors into shapefile format.

In order to determine the uncertainty of lidar-derived vectors, lidar point data was compared to CPs of higher accuracy to determine vertical uncertainties, and then further compared to the morphologic slope around the derived vectors at sample sites in the project area. Based on this assessment the MHW lidar-derived shoreline vectors for subproject PR1401B-TB-N meet a horizontal accuracy of 1.4 meters at the 95% confidence level, and the MLLW lidar-derived vectors meet a horizontal accuracy of 1.9 meters at the 95% confidence level. NOAA supplied the lidar-derived MHW and MLLW shapefiles to be segmented, edited, and attributed by Dewberry. For further information on lidar data processing and products refer to the Final Report of Survey on file within the RSD Electronic Data Library.

Orthoimage Processing

Orthoimagery was generated for project PR1401-TB-N by NGS personnel using POS AV GPS-aided inertial navigation solution parameters (Direct Georeferencing) along with elevation data from the USGS 3D Elevation Program (3DEP) within Open Source Software Image Map (OSSIM) software. A detailed list of aerial images included in orthoimage processing is on file in the RSD Electronic Data Library. Individual orthoimages were combined into a seamless mosaic using Ortho Vista (ver. 4.6) with a GSD of 0.15 meters.

An accuracy assessment of the orthoimagery was completed using 27 photo-identifiable CPs. The Root Mean Square (RMS) of the standard deviations, in both X and Y directions, was calculated and used to determine a predicted horizontal circular error at the 95% confidence level of 0.7 meters. The results of the assessment (PR1401_ortho_95%cc.xls) is on file with other project data within the RSD Electronic Data Library. All positional data is referenced to the North American Datum of 1983 (NAD 83).

Compilation

The data compilation phase of the project was initiated by Dewberry personnel in August 2017. NGS supplied the lidar-derived MHW and MLLW shapefiles to be edited, attributed and generalized by Dewberry. Additional features were then manually compiled using the orthoimagery as a base layer. Esri's ArcMap software was used for this work, enabling compilation of features into an Esri geodatabase where topological and attribution relationships could be enforced. Once compilation was complete, the geodatabase features were exported to shapefile format. 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.

Spatial data accuracies for subproject PR1401B-TB-N were determined according to standard

Federal Geographic Data Committee (FGDC) practices. Cartographic features compiled directly from the orthoimagery were tested to have a horizontal accuracy of 1.4 meters at the 95% confidence level. This predicted accuracy of well-defined points is derived by doubling the circular error calculated from the orthoimage accuracy assessment statistics. Lidar-derived features had horizontal accuracies that varied from 1.4 meters to 1.9 meters, as described above.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion by a senior member of Dewberry. The final QC review was completed in November 2018. 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 and criteria defined in C-COAST. The quality control process concluded with an inspection of topological connectivity within the GC using ArcGIS (ver. 10.7.1) software. All project data was evaluated for compliance to CMP requirements.

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

25677, Guanica Light to Punta Tuna Light, 22nd Ed., Jul. 2013
25681, Bahia de Guayanilla and Bahia de Tallaboa, 18th Ed., Dec. 2011
25683, Bahia de Ponce and Approaches, 20th Ed., Oct. 2012
25685, Punta Petrona to Isla Caja de Muertos, 9th Ed., Apr. 2003
25687, Bahia de Jobos and Bahia de Rincon, 13th Ed., Sep. 2013
25689, Puerto Arroyo, 10th Ed., Sep. 2013

End Products and Deliverables

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

RSD Electronic Data Library

- Airborne Positioning and Orientation Report (APOR)
- Final Report of Survey
- Project Completion Report (PCR)
- Image Sources Table
- Project database
- GC11662 in shapefile format
- CEF in shapefile format

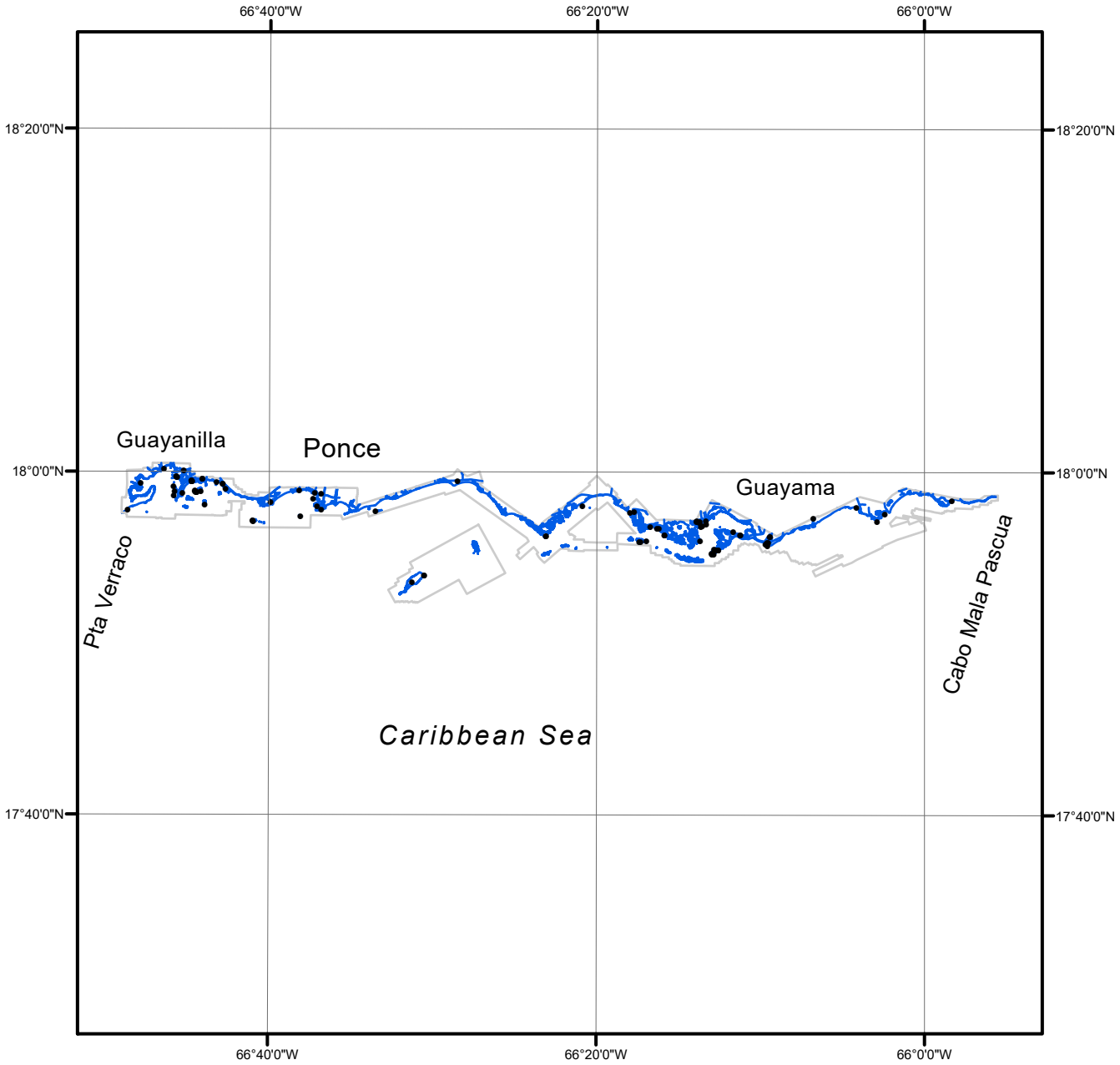
NOAA Shoreline Data Explorer

- GC11662 in shapefile format
- Metadata file for GC11662
- PCR in Adobe PDF format

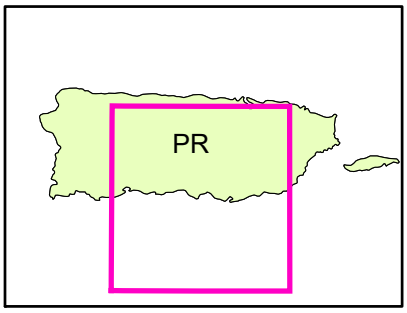
End of Report

SOUTHERN PUERTO RICO, PTA VERRACO TO CABO MALA PASCUA

PUERTO RICO



Overview



PR1401B-TB-N

GC11662