NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT PR1801D-TB-C

South Coast of Puerto Rico, Punta Toro to Punta Vaquero

Introduction

NOAA Coastal Mapping Program (CMP) Project PR1801D-TB-C provides a highly accurate database of new digital shoreline data for the south coast of Puerto Rico, from Punta Toro to Punta Vaquero. Project PR1801D-TB-C is a subproject of a larger project, PR1801-TB-C, which covers Puerto Rico in its entirety. 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

NOAA's National Geodetic Survey (NGS) Remote Sensing Division (RSD) 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. NOAA also provided shapefiles depicting the shoreline to be mapped and the boundaries of the main project area.

Dewberry was responsible for the planning, acquisition, and processing of all imagery and lidar data in order to support feature compilation. This includes the establishment of ground control and the post-processing of airborne GPS data. In addition, Dewberry provided shapefiles of the flight lines and exposure centers of the imagery to be used for compilation.

Field Operations

Dewberry and their subcontractor Leading Edge Geomatics, LLC (LEG) performed field operations for Project PR1801-TB-C in conjunction with Project VI1801-TB-C consisting of the acquisition of aerial photographs and topographic-bathymetric (topobathy) lidar, as well as the surveying of ground control points (GCPs), accuracy assessment checkpoints (CPs), and the establishment of base stations to support aerial collection and real-time kinematic survey operations.

LEG surveyed 95 ground control points for PR1801-TB-C, to be used for the aerial triangulation of the aerial imagery using Static and RTK GNSS/GPS Surveying methods. Survey field work was performed from January to March 2019. Dewberry performed a separate survey of 40 ground control points and 292 check points, to be used to evaluate the vertical and horizontal accuracy of the PR1801-TB-C lidar data. Dewberry's survey field work was performed from March to May 2019. For further information see the Ground Survey Reports on file with other project data within the RSD Electronic Data Library.

The lidar acquisition for projects PR1801-TB-C and VI1801-TB-C was conducted by LEG from January through June 2019, and consisted of 992 parallel flight lines and 44 cross-flights with a combined nominal point density of 4.28 pulses per square meter. Topobathy lidar data was captured using a RIEGL VQ880-GII Topobathymetric lidar system on a Piper Aztec aircraft. For further information on lidar acquisition and processing see the Topobathy Final Report of Survey on file within the RSD Electronic Data Library.

Aerial photography acquisition for PR1801-TB-C was conducted by LEG between February and November 2019, using four aircraft outfitted with three aerial mapping cameras. Persistent cloud cover was an issue with this project. Portions of flight lines had to be recollected at various altitudes in an attempt to fly under the cloud cover. The ground sample distance (GSD) of the acquired imagery varied due to the different flying heights. Originally the imagery was required to be tide-coordinated within ±3 hours of the Mean Lower Low Water (MLLW) tide stage, but later the tidal restriction was relaxed to ±4 hours around low tide, in order to help mitigate the cloud problem. A total of 238 flight lines of digital RGB imagery were acquired, including many re-flights and patches due to clouds. Of these flight lines, a subset of all or part of 39 lines were used for the PR1801D-TB-C subproject. For further information see the Final Orthoimagery and Analytical Aerotriangulation Reports on file within the RSD Electronic Data Library.

GPS Data Processing

Airborne kinematic GPS/IMU data for PR1801-TB-C were processed using a variety of techniques to determine trajectory and exterior orientation data for aerotriangulation of the imagery and processing of the lidar data. A combination of static base stations and CORS stations were utilized as reference stations for the kinematic data processing. The data were processed using Applanix POSPac MMS (ver. 8.4) or Novatel Inertial Explorer (ver. 8.70.3114) software for each mission depending on which aircraft/camera system was used. The processing mode used for each trajectory varied between Singlebase, Multi-Singlebase, Applanix Smartbase, or Smoothed Tightly-Coupled Combined, depending on the software used and the number of viable reference stations available in the vicinity of the trajectory. For further information refer to the Airborne Positioning and Orientation Report (APOR) and the Topobathy Final Report of Survey on file within the RSD Electronic Data Library.

Lidar Data Processing

Lidar point cloud data for Project PR1801-TB-C were processed from February through December 2019. Riegl RiProcess software was utilized to transform the lidar point cloud into a mapping projection and to check the calibration stability. Terrasolid software was used 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. Refraction correction was performed through Dewberry's lidar processor. Additional quality control (QC), point classification, and formatting were performed with GeoCue, Terrasolid, and Global Mapper software. NOAA VDatum software was used to convert the vertical datum of the lidar points from NAD83 ellipsoid to local MHW and MLLW tidal datums. 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.

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 numerous sample sites in the project area to determine the uncertainty of the vectors. Based on this assessment the MHW lidar-derived shoreline vectors meet a horizontal accuracy of 1.2 meters at the 95% confidence level, and the MLLW lidar-derived shoreline vectors meet a horizontal accuracy of 1.6 meters at the 95% confidence level. For further information refer to the Topobathy Final Report of Survey on file with other project data within the RSD Electronic Data Library.

Aerotriangulation

The aerotriangulation (AT) phase of PR1801-TB-C was performed by Dewberry subcontractor LEG using digital AT methods to establish the network of photogrammetric control required for the compilation phase. Inpho Match-AT software was used to perform automatic and interactive point measurements of tie points. The process included automatic point matching and least-squares-simultaneous-robust bundle-block adjustments consisting of three main blocks covering the mainland of Puerto Rico and the large islands of Culebra and Vieques. Additionally, there were 14 sub-blocks covering small islands off the coasts of the three main islands that could not be tied to the main blocks, and were adjusted separately using manually measured tie points and lidar-derived control points.

The PR1801D-TB-C subproject was covered by the Puerto Rico mainland block and six smaller sub-blocks (listed below). 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. The predicted horizontal accuracies for the PR1801D-TB-C main block and sub-blocks are as follows:

- Mainland Block: 0.2 meters
- 7 RI 1 Sub-block: 0.1 meters
- 7 RI 2 Sub-block: 0.4 meters
- 7 RI 3 Sub-block: 0.3 meters
- 7 RI 6 Sub-block: 0.2 meters
- 7 RI 7 Sub-block: 0.7 meters
- 7 RI 8 Sub-block: 0.3 meters

An AT Report is on file with other project data within the RSD Electronic Data Library. 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).

Compilation

Feature compilation for the project was initiated by Dewberry personnel in January 2021. NGS supplied the lidar-derived MHW and MLLW shapefiles to be edited, attributed and generalized. Additional features were then manually compiled using stereo imagery. Compilation was performed using the SOCET for ArcGIS module of BAE's SOCET SET (ver. 5.6)

photogrammetric software suite, 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 PR1801D-TB-C were determined according to standard Federal Geographic Data Committee (FGDC) practices. Horizontal accuracies at the 95% confidence level of cartographic features compiled from imagery for the PR1801D-TB-C main blocks and sub-blocks are listed below:

- Mainland Block: 0.4 meters
- 7 RI 1 Sub-block: 0.2 meters
- 7 RI 2 Sub-block: 0.8 meters
- 7 RI 3 Sub-block: 0.6 meters
- 7 RI 6 Sub-block: 0.4 meters
- 7 RI 7 Sub-block: 1.4 meters
- 7 RI 8 Sub-block: 0.6 meters

These predicted accuracies of compiled, well-defined points are derived by doubling the circular error calculated from the AT statistics. The lidar-derived features had horizontal accuracies that varied from 1.2 meters to 1.6 meters as discussed above.

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

Date	Time (UTC)	Flight Line #	Photo IDs	Tide Level *
3/12/2019	17:47 – 17:48	37-735	1002 – 1007	0.1 m
3/12/2019	17:54 – 17:56	37-734	1004 – 1018	0.0 m
3/12/2019	18:01 – 18:04	37-733	1001 – 1019	0.1 m
3/12/2019	18:11 – 18:16	37-732	1004 – 1034	0.0 m
3/12/2019	18:21 – 18:24	37-731	1003 – 1022	0.0 m
3/12/2019	18:24 – 18:34	37-731	2001 – 2065	0.0 m
3/12/2019	18:39 – 18:51	37-730	1003 – 1089	0.0 m
3/12/2019	18:59 – 19:13	37-729	1009 – 1103	0.0 m
3/14/2019	19:00 – 19:00	37-720	2007 – 2012	0.0 m
3/14/2019	19:41 – 19:42	37-732	2011 – 2018	0.0 m
4/2/2019	18:09 – 18:11	28-614	1089 – 1104	0.2 m
4/7/2019	16:45 – 16:48	28-613	1008 – 1028	0.1 m
4/15/2019	13:27 – 13:31	28-612	1089 – 1116	0.2 m
4/19/2019	16:27 – 16:34	28-715	1028 – 1073	0.1 m
4/19/2019	16:39 – 16:46	28-716	1001 – 1047	0.1 m

4/20/2019	14:19 – 14:25	28-717	1001 – 1047	0.1 m
4/20/2019	14:41 – 14:49	28-718	1028 – 1073	0.1 m
4/20/2019	14:54 – 14:56	28-719	1001 – 1016	0.1 m
4/26/2019	17:34 – 17:51	28-728	2001 – 2114	0.1 m
5/1/2019	14:34 – 14:42	28-727	1051 – 1112	0.2 m
5/3/2019	17:22 – 17:36	28-726	2001 – 2112	0.1 m
5/4/2019	16:21 – 16:31	28-725	3001 – 3062	0.1 m
5/10/2019	15:43 – 15:45	28-610	1001 – 1017	0.1 m
5/10/2019	16:22 – 16:23	28-609	1115 – 1127	0.1 m
5/10/2019	16:29 – 16:30	28-608	1001 – 1111	0.1 m
5/10/2019	17:10 – 17:12	28-607	1017 – 1127	0.1 m
5/14/2019	19:49 – 19:52	28-611	3103 – 3126	0.2 m
6/4/2019	14:41 – 14:43	28-730	2001 – 2015	0.0 m
6/4/2019	14:51 – 14:59	28-727	2001 – 2050	0.0 m
6/4/2019	15:06 – 15:07	28-725	4001 – 4013	0.0 m
6/7/2019	14:30 – 14:32	28-712	3010 – 3023	0.1 m
6/7/2019	14:37 – 14:43	28-714	2004 – 2048	0.1 m
6/16/2019	17:53 – 17:55	28-724	2029 – 2046	0.0 m
7/18/2019	13:12 – 13:12	11-749	1001 – 1010	0.1 m
7/18/2019	13:20 – 13:21	11-750	1001 – 1011	0.1 m
7/18/2019	13:28 – 13:28	11-751	1001 – 1008	0.1 m
7/18/2019	13:34 – 13:34	11-623	1001 – 1006	0.1 m
7/18/2019	13:42 – 13:47	11-624	1001 – 1057	0.1 m
7/21/2019	17:26 – 17:29	11-625	2008 – 2055	0.2 m
7/21/2019	17:32 – 17:36	11-626	1001 – 1047	0.2 m
7/21/2019	17:49 – 17:50	11-628	1001 – 1009	0.2 m
7/21/2019	17:54 – 17:55	11-629	1001 – 1009	0.2 m
11/22/2019	12:21 – 12:22	42-634	1001 – 1004	0.3 m

* Water levels are given in meters above MLLW and are based on verified observations recorded by the NOS tide gauge at Magueyes Island, PR - Station ID: 9759110. The MHW tidal datum is 0.201 meters above MLLW at the gauge.

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 April 2021. 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. 10.8.1) software. All project data was evaluated for compliance to CMP requirements.

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

25659, Puerto Maunabo, 9th Ed., Mar. 2003
25677, S. Coast of Puerto Rico, Guanica Light to Punta Tuna, 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:

Remote Sensing Division Electronic Data Library

- Project database
- Ground Survey Reports
- Airborne Positioning and Orientation Report (APOR)
- Orthoimagery Final Report
- Topobathy Final Report of Survey
- Aerotriangulation Report
- Project Completion Report (PCR)
- GC11532 in shapefile format
- CEF in shapefile format

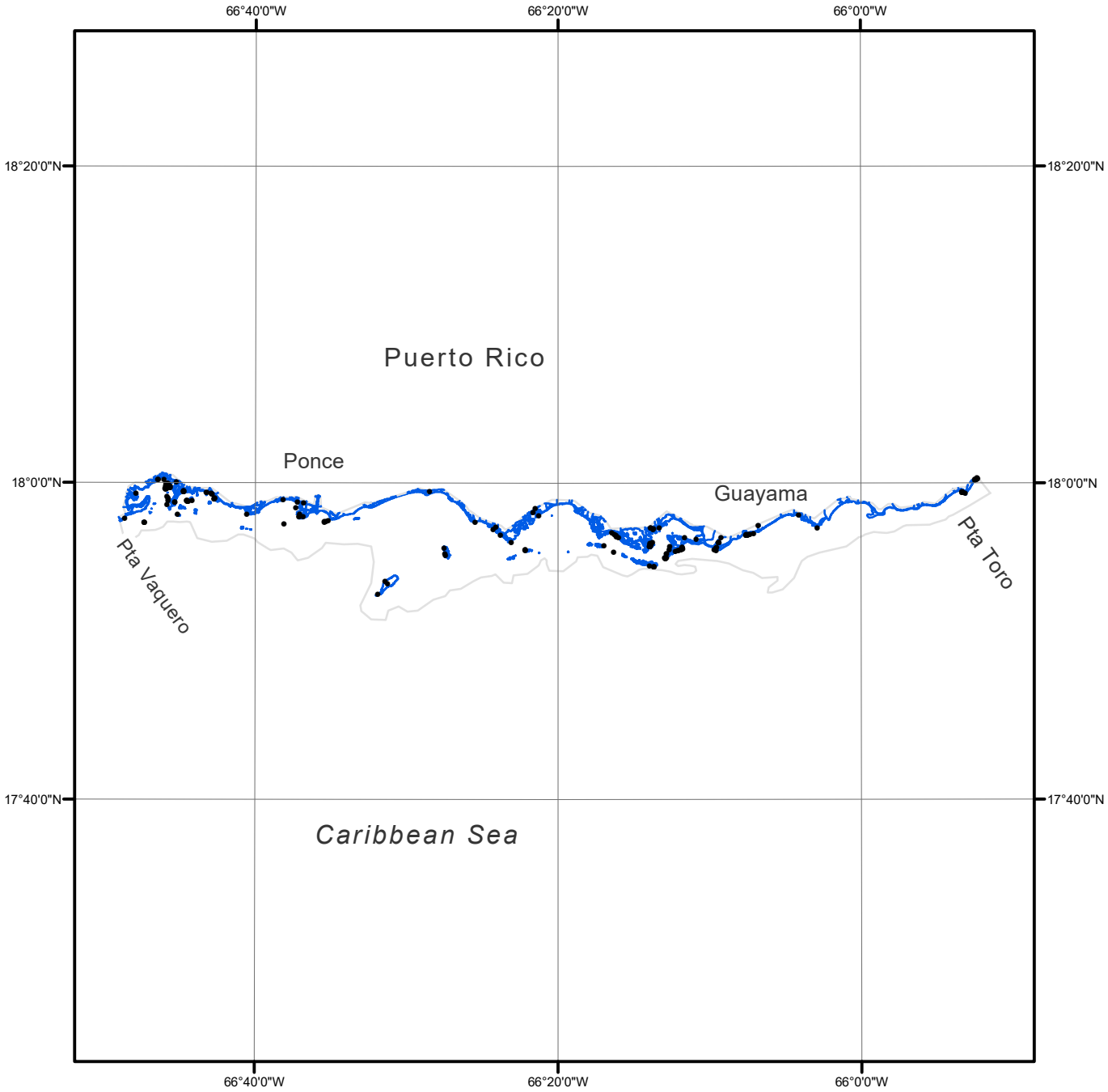
NOAA Shoreline Data Explorer

- GC11532 in shapefile format
- Metadata file for GC11532
- PCR in Adobe PDF format

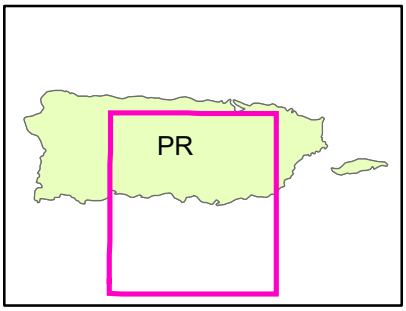
End of Report

SOUTH COAST OF PUERTO RICO, PTA TORO TO PTA VAQUERO

PUERTO RICO



Overview



PR1801D-TB-C

GC11532