

NOAA COASTAL MAPPING PROGRAM PROJECT COMPLETION REPORT

PROJECT PR1801C-TB-C

Isla De Culebra and Isla De Vieques, Puerto Rico

Introduction

NOAA Coastal Mapping Program (CMP) Project PR1801C-TB-C provides a highly accurate database of new digital shoreline data for Isla De Culebra, Isla De Vieques, and various other smaller islands nearby, in Puerto Rico. Project PR1801C-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 30 lines were used for the PR1801C-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 1.3 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 PR1801C-TB-C subproject was covered by the Culebra and Vieques main blocks and two smaller sub-blocks (4 RI 1 & 5 RI 1). 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 PR1801C-TB-C main blocks and sub-blocks are as follows:

- Culebra Block: 0.2 meters
- Vieques Block: 0.2 meter
- 4 RI 1 Sub-block: 0.5 meters
- 5 RI 1 Sub-block: 0.4 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 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 PR1801C-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 PR1801C-TB-C main blocks and sub-blocks are listed below:

- Culebra Block: 0.4 meters
- Vieques Block: 0.4 meter
- 4 RI 1 Sub-block: 1.0 meters
- 5 RI 1 Sub-block: 0.8 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 1.3 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 *
3/6/2019	20:50 – 20:54	37-404	1002 – 1025	0.2 m
3/21/2019	18:17 – 18:18	28-402	1003 – 1014	0.1 m
3/21/2019	18:31 – 18:34	28-403	1004 – 1022	0.1 m
3/21/2019	18:48 – 18:54	28-405	1001 – 1039	0.1 m
4/7/2019	15:40 – 15:51	28-510	1003 – 1074	0.1 m
4/7/2019	15:56 – 16:05	28-509	1003 – 1075	0.1 m
4/7/2019	16:13 – 16:14	28-502	1004 – 1012	0.1 m
4/7/2019	16:20 – 16:22	28-503	1004 – 1023	0.1 m
4/7/2019	17:13 – 17:22	28-508	1003 – 1075	0.1 m
4/13/2019	14:38 – 14:43	28-504	1004 – 1036	0.2 m
4/13/2019	14:47 – 14:55	28-505	1001 – 1048	0.2 m
4/13/2019	15:02 – 15:10	28-506	1005 – 1065	0.2 m
4/15/2019	12:43 – 12:52	28-507	1003 – 1071	0.2 m
6/1/2019	13:45 – 13:50	28-512	2005 – 2035	0.1 m
6/10/2019	19:15 – 19:18	28-410	2001 – 2019	0.2 m
6/10/2019	19:27 – 19:31	28-409	2007 – 2039	0.2 m
6/15/2019	17:47 – 17:54	28-406	2002 – 2042	0.0 m
6/15/2019	18:24 – 18:33	28-511	2006 – 2065	0.1 m
6/16/2019	16:18 – 16:25	28-408	3001 – 3037	0.0 m
6/24/2019	14:39 – 14:45	28-407	4002 – 4040	0.2 m

7/21/2019	16:49 – 16:51	11-516	1001 – 1024	0.2 m
7/21/2019	17:00 – 17:01	11-515	1001 – 1024	0.2 m
7/21/2019	17:10 – 17:11	11-514	1001 – 1014	0.2 m
7/23/2019	13:33 – 13:34	11-411	1001 – 1018	0.2 m
7/23/2019	13:41 – 13:42	11-412	1013 – 1025	0.2 m
11/21/2019	12:37 – 12:40	42-517	1001 – 1011	0.3 m
11/21/2019	12:58 – 12:59	42-518	1001 – 1004	0.3 m
11/22/2019	13:58 – 13:59	42-519	1001 – 1004	0.3 m
11/23/2019	12:59 – 13:00	42-424	1001 – 1006	0.4 m
11/23/2019	13:05 – 13:05	42-520	1001 – 1004	0.3 m

* Water levels are given in meters above MLLW and are based on verified observations recorded by the NOS tide gauges at Esperanza, Vieques Island, PR - Station ID:9752695 and Culebra, PR - Station ID: 9752235. The MHW tidal datum is 0.220 meters above MLLW at the Esperanza gauge and 0.280 meters at the Culebra 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:

25650, Virgin Passage and Sonda De Vieques, 37th Ed., Feb. 2014
 25653, Isla de Culebra and Approaches, 13th Ed., Dec. 2002
 25654, Ensenada Honda, 14th Ed., Sep. 2018
 25655, Ensenada Honda to Canal de Luis Pena, 12th Ed., Jul. 2004
 25663, Pasaje De San Juan to Puerto De Humacao, 29th Ed., Mar. 2014
 25664, Pasaje de Vieques and Radas Roosevelt, 18th Ed., Mar. 2014

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)
- GC11531 in shapefile format
- CEF in shapefile format

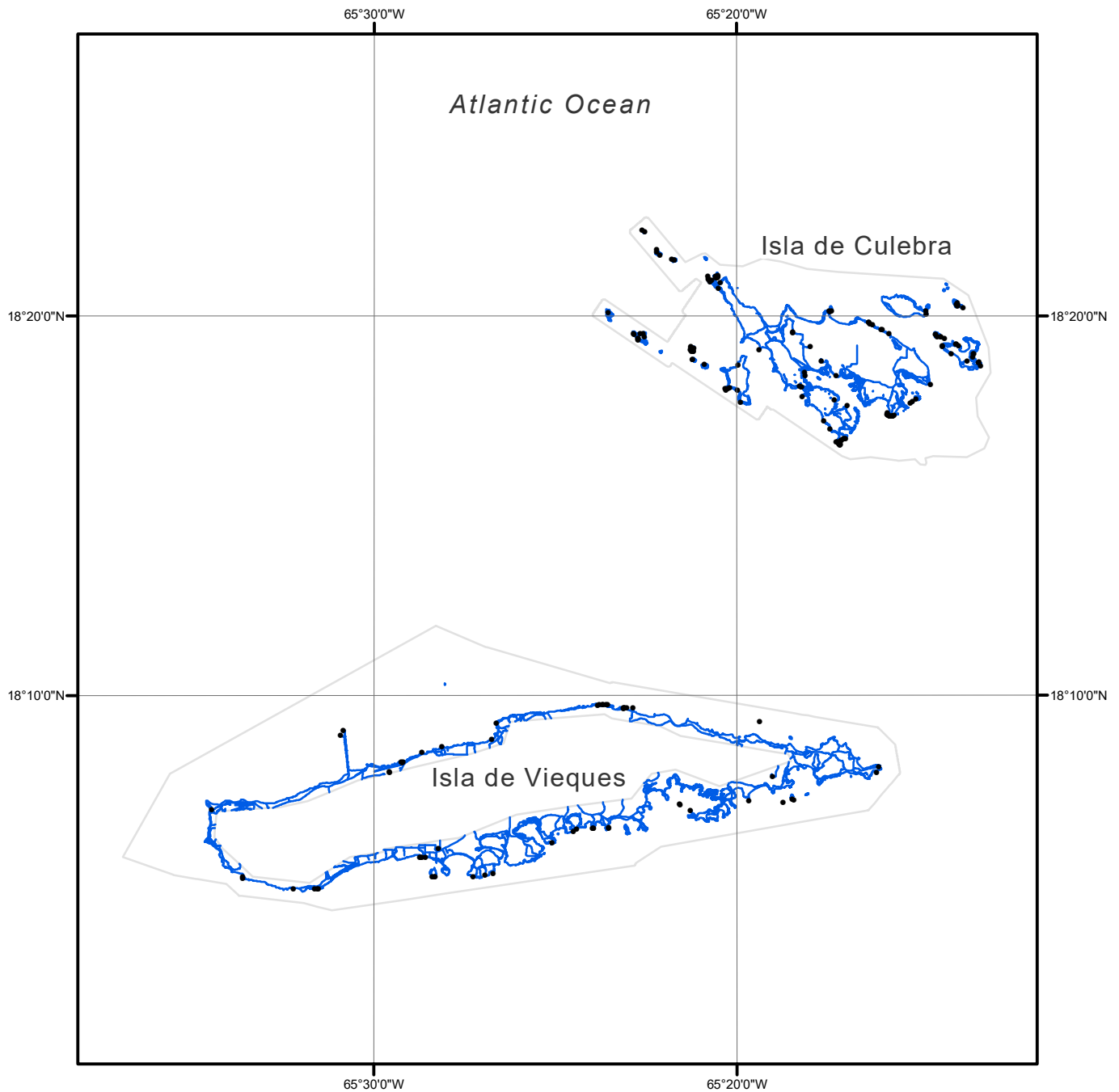
NOAA Shoreline Data Explorer

- GC11531 in shapefile format
- Metadata file for GC11531
- PCR in Adobe PDF format

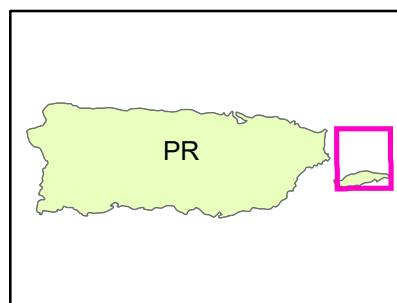
End of Report

ISLA DE CULEBRA AND ISLA DE VIEQUES

PUERTO RICO



Overview



PR1801C-TB-C

GC11531