NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT WA1402-CM-N

Puget Sound, Foulweather Bluff to Vashon Island, Washington

Introduction

NOAA Coastal Mapping Program (CMP) Project WA1402-CM-N provides highly accurate digital shoreline for Puget Sound from Foulweather Bluff to Vashon Island, in Washington. 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

The Requirements Branch (RB) of the Remote Sensing Division (RSD) formulated the photographic mission instructions for this project following the guidelines of RSD's Photo Mission Standard Operating Procedures. The instructions discussed the project's purpose, geographic area of coverage, scope and priority; photographic requirements; Global Positioning System (GPS) data collection procedures and guidelines for both kinematic and static surveys; data recording and handling instructions. RB created a Project Layout Diagram, flight maps and input files for the aircraft's flight management system.

Field Operations

The field operations consisted of the collection of static and kinematic Global Positioning System (GPS) data, Inertial Measurement Unit (IMU) data, and the acquisition of aerial imagery. The tide coordinated photographic mission operations were conducted with the NOAA King Air (N68RF) aircraft on July 27, 2014 for Mean Lower Low Water (MLLW) imagery and August 8-11, 2014 for Mean High Water (MHW) imagery. Nineteen strips of color (RGB) and infrared (IR) digital images were acquired concurrently with an Applanix Digital Sensor System (DSS) 439 dual camera at a nominal altitude of 10,500 feet, resulting in an approximate ground sample distance (GSD) of 0.37 meters.

Direct Georeferencing Data Processing

The GPS/IMU data was collected and processed by RSD personnel to yield precise positions and orientations of camera centers for direct geo-referencing (DG) of the imagery as well as to provide a control network necessary for aerotriangulation. A local GPS base station was established for use as a reference station for kinematic GPS processing operations. The position of the base station was determined using the NGS Online Processing User Service (OPUS), which computed fixed baseline solutions from nearby CORS stations. The kinematic GPS data was processed using Applanix POSPAC (ver. 6.2) software in August and September 2014. For further information refer to the Airborne Positioning and Orientation Reports (APOR) on file with other project data within the Remote Sensing Division Electronic Data Library. All positional data is referenced to the North American Datum of 1983 (NAD 83).

The processed GPS/IMU data were used to derive precise exterior orientation (EO) values of the camera centers suitable for digital feature extraction. The predicted horizontal accuracy of the imagery was determined by propagating sensor EO and image measurement uncertainties through the photogrammetric collinearity equations using the Exterior Orientation Total Propagated Uncertainty (EO-TPU) tool developed by NGS. Using this tool, the predicted horizontal uncertainty at the 95% confidence level for all project imagery was calculated to be 1.46 meters. NGS third-order geodetic control was used to verify the horizontal integrity of the directly georeferenced (DG) data, and all stereo models were examined and found to have acceptable levels of parallax for mapping purposes.

Aerotriangulation

Routine softcopy aerotriangulation methods were applied to establish a network of precise camera positions and other control for mapping, and to provide model parameters and orientation elements required for digital compilation. This work was performed by RSD Applications Branch (AB) personnel in July 2016 utilizing a softcopy photogrammetric workstation. Color and IR imagery covering portions of the project within port areas was measured and adjusted together in separate blocks for each port area using the Multi-Sensor Triangulation (MST) module of BAE Systems SOCET SET (v 5.6.0) software. Upon successful completion of this process, the MST module provided the standard deviations for each aerotriangulated ground point, which were used to compute predicted horizontal circular error at the 95% confidence level of 0.31 to 0.35 meters for each subblock. An Aerotriangulation Report with a diagram depicting the blocks of adjusted imagery was written and is on file with other project data within the RSD Electronic Data Library.

Compilation

The data compilation phase of this project was accomplished by a member of AB in November 2016. Digital mapping was performed using the Feature Extraction module within SOCET SET (v 5.6.0) photogrammetric software. Feature identification and the assignment of cartographic codes were based on image analysis of the project digital images and information extracted from the appropriate NOAA Nautical Charts, 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.

Spatial data accuracies for Project WA1402-CM-N were determined according to standard Federal Geographic Data Committee (FGDC) practices. Cartographic features compiled within port areas from aerotriangulated imagery were compiled to meet a horizontal accuracy of 0.7 meters at the 95% confidence level. All other feature data was compiled to meet a horizontal accuracy of 2.9 meters. The predicted accuracies of compiled, well defined points are derived by doubling 95% confidence level values derived from either AT statistics or the EO-TPU tool respectively.

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

Date	Time (UTC)	Color Imagery		Infrared Imagery		Tide Level*
		Roll	Images	Roll	Images	
7-27-2014	18:29 – 18:33	14NC61	13587 – 13616	14NR52	10335 – 10364	-0.2 m
7-27-2014	18:34 – 18:38	14NC61	13617 – 13641	14NR52	10365 – 10389	-0.2 m
7-27-2014	18:42 – 18:44	14NC61	13642 – 13654	14NR52	10390 – 10402	-0.2 m
7-27-2014	18:46 – 18:51	14NC61	13655 – 13687	14NR52	10403 – 10435	-0.3 m
7-27-2014	18:55 – 18:59	14NC61	13688 – 13715	14NR52	10436 – 10463	-0.2 m
7-27-2014	19:03 – 19:08	14NC61	13716 – 13752	14NR52	10464 – 10500	-0.2 m
7-27-2014	19:11 – 19:15	14NC61	13753 – 13774	14NR52	10501 – 10522	-0.2 m
7-27-2014	19:20 – 19:24	14NC61	13775 – 13801	14NR52	10522 – 10549	-0.2 m
7-27-2014	19:29 – 19:33	14NC61	13802 – 13834	14NR52	10550 – 10582	-0.2 m
7-27-2014	19:37 – 19:41	14NC61	13835 – 13857	14NR52	10583 – 10605	-0.1 m
7-27-2014	19:45 – 19:46	14NC61	13858 – 13867	14NR52	10605 – 10615	0 m
7-27-2014	19:50 – 19:53	14NC61	13868 – 13888	14NR52	10616 – 10636	0 m
7-27-2014	19:57 – 19:59	14NC61	13889 – 13906	14NR52	10637 – 10654	0.1 m
7-27-2014	20:03 – 20:05	14NC61	13907 – 13924	14NR52	10655 – 10672	0 – 0.1 m
7-27-2014	20:09 – 20:11	14NC61	13925 – 13935	14NR52	10673 – 10683	0.1 m
7-27-2014	20:15 – 20:16	14NC61	13936 – 13947	14NR52	10684 – 10695	0.2 m
7-27-2014	20:19 – 20:21	14NC61	13948 – 13961	14NR52	10696 – 10709	0.2 m
7-27-2014	20:26 – 20:28	14NC61	13962 – 13975	14NR52	10710 – 10723	0.3 – 0.4 m
7-27-2014	20:33 – 20:36	14NC61	13976 – 14002	14NR52	10724 – 10750	0.3 – 0.4 m
8-08-2014	23:24 – 23:26	14NC67	15914 – 15927	14NR58	12662 – 12675	2.9 – 3.0 m
8-08-2014	23:34 – 23:38	14NC67	15928 – 15954	14NR58	12675 – 12702	3.1 – 3.2 m
8-08-2014	23:44 – 23:46	14NC67	15955 – 15968	14NR58	12703 – 12716	3.2 m
8-10-2014	00:37 – 00:38	14NC68	16384 – 16394	14NR59	13132 – 13142	3.3 m
8-10-2014	00:45 – 00:48	14NC68	16395 – 16416	14NR59	13143 – 16164	3.3 m
8-10-2014	00:55 – 00:58	14NC68	16417 – 16434	14NR59	13165 – 13182	3. 3 m
8-10-2014	23:20 – 23:24	14NC70	16535 – 16564	14NR61	13283 – 13312	3.0 m
8-10-2014	23:29 – 23:33	14NC70	16565 – 16592	14NR61	13313 – 13340	3.1 m
8-10-2014	23:37 – 23:42	14NC70	16593 – 16625	14NR61	13341 – 13373	3.0 – 3.1 m
8-10-2014	23:47 – 23:52	14NC70	16626 – 16662	14NR61	13374 – 13410	3.2 m
8-10-2014	23:56 – 23:58	14NC70	16663 – 16674	14NR61	13411 – 13422	3.3 m
8-11-2014	00:04 – 00:08	14NC70	16675 – 16697	14NR61	13423 – 13445	3.3 m
8-11-2014	00:13 – 00:16	14NC70	16698 – 16718	14NR61	13446 – 13466	3.4 m
8-11-2014	23:31 – 23:35	14NC71	16719 – 16745	14NR62	13467 – 13493	2.9 m

8-11-2014	23:41 – 23:46	14NC71	16746 – 16778	14NR62	13494 – 13526	3.0 m
8-11-2014	23:51 – 23:55	14NC71	16779 – 16803	14NR62	13527 – 13551	3.1 m
8-12-2014	00:01 – 00:03	14NC71	16804 – 16816	14NR62	13552 – 13564	3.2 m
8-12-2014	00:06 – 00:09	14NC71	16817 – 16834	14NR62	13565 – 13582	3.2 – 3.3 m
8-12-2014	00:15 – 00:16	14NC71	16835 – 16844	14NR62	13583 – 13592	3.3 m

*Tide levels are given in meters above MLLW and were calculated using the Pydro software tool with a TCARI grid referenced to verified water level observations at NOS gauges. The height of the MHW tidal datum in the project area varies between 2.78 – 3.15 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 November 2016. The review process included analysis of aerotriangulation 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 10.3.1 software. All project data was evaluated for compliance to CMP requirements.

Comparisons of the largest scale NOAA nautical charts with the 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:

- 18441 Puget Sound, Northern Part, 1:80,000 scale, 47th Ed., Jun. 2011
- 18446 Puget Sound, Apple Cove Pt to Keyport, 1:25,000 scale, 18th Ed, Mar. 2011
        Including 1:10,000 inset of Agate Passage
- 18448 Puget Sound, Southern Part, 1:80,000 scale, 36th Ed., Dec. 2015
- 18449 Puget Sound, Seattle to Bremerton, 1:25,000 scale, 36th Ed., Dec. 2015
- 18452 Sinclair Inlet, 1:10,000 scale, 17th Ed., Oct. 2011
- 18473 Puget Sound, Oak Bay to Shilshole Bay, 1:40,000 scale, 9th Ed., Apr. 2016
        Including 1:10,000 inset of Appletree Cove
- 18474 Puget Sound, Shilshole Bay to Commencement Bay, 1:40,000 scale, 11th Ed., Dec. 2015
- 18477 Puget Sound Entrance to Hood Canal, 1:25,000 scale, 5th Ed., Aug. 2001

End Products and Deliverables

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

Remote Sensing Division Electronic Data Library
- Project database
- Airborne Positioning and Orientation Reports (APOR)
- Aerotriangulation Report
- GC11222 in shapefile format
- Project Completion Report (PCR)
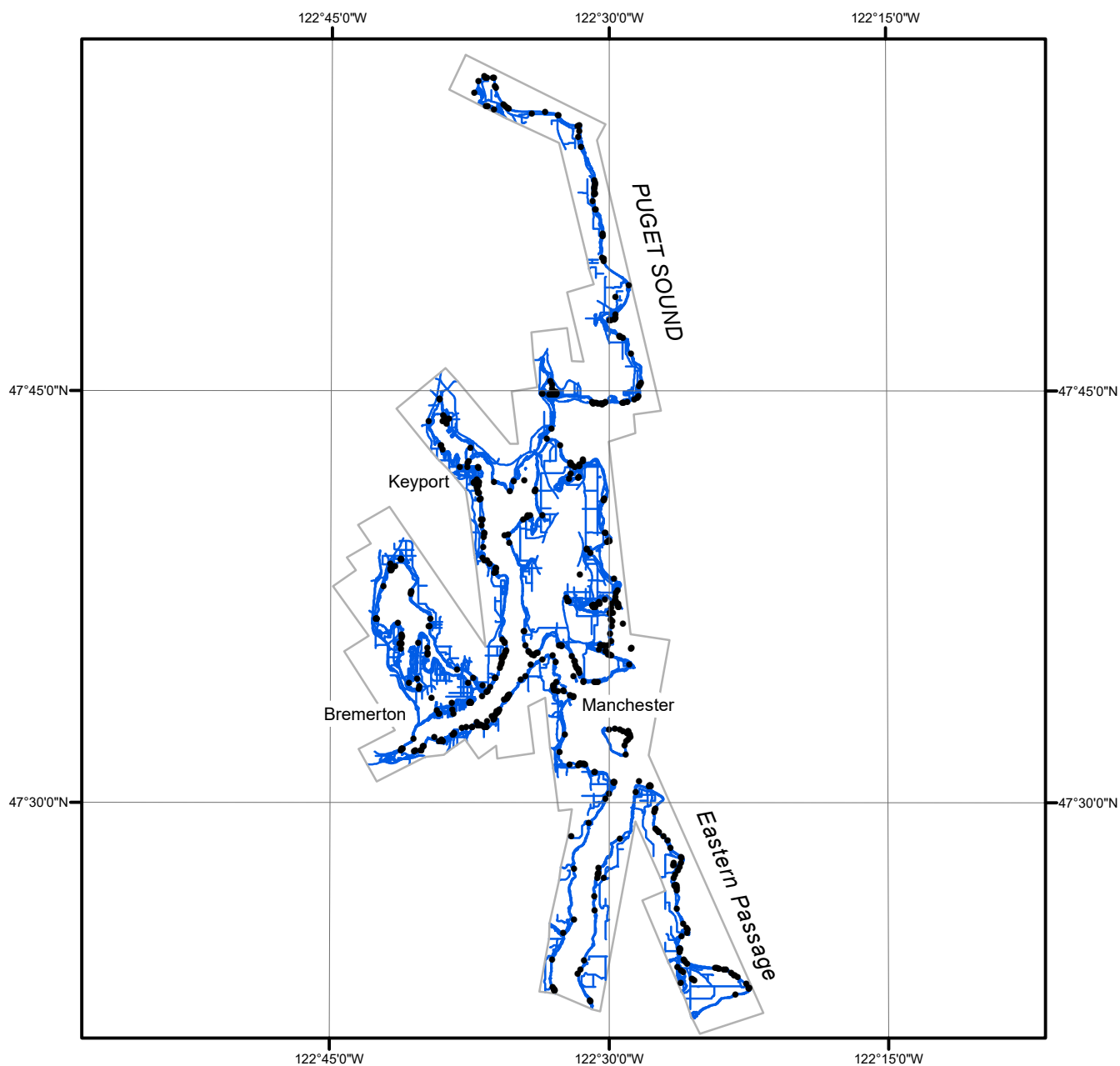- Chart Evaluation File in shapefile format

NOAA Shoreline Data Explorer
- GC11222 in shapefile format
- Metadata file for GC11222
- Digital copy of the PCR in Adobe PDF format

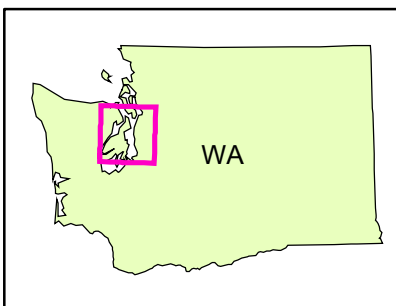## End of Report

PUGET SOUND, FOULWEATHER BLUFF TO VASHON ISLAND

WASHINGTON

122°45'0"W 122°30'0"W 122°15'0"W

PUGET SOUND

47°45'0"N

Keyport

Bremerton

Manchester

Eastern Passage

47°30'0"N

122°45'0"W 122°30'0"W 122°15'0"W

Overview

WA

WA1402-CM-N

GC11222