

NOAA COASTAL MAPPING PROGRAM PROJECT COMPLETION REPORT

PROJECT MN0904B

Thompson Island, Ontario to Lutsen, Minnesota

Introduction

NOAA Coastal Mapping Program (CMP) Project MN0904B provides a highly accurate database of new digital shoreline data for a portion of the coast of Lake Superior from Thompson Island, Ontario, Canada, to Lutsen, Minnesota. Project MN0904B is a sub-project of a larger project, MN0904, which includes shoreline mapping for the north coast of Lake Superior from Isle Royale, near the Canadian border, to Lutsen, Minnesota.

Successful completion of this project resulted in 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 photographs and metadata related to photogrammetric compilation. Base mapping was conducted in a digital environment using stereo softcopy photogrammetry and associated cartographic practices.

Project Design

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 13B, dated January 2008. 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.

This project used digital aerial imagery previously acquired under a contract with the National Geospatial-Intelligence Agency (NGA). The purpose of the NGA project was to produce digital ortho-rectified images maps of the U.S./Canada border regions in the Great Lakes. NOAA recognized the value of using the NGA project data for updating the nautical charts under the Coastal Mapping Program, and arranged with NGA to obtain the original stereo imagery and associated positioning data needed for photogrammetric mapping.

NOAA forwarded all of the NGA provided project imagery, aerotriangulation output data, ground control coordinates, airborne GPS and IMU data, and Photogrammetric Reports to NOVA Digital Systems, Inc. in order to support photogrammetric processing and feature compilation. NOAA also provided shapefiles depicting the shoreline to be mapped, the boundaries of the main project and sub-project compilation areas, and flight lines and exposure centers of the imagery to be used for compilation.

Field Operations

Since all source data was provided by NGA through NOAA, NOVA was not required to perform any field operations in connection with this project. The field operations that were performed by NGA's contractor (3001, Inc.) and their sub-contractor (Photo Science, Inc) are described in detail in their Photogrammetric Reports for AOIs 18 and 23, which cover this project area. Following is a brief summary of the field operations as described in those reports.

AOI 18:

Field operations included the surveying of ground control points (GCPs) and the acquisition of aerial imagery. Coordinates of ten (10) GCPs were established using static and rapid-static GPS techniques. Survey field work was performed between 9/09/2008 and 9/13/2008 by Photo Science, Inc. Aerial imagery was acquired using two Z/I DMC digital cameras operated by Photo Science, Inc. in seven flights flown between 9/20/2008 and 8/07/2009. Forty-seven (47) lines of panchromatic, RGB, and NIR imagery were acquired at an approximate altitude of 9,840 feet above mean terrain, resulting in a nominal pan-sharpened image resolution of 0.30 meters GSD. Airborne GPS and Inertial Measurement Unit (IMU) data were collected during the image acquisition flights, along with NAVCOM VueStar data (a global satellite based GPS augmentation system), in order to determine precise camera position and orientation parameters.

AOI 23:

In this part of the project area coordinates of three (3) GCPs were established using static and rapid-static GPS techniques. Survey field work was performed on 9/10/2008 and 9/12/2008 by Photo Science, Inc. Aerial imagery was acquired using two Z/I DMC digital cameras operated by Photo Science, Inc. in nine flights flown between 6/14/2009 and 8/12/2009. Thirty-one (31) lines of panchromatic, RGB, and NIR imagery were acquired at an approximate altitude of 9,840 feet above mean terrain, resulting in a nominal pan-sharpened image resolution of 0.30 meters GSD. Airborne GPS/IMU and NAVCOM VueStar data were collected during the image acquisition flights in order to determine precise camera position and orientation parameters.

GPS Data Reduction

Since pre-processed GPS and IMU data was provided by NGA through NOAA, NOVA was not required to perform any GPS data reduction for this project. All GPS/IMU data processing tasks were completed by Photo Science, Inc. and are described in detail in their Photogrammetric Reports for AOIs 18 and 23, which cover this project area. Following is a brief summary of the GPS/IMU data processing tasks described in those reports.

Final GCP coordinate values were determined utilizing precise point positioning techniques using Applanix TerraPOS (ver. 1.2) software and the NGS Online Positioning User Service (OPUS). Though the NAVCOM VueStar system provided decimeter level GPS navigation information in real time, the airborne GPS (ABGPS) data was post-processed using TerraPOS software to improve on the real time results. The Applanix POSPac (AIR) software (ver. 5.1) was used to process the IMU data, and with the POSProc and POSEO modules, post-processed GPS was combined with the IMU data to compute an optimally accurate navigation solution, and final exterior orientation (EO) parameters (x, y, z, omega, phi, kappa) for each photograph.

Aerotriangulation

Since final exterior orientation values for each photograph were provided by NGA through NOAA, NOVA was not required to perform any Aerial Triangulation (AT) for this project. All AT tasks were completed by Photo Science, Inc. and are described in detail in their Photogrammetric Reports for AOIs 18 and 23, which cover this project area. Following is a brief summary of the AT tasks described in those reports.

Z/I Mission software (ver. 1.4.0.10) was used to export the frame exposure information collected during the flights, and convert it into ImageStation Photogrammetric Manager (ISPM) format. Intergraph ISPM software (ver. 5.2) was used to create a project from these frame exposure files. Z/I Post Processing System (PPS) software (ver. 5.3) was then utilized to produce 8-bit GeoTIFF images from the raw image data collected during the flights, and corrected EO parameters derived from ABGPS/IMU data were incorporated.

For each DMC virtual image stereo pair, correlated points were generated by an automatic point-matching algorithm using Intergraph ImageStation Automatic Triangulation (ISAT) software (ver. 5.1). Similarly, for each block of images, tie points (photo-identifiable points that occur in the overlap between adjacent flight lines) were automatically generated and GCPs were measured. The ISAT software was then used to develop a least squares bundle adjustment for each block, using the generated tie points, measured GCPs, and post-processed ABGPS/IMU solution as observations. The results of the bundle adjustment were then checked to verify compliance with the accuracy requirement of the project.

The Photogrammetric Reports provided by NGA's contractor included accuracy analyses of their resultant orthophoto images, but did not include full accuracy assessments of the least squares bundle adjustments. Therefore NOVA used the ISAT output "control" files, which were provided with the rest of the project data, to compute the horizontal accuracy according to NOAA specifications. The "control" file provided the standard deviations of the residuals for each aerotriangulated ground point. From these standard deviation values the root-mean-square (RMS) for both X and Y coordinates was computed, and these were used to compute a predicted horizontal circular error at the 95% confidence level of 0.13 meters for the AOI 18 image block, and 0.17 meters for the AOI 23 image block.

Note that the photos in AOI 23 that cover the area outside of the United States (in Canada) were not included in the AT solution, and were directly georeferenced using only the EO parameters derived from the ABGPS/IMU data. The description above of the AT process and accuracy computation does not apply to this set of photos.

Positional data for AOI 18 was referenced to UTM Zone 15N, and data for AOI 23 was referenced to UTM Zone 16N, North American Datum of 1983 (NAD83).

Compilation

Since most of the project's positional data was referenced to UTM Zone 16N, NOVA made the necessary transformations to convert all the data references into this zone. The data compilation phase of the project was initiated by NOVA in January 2010. Digital feature extraction was completed in a softcopy stereo environment using Socet Set v5.3.0 Feature Extraction software. All coding and classification of features occurred as features were collected, and was

based on interpretation of the project imagery, and on information extracted from the appropriate NOAA nautical charts 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 MN0904B were determined according to standard Federal Geographic Data Committee (FGDC) practices. Cartographic features in the U.S. portion of the project were compiled to meet a horizontal accuracy of 0.3 meters at the 95% confidence level. This predicted accuracy of compiled, well defined points is calculated by doubling the circular error derived from the aerotriangulation statistics. Features in the Canadian portion of the project were compiled to meet a horizontal accuracy of 2.0 meters, based on commonly expected results of ABGPS/IMU derived EO parameters.

The following table provides information on aerial photographs used in the project completion:

Date	Time (UTC)	AOI Block	Line Number	Photo Numbers	GSD (nominal)	Lake Level*
6/24/2009	15:45:54-15:47:12	18	56031	167 – 177	0.30 m	183.3 m.
6/24/2009	15:53:34-15:55:55	18	56032	178 – 166	0.30 m	183.3 m.
6/25/2009	13:57:48-14:01:37	18	56038	145 – 172	0.30 m	183.3 m.
6/25/2009	14:12:05-14:16:49	18	56039	147 – 123	0.30 m	183.3 m.
6/25/2009	14:59:49-15:02:53	18	56040	117 – 139	0.30 m	183.3 m.
6/25/2009	15:16:37-15:20:38	18	56041	127 – 107	0.30 m	183.3 m.
6/25/2009	15:33:21-15:35:08	18	56043	023 – 036	0.30 m	183.3 m.
6/25/2009	15:48:16-15:49:19	18	56045	022 – 017	0.30 m	183.3 m.
6/26/2009	13:53:39-13:54:59	18	56033	163 – 172	0.30 m	183.3 m.
6/26/2009	14:00:28-14:04:35	18	56036	178 – 155	0.30 m	183.3 m.
6/26/2009	14:59:40-15:00:16	18	56034	161 – 165	0.30 m	183.3 m.
6/26/2009	15:07:42-15:12:40	18	56037	177 – 149	0.30 m	183.3 m.
6/26/2009	16:05:44-16:08:41	18	56035	158 – 177	0.30 m	183.3 m.
7/10/2009	14:26:26-14:27:01	18	56033	173 – 178	0.30 m	183.3 m.
7/10/2009	14:34:10-14:36:01	18	56034	178 – 166	0.30 m	183.3 m.
8/7/2009	14:52:09-14:53:51	23	61009	001 – 014	0.30 m	183.3 m.
8/7/2009	15:35:56-15:36:38	23	61008	007 – 001	0.30 m	183.3 m.
8/11/2009	14:43:29-14:47:31	23	61012	001 – 036	0.30 m	183.4 m.
8/11/2009	14:59:29-15:02:51	23	61011	029 – 001	0.30 m	183.4 m.
8/11/2009	15:07:58-15:10:24	23	61010	001 – 022	0.30 m	183.4 m.

8/11/2009	15:31:29-15:34:03	23	61014	063-083	0.30 m	183.4 m.
8/11/2009	15:55:29-16:00:09	23	61016	086-050	0.30 m	183.4 m.
8/11/2009	16:05:26-16:10:36	23	61017	046-087	0.30 m	183.4 m.
8/11/2009	21:09:34-21:14:20	23	61015	086-049	0.30 m	183.4 m.
8/11/2009	21:16:00-21:19:58	23	61015	035-001	0.30 m	183.4 m.
8/11/2009	21:25:53-21:29:04	23	61014	001-029	0.30 m	183.4 m.
8/11/2009	21:31:22-21:33:15	23	61014	048-062	0.30 m	183.4 m.
8/11/2009	21:41:23-21:47:05	23	61016	049-001	0.30 m	183.4 m.
8/11/2009	21:53:16-21:57:32	23	61017	001-035	0.30 m	183.4 m.
8/11/2009	21:58:33-21:58:48	23	61017	043-045	0.30 m	183.4 m.
8/12/2009	13:24:30-13:26:39	23	61014	030-047	0.30 m	183.4 m.
8/12/2009	13:32:37-13:34:12	23	61015	048-036	0.30 m	183.4 m.
8/12/2009	13:38:13-13:38:58	23	61017	036-042	0.30 m	183.4 m.

* Lake water levels are given in meters above IGLD 1985 and are based on verified observations at the Grand Marais, Lake Superior Station in Minnesota. The Low Water Datum (LWD) for the portion of Lake Superior covered by this project is 183.2 m. above IGLD 1985.

Quality Control / Final Review

Quality control tasks were conducted during all phases of project completion. The final QC review was completed in April 2010. 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 ArcMap software. All project data was evaluated for compliance to CMP requirements.

Comparisons of the largest scale NOAA nautical charts with 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:

Chart 14967 - Beaver Bay to Pigeon Point, Scale 1:120,000, 23rd Ed., Jul. /07

Chart 14968 - Grand Portage Bay, Minn. to Shesheeb Point, Ont., Scale 1:120,000, 28th Ed. Sep./04

End Products and Deliverables

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

RSD Applications Branch Archive

- Hardcopy of the Photogrammetric Report
- Hardcopy of the Project Completion Report (PCR)
- Page-size graphic plot of GC10841 file contents, attached to PCR

Remote Sensing Division Electronic Data Library

- Project Database
- GC10841 in shapefile format
- Digital copy of the PCR in Adobe PDF format
- Chart Evaluation File in shapefile format

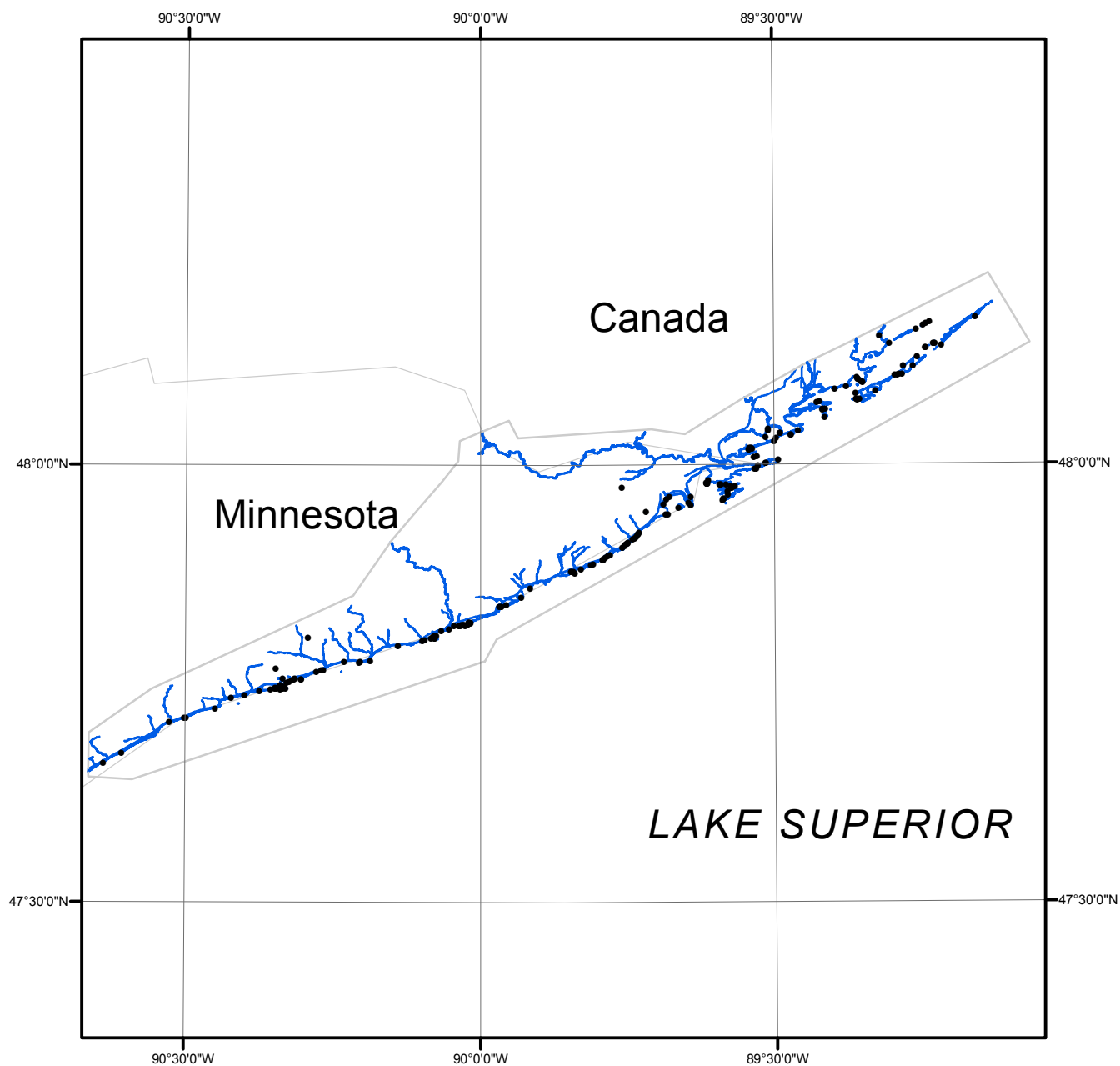
NOAA Shoreline Data Explorer

- GC10841 in shapefile format
- Metadata file for GC10841
- Digital copy of the PCR in Adobe PDF format

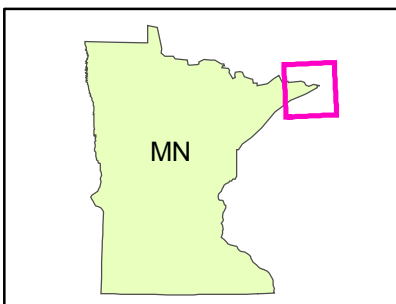
End of Report

THOMPSON ISLAND TO LUTSEN

ONTARIO AND MINNESOTA



Overview



MN0904B

GC10841