

NOAA COASTAL MAPPING PROGRAM PROJECT COMPLETION REPORT

PROJECT MI0904E

Lake Superior, Keweenaw Bay to Au Train Point, MI

Introduction

NOAA Coastal Mapping Program (CMP) Project MI0904E provides a highly accurate database of new digital shoreline data for a portion of Lake Superior along the northern shore of Michigan, from Keweenaw Bay to Au Train Point, Michigan. Project MI0904E is a sub-project of a larger project, MI0904, which includes shoreline mapping of Lake Superior from Lutsen, (located south of the city of Grand Marais), Minnesota to Au Train Point, Michigan.

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 Tuck Mapping Solutions, Inc. (TMSI) 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, TMSI 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 AOI 26 and AOI 28 which cover this project area. Following is a brief summary of the field operations as described in those reports.

AOI 26 (note that the cover sheet incorrectly indicates AOI #22 Thunder Bay, Ontario): Field operations included the surveying of ground control points (GCPs) and the acquisition of aerial imagery. Coordinates of sixteen (16) GCPs were established using static and rapid-static GPS techniques. Survey field work was performed on 8/23/2008 – 8/24/2008 by Photo Science, Inc. Aerial imagery was acquired using a Z/I DMC digital camera operated by Photo Science, Inc. in four flights on 9/10/2008 and 6/12, 14, & 15 /2009. Thirty-nine (39) 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 28:

In this part of the project area coordinates of twelve (12) GCPs were established using static and rapid-static GPS techniques. Survey field work was performed on 8/21/2008 – 8/23/2008 by Photo Science, Inc. Aerial imagery was acquired using a Z/I DMC digital camera operated by Photo Science, Inc. in five flights on 8/25-26/2008 and 9/10/2008. Nineteen (19) 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, TMSI 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 AOI 26 and AOI 28, 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, the 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, TMSI 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 AOI 26 and AOI 28 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 TMSI 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 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 0.86 m for the AOI 26 image block and 0.27 for the AOI 28 image block.

Positional data is referenced to UTM Zone 16N, North American Datum of 1983 (NAD83).

Compilation

The data compilation phase of the project was initiated by TMSI in October 2010. Digital feature extraction was completed in a softcopy stereo environment using BAE Socet Set v5.4 utilizing the Feature Extraction module. All coding and classification of features occurred within the Socet Set environment 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 MI0904E were determined according to standard Federal Geographic Data Committee (FGDC) practices. Cartographic features were compiled to meet a horizontal accuracy at the 95% confidence level of 1.8 meters for AOI26 and 0.6 meters for AOI28. The predicted accuracy of compiled, well defined points is calculated by doubling the circular error derived from the aerotriangulation statistics.

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*
08-25-08	17:43 – 17:51	28	64015	21 – 22	0.30 m.	183.4
08-25-08	18:10 – 18:10	28	64019	02 – 04	0.30 m.	183.4
08-25-08	18:17 – 18:23	28	64018	01 – 50	0.30 m.	183.4
08-25-08	18:28 – 18:35	28	64016	08 – 67	0.30 m.	183.4
08-25-08	19:29 – 19:31	28	64002	18 – 33	0.30 m.	183.4
08-25-08	19:39 – 19:40	28	64006	32 – 41	0.30 m.	183.4
08-25-08	19:52 – 19:54	28	64003	01 – 36	0.30 m.	183.4
08-25-08	19:55 – 19:56	28	64003	42 – 37	0.30 m.	183.4
08-26-08	15:19 – 15:25	28	64005	31 – 44	0.30 m.	183.4
08-26-08	16:04 – 16:10	28	64004	01 – 47	0.30 m.	183.4
09-10-08	15:22 – 15:30	28	64017	03 – 63	0.30 m.	183.4
09-10-08	16:04 – 16:05	26	63028	52 – 65	0.30 m.	183.4
09-10-08	16:14 – 16:16	26	63027	52 – 63	0.30 m.	183.4
09-10-08	16:33 – 16:37	26	63026	26 – 60	0.30 m.	183.4
09-10-08	16:44 – 16:49	26	63025	16 – 57	0.30 m.	183.4
09-10-08	16:59 – 17:04	26	63024	11 – 56	0.30 m.	183.4
09-10-08	17:29 – 17:31	26	63022	12 – 52	0.30 m.	183.4
09-10-08	17:38 – 17:40	26	63021	10 – 27	0.30 m.	183.4
06-12-09	14:57 – 14:59	26	63033	12 – 26	0.30 m.	183.3
06-12-09	15:08 – 15:10	26	63032	14 – 29	0.30 m.	183.3
06-12-09	15:14 – 15:16	26	63029	49 – 64	0.30 m.	183.3
06-15-09	15:21 – 15:23	26	63019	10 – 27	0.30 m.	183.3
06-15-09	15:30 – 15:31	26	63013	06 – 11	0.30 m.	183.3
06-15-09	15:43 – 15:45	26	63017	08 – 23	0.30 m.	183.3
06-15-09	15:53 – 15:59	26	63023	12 – 56	0.30 m.	183.3
06-15-09	16:07 – 16:09	26	63015	05 – 15	0.30 m.	183.3
06-15-09	17:24 – 17:26	26	63030	33 – 49	0.30 m.	183.3
06-15-09	17:41 – 17:43	26	63031	14 – 29	0.30 m.	183.3

06-15-09	18:09 – 18:10	26	63034	13 – 23	0.30 m.	183.3
06-15-09	18:21 – 18:22	26	63035	13 – 19	0.30 m.	183.3

* Lake water levels are given in meters above IGLD 1985 and are based on verified observations recorded by the NOS gauge Marquette C. G., Michigan. 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 2011. 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 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:

- 14963, Grand Marais to Big Bay Point, 1:120,000, 20th Ed. Mar 2/96
- 14964, Big Bay Point to Redridge, 1:120,000, 21st Ed. Mar/04
- 14969, Munising Harbor and Approaches, 1:30,000, 22nd Ed. Apr/05
- 14970, Marquette and Presque Isle Harbors, 1:15,000, 26th Ed. Aug/04
- 14971, Keweenaw Bay, 1:30,000, 21st Ed. Aug 15/98

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 GC10796 file contents, attached to PCR

Remote Sensing Division Electronic Data Library

- Project Database
- GC10796 in shapefile format
- Digital copy of the PCR in Adobe PDF format
- Chart Evaluation File in shapefile format

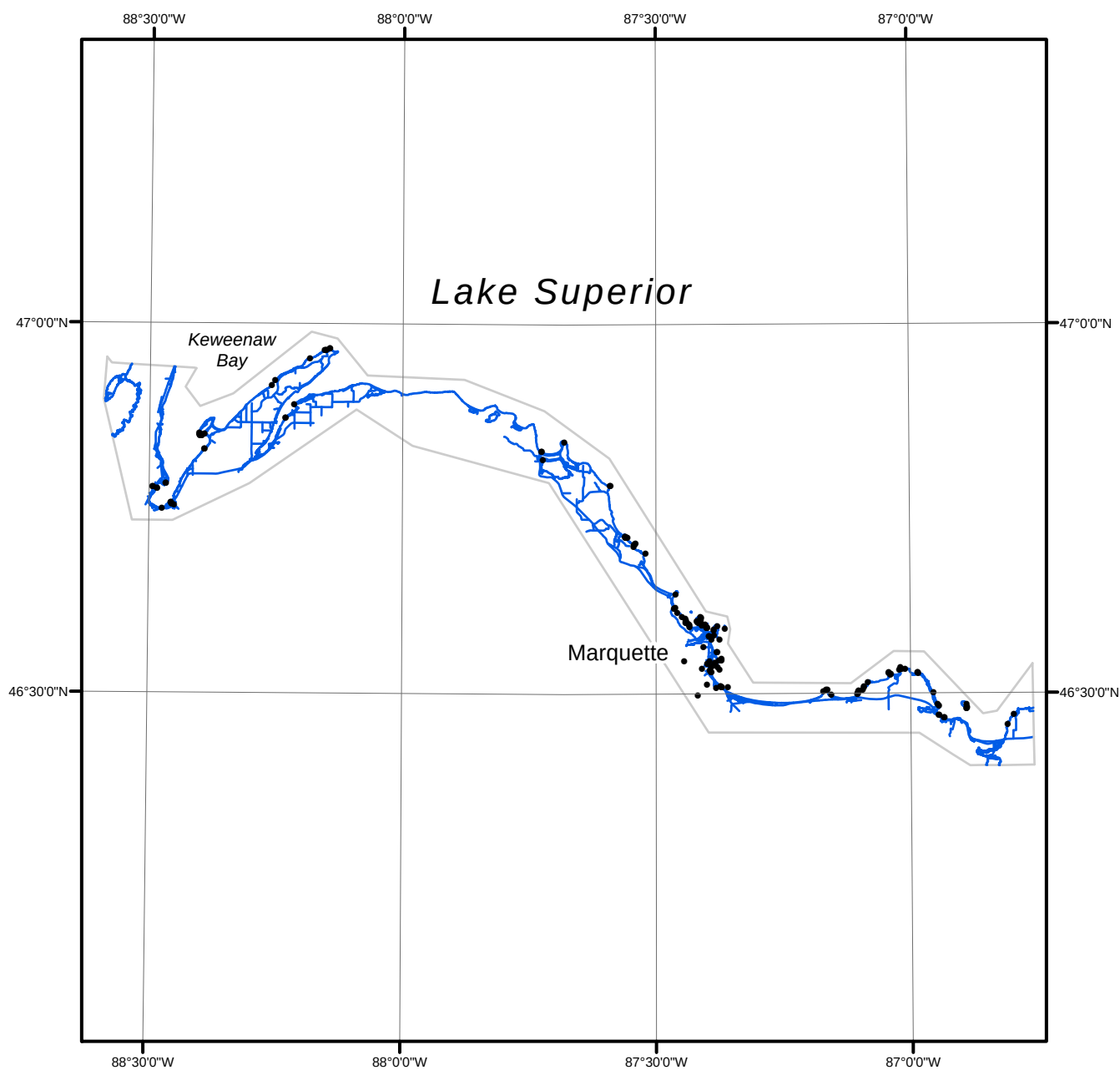
NOAA Shoreline Data Explorer

- GC10796 in shapefile format
- Metadata file for GC10796
- Digital copy of the PCR in Adobe PDF format

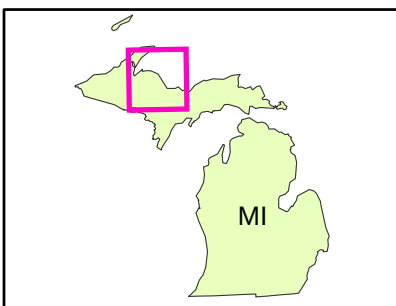
End of Report

LAKE SUPERIOR, KEWEENAW BAY TO AU TRAIN POINT

MICHIGAN



Overview



MI0904E

GC10796