

# **NOAA COASTAL MAPPING PROGRAM PROJECT COMPLETION REPORT**

## ***PROJECT MI0904C***

### ***Lake Superior, Chequamegon Bay to Misery Bay, WI and MI***

#### **Introduction**

NOAA Coastal Mapping Program (CMP) Project MI0904C provides a highly accurate database of new digital shoreline data for a portion of Lake Superior along the northern shore of Wisconsin and Michigan, extending from Chequamegon Bay, WI to Misery Bay, MI. Project MI0904C is a sub-project of a larger project, MI0904, which includes shoreline mapping of Lake Superior from Lutsen, 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 AOIs 21 and 24, which cover this project area. Following is a brief summary of the field operations as described in those reports.

### **AOI 21:**

Field operations included the surveying of ground control points (GCPs) and the acquisition of aerial imagery. Coordinates of fifteen (15) GCPs were established using static and rapid-static GPS techniques. Survey field work was performed on 8/24/2008 – 8/25/2008 by Photo Science, Inc. Aerial imagery was acquired using a Z/I DMC digital camera operated by Photo Science, Inc. in four flights on 9/12, 16, 17, & 19 /2008. Thirty-three (33) 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 24:**

In this part of the project area coordinates of nine (9) GCPs were established using static and rapid-static GPS techniques. Survey field work was performed on 8/22/2008 – 8/23/2008 by Photo Science, Inc. Aerial imagery was acquired using a Z/I DMC digital camera operated by Photo Science, Inc. in three flights on 9/19/2008, 10/05/2008 & 10/14/2008. Fifteen (15) 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 AOIs 21 and 24, 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 AOIs 21 and 24, 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 0.78 meters for the AOI 21 image block and 0.24 meters for the AOI 24 image block.

Positional data is referenced to UTM Zone 15N, North American Datum of 1983 (NAD83) for AOI21 and UTM Zone 16N, North American Datum of 1983 (NAD83) for AOI24.

## **Compilation**

The data compilation phase of the project was initiated by TMSI in June 2010. MI0904C imagery was located in UTM zones 15N and 16N. To allow compilation of the shoreline in one UTM zone a new SocetSet project was created in UTM Zone 16N and the imagery for AOI 24 was imported. Within the SocetSet environment the new project was converted from UTM Zone 16N to UTM Zone 15N. Previously compiled features in UTM Zone 15N were compared to the transformed imagery to assure the process had been performed correctly. 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 MI0904C 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 1.6 m. for features compiled from AOI 21 images and 0.5 m. for features compiled from AOI 24 images. 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:

<b>Date</b>	<b>Time (UTC)</b>	<b>AOI Block</b>	<b>Line Number</b>	<b>Photo Numbers</b>	<b>GSD (nominal)</b>	<b>Lake Level*</b>
09-12-08	18:33 – 18:37	21	59025	63 – 39	0.30 m.	183.4
09-12-08	18:52 – 18:57	21	59024	24 – 61	0.30 m.	183.4
09-12-08	19:06 – 19:09	21	59020	45 – 20	0.30 m.	183.4
09-12-08	19:20 – 19:22	21	59019	16 – 33	0.30 m.	183.4
09-12-08	19:32 – 19:35	21	59018	28 – 11	0.30 m.	183.4
09-12-08	19:43 – 19:47	21	59017	09 – 42	0.30 m.	183.4
09-12-08	19:54 – 19:58	21	59016	39 – 09	0.30 m.	183.4
09-17-08	18:43 – 18:46	21	59015	10 – 38	0.30 m.	183.4
09-17-08	18:59 – 19:02	21	59014	35 – 10	0.30 m.	183.4
09-17-08	19:11 – 19:14	21	59013	10 – 30	0.30 m.	183.4
09-17-08	19:31 – 19:32	21	59012	22 – 13	0.30 m.	183.4
09-17-08	20:17 – 20:21	21	59023	21 – 59	0.30 m.	183.4
09-17-08	20:30 – 20:34	21	59022	49 – 23	0.30 m.	183.4
09-17-08	20:45 – 20:48	21	59021	21 – 45	0.30 m.	183.4
09-17-08	20:52 – 20:54	21	59018	43 – 29	0.30 m.	183.4
09-17-08	21:00 – 21:01	21	59019	34 – 44	0.30 m.	183.4
09-19-08	15:18 – 15:20	21	59024	07 – 23	0.30 m.	183.4
09-19-08	15:28 – 15:32	21	59025	38 – 09	0.30 m.	183.4
09-19-08	15:41 – 15:46	21	59026	10 – 59	0.30 m.	183.4
09-19-08	15:54 – 16:01	21	59027	56 – 11	0.30 m.	183.4
09-19-08	16:11 – 16:15	21	59028	11 – 51	0.30 m.	183.4
09-19-08	16:23 – 16:28	21	59029	46 – 12	0.30 m.	183.4

09-19-08	16:58 – 16:59	24	62001	02 – 07	0.30 m.	183.4
09-19-08	17:05 – 17:07	24	62002	03 – 25	0.30 m.	183.4
09-19-08	18:09 – 18:16	24	62011	25 – 92	0.30 m.	183.4
09-19-08	19:28 – 19:31	24	62006	92 – 77	0.30 m.	183.4
10-05-08	17:33 – 17:43	24	62005	02 – 89	0.30 m.	183.4
10-05-08	17:48 – 18:00	24	62009	92 – 01	0.30 m.	183.4
10-05-08	18:05 – 18:24	24	62007	01 – 92	0.30 m.	183.4
10-14-08	18:11 – 18:14	24	62003	04 – 30	0.30 m.	183.3
10-14-08	18:17 – 18:19	24	62004	03 – 18	0.30 m.	183.3
10-14-08	18:29 – 18:39	24	62006	76 – 01	0.30 m.	183.4
10-14-08	18:45 – 18:55	24	62008	01 – 91	0.30 m.	183.4
10-14-08	18:59 – 19:01	24	62004	27 – 19	0.30 m.	183.4
10-14-08	19:08 – 19:20	24	62010	93 – 01	0.30 m.	183.4
10-14-08	19:40 – 19:42	24	62011	01 – 24	0.30 m.	183.4

\* Lake water levels are given in meters above IGLD 1985 and are based on verified observations recorded by the NOS gauge Ontonagon, 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 December 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 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:

14965: Redridge to Saxon Harbor, 1:120,000 scale, 21<sup>st</sup> Ed. Jan/03

Saxon Harbor, 1:2,500 Inset

Black River Harbor, 1:5,000 Inset

Ontonagon Harbor, 1:10,000 Inset

14966: Little Girls Point to Silver Bay, 1:120,000 scale, 27<sup>th</sup> Ed. May/05

14973: Apostle Islands, 1:60,000 scale, 27<sup>th</sup> Ed. Feb/03

14974: Ashland and Washburn Harbors, 1:15,000 scale, 24<sup>th</sup> Ed. May 18/96

## 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 GC10794 file contents, attached to PCR

### **Remote Sensing Division Electronic Data Library**

- Project Database
- GC10794 in shapefile format
- Digital copy of the PCR in Adobe PDF format
- Chart Evaluation File in shapefile format

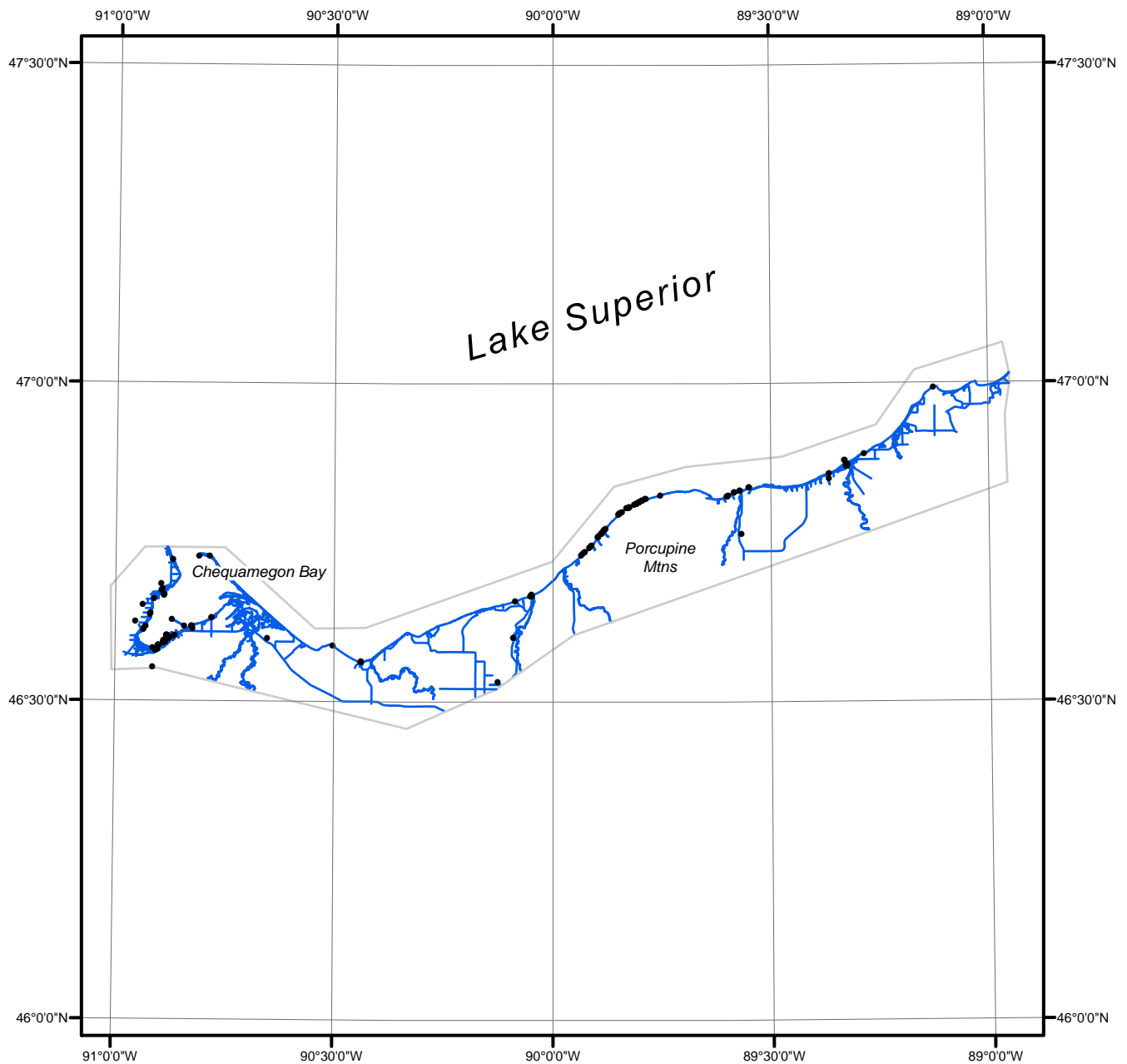
### **NOAA Shoreline Data Explorer**

- GC10794 in shapefile format
- Metadata file for GC10794
- Digital copy of the PCR in Adobe PDF format

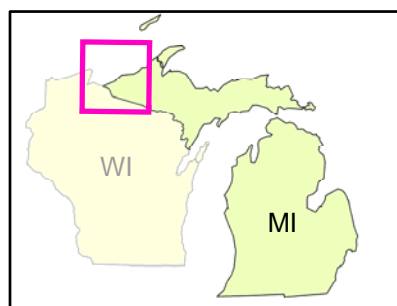
**End of Report**

# LAKE SUPERIOR, CHEQUAMEGON BAY TO MISERY BAY

## WISCONSIN AND MICHIGAN



Overview



MI0904C

GC10794