COASTAL MAPPING PROGRAM

PROJECT OH0001B
COMPLETION REPORT

OHIO

TOLEDO HARBOR

A Photogrammetric Survey
Based on 2000 Aerial Photography

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
National Geodetic Survey
Remote Sensing Division

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COMPLETION REPORT

OHIO
Toledo Harbor

Clearance

This report summarized the photogrammetric operations related to project completion and is submitted for approval. The project data and this report meet the requirements and standards of the Coastal Mapping Program.

Submitted by,

Timothy P. Blackford
Senior Cartographer
Applications Branch

Approved:

Robert W. Rodkey, Jr.
Chief, Applications Branch
Remote Sensing Division

10/2/01
Date

for Captain Jonathan W. Bailey, NOAA
Chief, Remote Sensing Division
National Geodetic Survey, NOS, NOAA

10/2/01
Date

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OHIO
Toledo Harbor

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COASTAL MAPPING PROGRAM
PROJECT OH0001B
SUMMARY

Introduction

Project OH0001B provides highly accurate digital shoreline data for Toledo Harbor including the Maumee River. OH0001B is a sub-project of a larger Coastal Mapping project, OH0001, which covers from Toledo to Cleveland, Ohio.

Successful completion of this project resulted in a densification of the National Spatial Reference System (NSRS), a set of controlled metric quality aerial photographs and companion high resolution digital scans, and digital cartographic feature files of the coastal zone to complement the Nautical Charting Program (NCP) and other geographic information systems.

The project database consists of information measured and extracted from aerial photographs and metadata related to photogrammetric compilation. Base mapping was conducted in a fully digital environment using softcopy stereo photogrammetry and associated cartographic practices. Positional data is reference to the North American Datum 1983 (NAD83).

Planning

The planning phase of Project OH0001 was accomplished by the Requirements Branch, Remote Sensing Division. Photogrammetric requirements were formulated during project planning and issued in the General Information / Instructions. These instructions, included as Appendix A, discuss in detail the following: photographic requirements, flight lines, GPS control requirements, guidelines for static and kinematic data collection and handling, project priority, and communication guidelines.

Field Operations

Initial field operations consisted of the collection of static and kinematic GPS/IMU data and the acquisition of aerial photographs. The general procedures followed are described in the GPS Controlled Photogrammetry Field Operations Manual, of Oct. 25, 1999. In September 2000 an aerial photographic survey was conducted, based out of Toledo Express Airport (TOL) in Toledo, OH. The survey utilized the NOAA Cessna Citation II (N52RF) aircraft, and the Wild RC-30 camera with the NOS "A" lens cone. Two strips of natural color vertical photographs were acquired from an altitude of approximately 4300 meters above ground, resulting in a photographic scale of about 1:28,000. Static and kinematic GPS and IMU data were collected during the photo mission, allowing for the computation of precise camera positions and orientations as a means of controlling the photographs. A ground control survey was conducted in August 2001 in order to resolve and correct a systematic error in the image georeferencing.

Image Georeferencing

High-resolution color scans were made of all the photos in the two strips covering this project area. The GPS/IMU data collected during the aerial survey were processed to provide precise camera positions and orientations for the photographs. The photogrammetric exterior orientation parameters resulting from this processing step were used, in conjunction with interior orientation data, to directly model the transformation from image to object space required for digital compilation. No conjugate points were measured in the images, and no aerotriangulation procedures were performed. Refer to Appendix B, Image Georeferencing Report, for detailed information regarding data collection and processing.

Compilation

Compilation requirements for Project OH0001B included digital base mapping, the production of cartographic feature files in ESRI shapefile format, and the construction of supplemental data for the Nautical Charting Program.

Digital mapping was accomplished by the Applications Branch, Remote Sensing Division, from May 2001 through July 2001, using the SocetSet Feature Extraction software module on a digital photogrammetric workstation (DPW), which is a configuration of computer hardware, SocetSet modular software components and other associated peripheral devices.

Cartographic features were compiled from the high-resolution color scans of the project photographs using digital stereo compilation methods. See Appendix C for a diagram of the project area showing geographic coverage and approximate photographic flight lines, and a table describing the source photographs used to compile cartographic features.

Features were compiled to meet 2.2 meters horizontal accuracy. This predicted accuracy of compiled well-defined points is a deductive estimate based on the comparison of five sampled image positions to the corresponding photo-identifiable check points obtained from a higher order GPS survey. The predicted error budget was also increased to account for potential misinterpretation during compilation. Feature identification and the assignment of cartographic codes were based on the interpretation of these photographs, NOS nautical charts, and the U.S. Coast Guard Light list Publication, 2000 (Vol. VII).

Final Review

Final review evaluation tasks were initiated in June 2001. The digital cartographic features files were evaluated for completeness and adherence to the Coastal Mapping Program (CMP) requirements and established NOS accuracy standards. Discrete point data for Project OH0001B were compared with the USCG Light List and the nautical chart for consistency. Cartographic feature codes conform with the CMP's Coastal Cartographic Object Attribute Source Table (C-COAST). Nomenclature was assigned to cartographic features requiring further description.

Data review included a comparison of digital compilation against the NOS nautical chart: 14847 Toledo Harbor, 1:20,000 scale, 30th edition. Results of this comparison are reflected on the Chart Maintenance Print, a copy of the NOS nautical chart annotated with comments to advise the nautical chart compiler. A page-size plot of the Digital Cartographic Feature File (DCFF) is included in Appendix D.

Project Final Data and Products

Agency Archive:

- Original Project Completion Report (PCR)
- Project Folder contents, e.g. field reports, memos, etc.

Agency Reference Library:

- Copy of Project Completion Report

Photogrammetric Electronic Data Library:

- Project Data Base
- Digital Cartographic Feature Files for GC-1049
- Copy of DCFF in ESRI shapefile format
- Chart Maintenance Prints
- Abbreviated copy of PCR

APPENDIX A

June 27, 2000

OH-0001
SHORE OF LAKE ERIE

PORT OF TOLEDO
PORT OF LORAIN
PORT OF CLEVELAND
OLD WOMAN CREEK NERR

STATE OF OHIO

General Information/Instructions - Aerial Photographic Survey

1.0. **General:** These instructions supplement the Photo Mission Standard Operating Procedure Version II, July 1, 1993; and the GPS Controlled Photogrammetry, Field Operations Manual, January 2, 1996, et al.

1.1 **Introduction:** Aerial survey OH0001 is a survey to provide controlled, metric quality photographic images of the Ohio, Lake Erie Shoreline from the Michigan State line to the Pennsylvania State line. The survey is being conducted in cooperation with the Sanctuaries and Reserves Office and the Office of Coast Survey in partial completion of their Nautical Charting Plan, Fourth Edition, August 1999. This survey will also provide controlled metric quality images of the Port of Toledo, the Port of Lorain, the Port of Cleveland, and the Old Woman Creek National Estuarine Research Reserve (NERR). The survey will provide imagery useful in determining any changes to the Coast, the Ports and the NERR area.

1.2. **Coverage:** This imagery acquisition mission will cover the state shoreline from the Michigan state line to the Pennsylvania state line along Lake Erie. Nautical charts that may be effected by this imagery are: 14820, 14824, 14825, 14826, 14828m, 14829m, 14830, 14830m, 14835, 14836, 14837, 14839, 14841, 14842, 14843, 14844, 14845, 14846, & 14847.

1.3. **Scope:** 2 flight lines of natural color negative imagery at 1:20,000 scale, 7 flight lines of natural color negative imagery at 1:30,000 and 11 flight lines of natural color negative imagery at 1:48,000 are required to provide adequate photographic coverage for reconnaissance of shoreline features, Ports, changes and NERRS. Control for aerotriangulation will be provided by airborne kinematic GPS data acquired concurrently with the imagery acquisition provided for in these instructions and from airborne data previously acquired..

1.4 **Compilation:** Compilation of new shoreline features will be done only where an examination of the imagery shows significant change.

2.0 Photographic Requirements:

2.1 All exposures will be taken along the flight lines indicated on the accompanying flight maps and way point files.

2.2 2 Flight lines are to be flown at an altitude that produces a nominal photographic scale of 1:20,000, 7 flight lines to produce a scale of 1:30,000 and 11 flight lines to produce a scale of 1:48,000.

2.3. Expose all images so that they have a nominal end lap of 60%

2.4. All flight lines are to be flown using only natural color negative film. (Standard NOS Emulsion)

2.5. All flight lines will be navigated using the UNS1K flight management system.

2.5.1 Flight lines may be patched if flown under GPS navigation and kinematic data are received for both sides of the split flight line.

2.5.2. Begin the second portion of a patched flight line at least two photographs before the break.

2.6. The aircraft commander is not afforded the discretion to alter the required image scales without prior approval from the Requirements Branch.

3.0. Flight Line Priority:

3.1. The 1:30,000 lines are the first priority of the survey.

3.2. The 1:20,000 lines are the second priority of the survey.

3.3. The 1:48,000 lines are the third priority.

4.0. Tide Coordination:

4.1. There is no tide coordination requirement for this survey.

5.0. Photographic Control for Aerotriangulation:

5.1. Airborne kinematic GPS data are required for all natural color negative imagery.

5.2. All flight lines may be flown with out a bank angle restriction. However caution must be observed when banking so that at least 4 satellites are being tracked continuously. (See GPS Controlled Photogrammetry, Field Operations Manual, Section X)

5.3. No support from the NGS Field Operations Branch is required for this aerial survey.

6.0. **GPS Reference Receivers:**

6.1. Primary Reference Receiver. Establish a GPS primary reference receiver station at the airport you choose as your base of operations in accordance with the procedures given in GPS Controlled Photogrammetry, Field Operations Manual, Section V.

6.1.1. The following airports within the survey area can handle operations of the Citation aircraft: Burke Lakefront Airport and Toledo Express Airport.

6.2. Send the static GPS survey data to Mr. Tim Blackford of the Applications Branch via the Post Office, or commercial courier (FedX).

6.3. Secondary Reference Receivers: There is no requirement for secondary reference receivers for this aerial survey.

7.0. **Project Schedule/Priority:**

7.1. This survey is scheduled to be accomplished in August 2000.

7.2. There is no particular priority assigned to this survey. The Mission Commander is afforded the discretion to move the survey aircraft between this and other near by aerial survey areas to take advantage of the most advantageous weather and/or tidal conditions.

8.0. **Data Recording/ Handling:**

8.1. The imagery acquisition code for this survey is OH0001. If the photo mission diverts to obtain airport imagery contact the Requirements Branch to obtain the proper imagery acquisition codes for airport imagery.

8.2. Record and handle all photographic data as provided for in the Photo Mission Standard Operating Procedure.

8.3. Record and handle all digital GPS data as provided for in the GPS Controlled Photogrammetry, Field Operations Manual.

8.4. Send one (1) copy of the kinematic GPS data from the aircraft and ground based receiver to Mr. Tim Blackford of the Applications Branch weekly, unless otherwise requested.

8.5. Send a digital copy of the EDI files to Mr. Brian Thornton of the Systems & Quality Assurance Branch with the exposed roll of film. EDI files are critical for data management, film indexing, and photo dissemination; therefore, resolve EDI malfunctions to the best of your ability prior to acquiring imagery. If a problem persists, call the appropriate individual for guidance.

8.6. In addition to the data normally required on the Photographic Flight Report (PFR), clearly record data for all test exposures, accidentally taken exposures, exposures taken when not navigating a flight line, interruptions of imagery acquisition and or any situation that causes a break in imagery or data acquisition. In general; if the camera shutter trips and/or a data pulse is recorded an entry in the PFR is required.

8.7. Record on the PFR any GPS failure, data logger failure, failure to start the system, or any data recording failures.

8.8. FAX a copy of the PFR for each roll of exposed film to the Requirements Branch when the film and the original report are sent to the contract photo laboratory for processing.

9.0. **General Guidelines for Aircraft GPS Operations:**

9.1. Download GPS satellite ephemeris and health data from the Arinc web site daily to ensure that the satellite constellation is adequate for kinematic operations. Their URL is: WWW.ARINC.COM\PRODUCTS_SERVICES\GPSSTAT.HTML Download the three files that pertain to the daily and monthly ephemeris and satellite health data. These will all run under the same SEM program that has been previously used.

9.2. Run satellite visibility plots and PDOP predictions daily if necessary.

9.3. Base daily operations on the most current satellite ephemeris.

9.4. Standard Operating Procedures for conducting an airborne kinematic GPS survey are found in GPS Controlled Photogrammetry, Field Operations Manual Sections V.I.; V.I.B.; V.I.C.

9.5. Imaging operations will be conducted within approximately 300 km of the primary reference receiver.

10.0. **Contacts/Communications:**

10.1. E-mail, FAX, or phone a project status or move report to the Requirements Branch daily, even if there has been no change in project status or progress. A report of "no progress" or "no change" is required.

10.2. Check your E-mail box frequently; RSD, Requirements Branch personnel will forward any project changes or other pertinent data to E-mail address: **Photo1@Earthlink.net**.

10.3. For questions or information regarding the operational aspect of this project contact:

Lloyd W. Harrod Jr. (Requirements Branch)
Phone: (W) 301-713-2671x198
(H) 301-341-3586
(FAX) 301-713-4572
Internet: lloyd@ngs.noaa.gov

10.4. For questions or information regarding the operational or theoretical GPS aspect of this project or in the event of total GPS failure contact:

LT Mike Weaver
Phone: (W) 301-713-0443
(H) 703-864-5139
(FAX) 301-713-4572
Internet: Mike.Weaver@ngs.noaa.gov
Msweaver@erols.com

10.5. For questions or information regarding aerial camera maintenance or repair contact:

Steve Nicklas
Phone: (W) 301-713-2671
(H)
(FAX) 301-713-4572
Internet: Snicklas@ngs.noaa.gov

10.6. For questions regarding GPS processing contact:

Tim Blackford (Applications Branch)
Phone: (W) 301-713-2685 x146
(H) 301-438-3359
(FAX) 301-713-4572
Internet: Tim.Blackford@noaa.gov

10.7. **Mailing Addresses:**

Tim Blackford
N/NGS33
SSMC-3, #5326
1315 East West Highway
Silver Spring, MD 20910

Brian Thornton
N/NGS31
SSMC-3, #5116
1315 East West Highway
Silver Spring, MD 20910

June 27, 2000

10.8. When communicating with anyone outside the Requirements Branch about any aspect of this project a copy of the communication must be forwarded to the Requirements Branch. This includes notifying the Applications Branch that data have been sent.

11.0. **Data Provided with these Instructions:**

Three copies of the flight maps
One floppy disk containing the files:
- OH0001.wpt - comma separated version of flight lines
- OH0001.wpx - way point input to flight management system
- OH0001.txt - text version of way point input

Two copies of these instructions

12.0. **Pilot Debriefing:**

Before returning to their assigned duty stations either at the conclusion of imaging operations or at a crew swap, at least one pilot assigned to this aerial survey may be required to report to Remote Sensing Division Headquarters to participate in a debriefing of photographic operations.

13.0. **Miscellaneous:**

Do not acquire imagery if visibility is less than 12 miles.

Approved: Edward D. Allen
Chief, Requirements Branch
Date: 6/29/00

Reviewed: Bob Rodkey
Chief, Applications Branch
Date: 6/29/00

Reviewed: Steve Matula
Chief, Systems & Quality Assurance Branch
Date: 7-13-2000

Approved: CDR Jonathan W. Bailey
Chief, Remote Sensing Division
Date: 7/17/2000

APPENDIX B

OH0001B
Toledo Harbor
Ohio

Image Georeferencing Report
September 2001

INTRODUCTION

The Global Positioning System (GPS) and Inertial Measurement Unit (IMU) data referred to in this report were processed to provide precise positions and orientations of camera centers, to be used to directly georeference the aerial photographs of the Coastal Mapping Program project OH0001B (Toledo Harbor). The results of this processing step were used, with additional data, to determine the image-space to object-space transformation required for feature compilation. During the compilation phase a systematic error in the image georeferencing was detected and removed.

DATA COLLECTION

An airborne kinematic survey was conducted, based out of Toledo Express Airport (TOL) in Toledo, OH on September 6th, 2000 according to the procedures described in the GPS Controlled Photogrammetry Field Operations Manual, of Oct. 25, 1999. The static or base station data for this survey was collected using a Trimble 4000SSi geodetic receiver in combination with a Compact L1/L2 antenna with ground plane. The static session was of 3 h. 10 m. duration with a measurement interval of 1 second. During this session the antenna was set up on a 2 meter fixed height tripod over the Primary Airport Control Station (PACS) "TOL C 2". The following coordinates for this station from the NGS Database were used during subsequent processing:

TOL C 2 (NAD 83):

Latitude:	41° 35' 15.55309" N
Longitude:	83° 48' 33.22524" W
Ellipsoid Height:	171.85 m.

Simultaneously positioning data was collected on board the aircraft with an Applanix POS/AV510 inertial navigation system; consisting of a GPS receiver and antenna, an IMU, and a computer control and data storage system. The kinematic GPS data was collected at a frequency of 2 Hz and the IMU data was recorded at 200Hz. Five flight lines were flown, and 38 photo events were recorded. No problems were reported in the observation log. The recorded Position and Orientation System (POS) data and static GPS data were downloaded from the systems to a portable computer. At the end of the mission the data files were copied to zip disks and forwarded to headquarters for processing. Upon receipt in the office, the data files were backed up and a project folder was created.

GPS/IMU DATA PROCESSING

The static GPS base station data along with the airborne POS dataset, 00TOL250, were processed in April 2001 using Applanix POSPac (ver. 3.0) software. First the real-time navigation solution was extracted from the raw data files. The extraction log file was examined for data continuity, and the solution plots were reviewed for quality. Next the POSGPS module was used to process the differential GPS data. Integer carrier phase ambiguities were successfully resolved in both forward and reverse directions. The separation between the forward and reverse solutions generally remained in the ±6 cm. range, with a few spikes to 10 cm. in northing and 20 cm. in elevation. A combined continuous kinematic iono-free phase solution was obtained. The RMS of the phase residuals for the combined solution remained below 10 cm. for the entire session.

The POSProc module was then used to process the extracted IMU data together with the GPS solution and lever arm data to produce an integrated inertial navigation solution. The results were further processed using a recursive smoother to produce a blended navigation solution for each time point. This optimal navigation solution is known as the Smoothed Best Estimate of Trajectory (SBET). Measurement residuals, estimated sensor errors, and RMS estimation uncertainties from the Kalman Filter data were analyzed. The final SBET solution residual RMS plots remained within ±6 cm.

Finally the SBET was combined with photo event data, geoid offset information, and IMU misalignment angles (boresight) using the POSEO module. The results were transformed to UTM (zone 17) coordinates, and the final output was a file containing the exterior orientation (EO) parameters of the aerial photographs required for georeferencing.

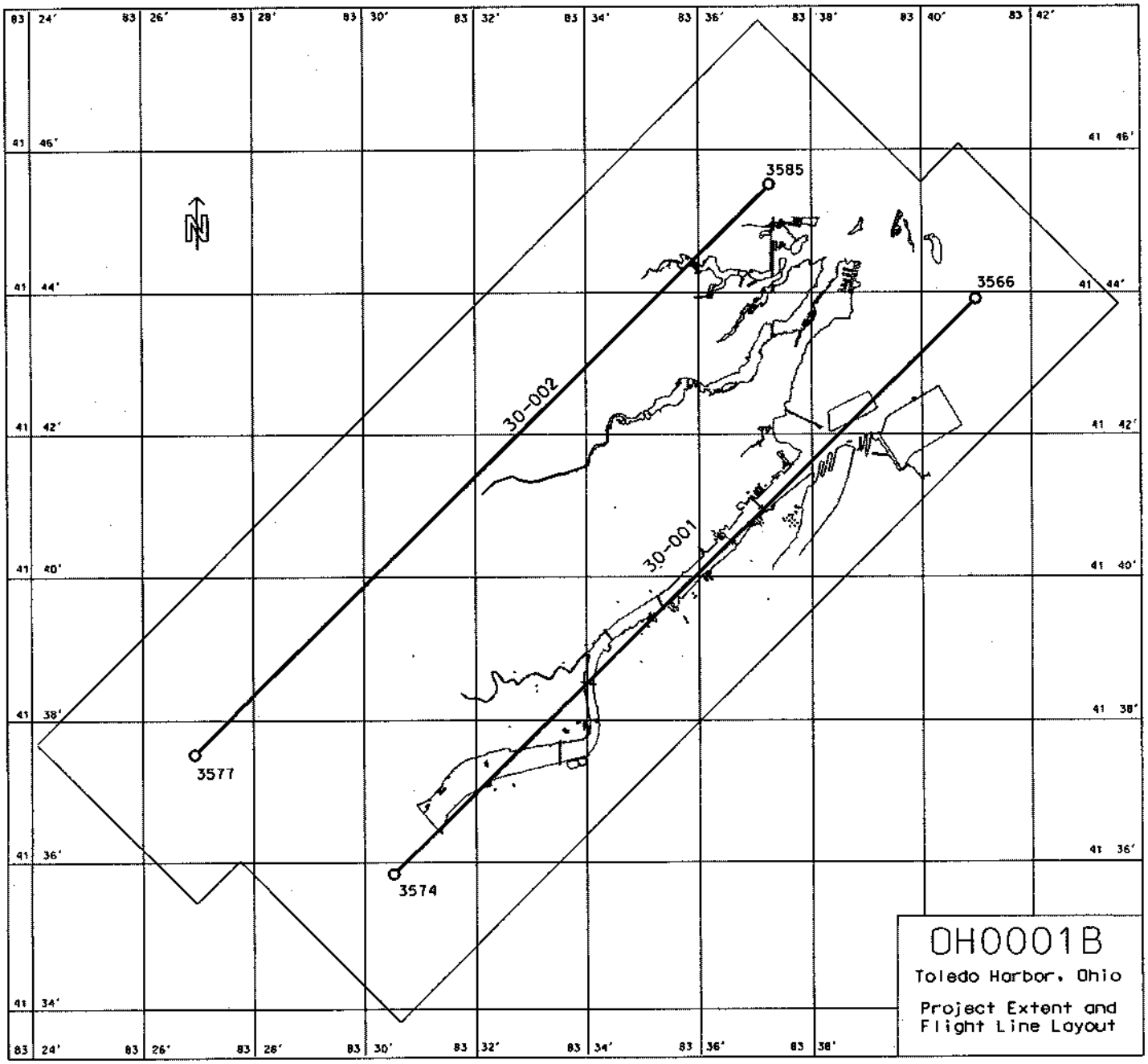
FINAL IMAGE GEOREFERENCING

The project OH0001B was created in SocetSet (ver. 4.3), a suite of digital photogrammetric software running in the Windows NT environment on a stereo-enabled PC-based graphics workstation. The POSEO output was edited to produce a file containing the frame EO data in the ALBANY format. During the frame import step in SocetSet, the EO data for each image was extracted from the ALBANY file. Interior Orientation (IO) parameters for the frames were determined from camera calibration data (NOS A-Cone 2000) and fiducial mark measurements performed in SocetSet. With both EO and IO parameters determined for each frame, the direct georeferencing of the images was complete, and the project could proceed to the compilation phase.

A couple of 3rd order intersect stations were found in the NGS Database that were also identifiable in the imagery. The published coordinates of the points were compared to their photogrammetrically derived positions using the SocetSet Coordinate Measurement too, and were found to match within 2-3 meters; as close as could be expected for points of that accuracy.

Later, after most of the compilation phase was complete, a systematic error in the image georeferencing was detected. A field party was dispatched to conduct an accurate ground control survey of the project area, and the five check points surveyed were used to quantify the magnitude and direction of the error. The shift was found to be consistent and equal in magnitude for all points, but opposite in direction for the two strips. After completion of the compilation phase a correction was applied to the digital data. Upon removal of the systematic error, the RMS of the residuals of the check point coordinates were used to calculate a rough approximation of the horizontal circular error radius for the project as a whole. This accuracy value was determined to be approximately 1.1 meters.

APPENDIX C


83 24'
83 26'
83 28'
83 30'
83 32'
83 34'
83 36'
83 38'
83 40'
83 42'
41 46'
41 44'
41 42'
41 40'
41 38'
41 36'
41 34'
N
3585
3566
3577
3574
30-002
30-001
OH0001B
Toledo Harbor, Ohio
Project Extent and
Flight Line Layout

Compilation Sources

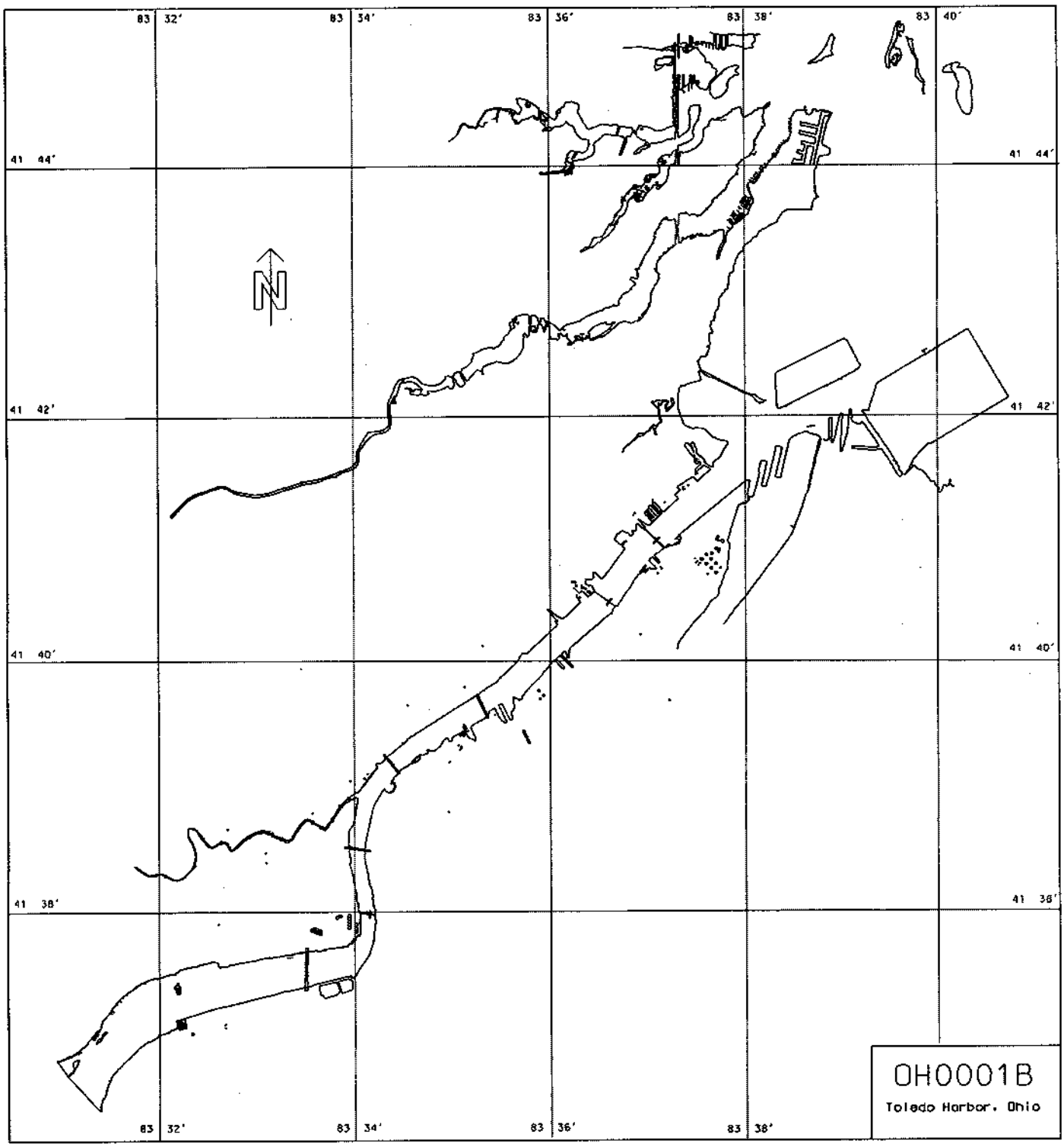
Project: OH0001B

Photography:

Date	Time	Roll / Frames	Scale	Water Level
09-06-00	1459-1502	00 ACN-19 #3566-3574	1:30,000	174.28
09-06-00	1507-1510	00 ACN-19 #3577-3585	1:30,000	174.29

Note: Water level data are in meters above the International Great Lakes Datum (IGLD) 1985 and are based on actual observations recorded by the NOS gauge at Toledo, Ohio, at the time of photography. Times shown are on UTC (GMT). The Plane of Reference (Low Water Datum) for Lake Erie is 569.2 feet (173.49 meters).

APPENDIX D


83 32'
83 34'
83 36'
83 38'
83 40'
41 44'
41 42'
41 40'
41 38'
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