Digital Reproduction of Historical Aerial Photographic Prints for Preserving a Deteriorating Archive

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Abstract

Aerial photography from the 1920s and 1930s is a unique record of historical information used by government agencies, surveyors, consulting scientists and engineers, lawyers, and individuals for diverse purposes. Unfortunately, the use of the historical aerial photographic prints has resulted in their becoming worn, lost, and faded. Few negatives exist for the earliest photography. A pilot project demonstrated that high-quality, precision scanning of historical aerial photography is an appealing alternative to traditional methods for reproduction. Optimum sampling rate varies from photograph to photograph, ranging between 31 and 42 μm/pixel for the USDA photographs tested. Inclusion of an index, such as a photomosaic or gazetteer, and ability to view the imagery promptly upon request are highly desirable.

The Problem

Aerial photography from the 1920s and 1930s is becoming increasingly recognized as a unique record of historical information. This historical aerial photography is used by government agencies, land surveyors, consulting scientists and engineers, lawyers, and individuals for diverse purposes. The Illinois State Geological Survey is a frequent user of the historical aerial photography. Common applications include identifying

- Distressed vegetation, and changes in surface land cover;
- Landfill activity;
- Flooding;
- Historical excavations, landfills, and other construction; and
- Past land use of individual parcels near highway improvements for evidence of historic locations of underground storage tanks and industrial/commercial facilities.

Other applications include

- Determining the potential for encountering wastes in excavations when planning for direct field drilling and soil gas sampling;
- Documentation of coastal erosion, stream migration or entrenchment, landslides, and other natural hazards; and
- Locating former oil-brine storage pits, possible disposal sites of radioactive wastes, and occurrence of gullies beneath industrial chemical landfills.

Unfortunately, the increased use of the historical aerial photographs, like the associated increased use of historical and ancient maps, is taking a high toll on this truly unique resource (Luman *et al.*, 1995). Damage to photographs occurs through

- Tearing or cracking of photographs from filing, ordinary use, handling, and storage;
- Cracking of emulsion as photographs are bent for stereoscopic viewing;
- Theft or loss;
- Pencil markings;
- Pin pricking;
- Removal of adhesive-backed notes which tear and detach cracked emulsion;
- Fading of detail because of inadequate fixing of prints; and
- Bleaching of detail from exposure to sunlight over time.

The University of Illinois, Map & Geography Library (Library) maintains a repository of more than 160,000 vertical aerial photographs of Illinois counties that were acquired from 1936 through 1995. This is the largest single collection of vertical aerial photography in Illinois. Contained within this collection are approximately 60,000 historical aerial photographs acquired from 1936 to 1941, the most complete U.S. Department of Agriculture coverage from this era known to exist in Illinois. The Library collection represents an important resource because of its availability and completeness.

Deterioration of the historical aerial photographs at the Library was recognized as use increased following the Illinois Responsible Property Transfer Act of 1989 (PA 86-0679; IL.Rev.Stat. Ch. 30 par. 901-908). The photography is used to determine past land usage of all types of property for activities which might have generated hazardous wastes, disposal or burial of wastes, and storage of fuels in underground storage tanks. For property transfers, the absence of historical photography may require expensive drilling and sample testing to insure absence of petrochemicals and hazardous wastes. The use of the collection, up to 2000 photos per month, results in damage and degradation of the historical aerial photographic prints. Unfortunately, the rate of attrition of the aerial photographs is unknown because the Library's collection is uncataloged.

The Library systematically replaces the post-1950 photographic prints which are available from the U.S. Department of Agriculture at the rate of one county per year. Unfortunately, the pre-1950 aerial photography cannot be replaced with prints of equal quality or resolution.

Negatives Destroyed

The ideal source for prints of pre-1950 aerial photography would be the original silver nitrate-based film negatives. Unfortunately, original negatives for the oldest Illinois aerial

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Figure 1. Contact print made from nitrate-based negative of Cicero, Illinois taken by the U.S. Army Corps of Engineers in 1933. The bright band in the center of the photo is where the negative becomes bonded with the surrounding emulsion of the roll as the nitrate-base becomes unstable.

photography (1936-1941) no longer exist. Those nitrate-based negatives were destroyed in a systematic program of destruction of nitrate-based film at the National Archives, because the film becomes unstable as the heat of hydration causes the nitrate-base to become gelatinous, adhering to adjacent emulsion (Figure 1).

In 1983, the U.S. Navy and the National Archives began a roll-to-roll, contact-duplicate conversion of nitrate-based negatives using Kodak 2422 Aerographic Duplicating Film. Initially, statewide photography (including Illinois) were duplicated using a 70-mm film format (Graeme McCluggage, National Archives, personal communication, 1997). In Illinois, users have complained that photographic prints produced from the 70-mm duplicate film are poor in quality (Figure 2), and therefore the existing prints of Illinois earliest aerial photography are the only remaining, high-quality source—and this collection continues to deteriorate because of excessive use.

The Solution

Two strategies are being employed at the University of Illinois Library to preserve the aerial photography collection: (1) prolong the life of the existing photos through simple preservation techniques and (2) reproduce the oldest historical aerial photography into a digital format. To prolong the life of the existing prints, the Map & Geography Library has experimented with several methods of preservation:

- Encapsulating photographs in a Mylar envelope,
- Reprography of the original prints, and
- Policies that minimize the handling of the prints but allow accessibility.

Encapsulating photographic prints was used temporarily but found to be inconvenient for the Library staff when large numbers of photos were requested for examination by a patron. Photographic reproduction of the pre-1950 aerial photographs is currently not an option due to the lack of available storage space. Aerial photographs are no longer permitted to leave the Library premises, but only a modest amount of photointerpretation equipment is available for patrons.

A second strategy that was investigated is the digital conversion of the oldest, existing aerial photography through a process of high quality scanning. This form of reproduction accomplishes two objectives: (1) it faithfully and permanently preserves original feature detail and (2) it does not require a second archive of photographic prints. In addition to preserving a copy of the aerial photography, the scanned imagery can undergo processing to improve contrast and repair damage caused by fading and inadequate processing of the originals. For example, details on original prints that have faded because of over 50 years of exposure to natural and artificial light sources can be restored by simple contrast enhancement and other image processing techniques.

Results of Scanning Tests

A pilot study was conducted using a Crosfield drum scanning system provided by Scantech Color Systems, Inc., Champaign, Illinois. Details of drum and flatbed scanners are described by Kolbl *et al.* (1996). Through experimentation with several scanning rates using examples of pre-1950 aerial photography, an optimal sampling rate was determined based upon factors including photo scale, print quality, and paper type. The optimum sampling rate varies from photograph to photograph, ranging between 31 and 42 micrometres per picture element (µm/pixel) for the USDA photographs tested. The relationship between these two sampling rates can be more easily understood by relating each to the resulting ground resolution (Table 1).

Using a 7- by 9-inch photograph at a nominal scale of 1:20,000, a sampling rate of 31 µm/pixel results in a digital file of approximately 55 megabytes and a ground resolution equivalent to 0.85 metres per pixel. Similarly, a sampling rate of 42 µm/pixel produces a digital file of approximately 32 megabytes and a ground resolution equivalent to 1.16 metres per pixel. Comparison of the original aerial photographs with the scanned imagery revealed that little feature detail was added at the higher sampling rate (i.e., 31 µm/pixel) and, in fact, some blurring of features was observed. In addi-

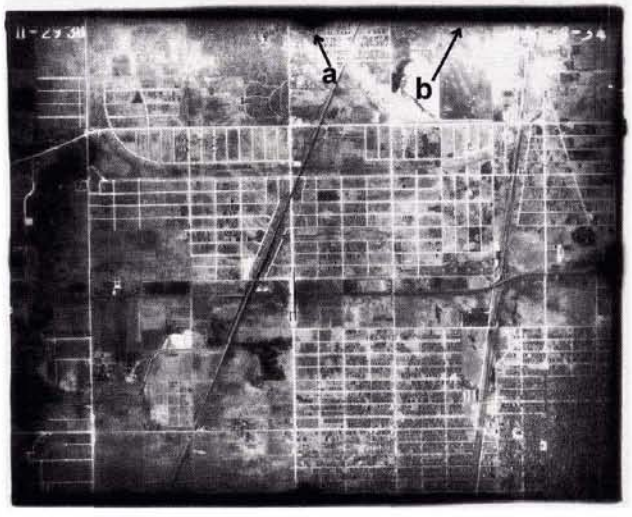


Figure 2. Copy of a 9-inch print made from a 70-mm negative reproduction of the original 9-inch nitrate-based negative from the National Archives. The fiducial marks and outside edge of the image are blurred, probably because the film was not properly flattened during the duplication process. The small format and poor reproduction of the negative make the print of marginal use.

TABLE 1. RELATIONSHIP BETWEEN IMAGE SCANNING RATE, FILE SIZE, AND QUALITY OF A 7- BY 9-INCH PHOTOGRAPH. ENTIRE 1:20,000-SCALE, BLACK-AND-WHITE AERIAL PHOTOGRAPH WAS SCANNED, INCLUDING FIDUCIAL MARKS AND HEADER. SCAN RATES GREATER THAN 31 µM/PIXEL YIELD BLURRED IMAGES.

Example	Scan Rate, µm/pixel	Ground Resolution, m/pixel (ft/pixel)	File Size, Mbytes	Quality
1	31	0.85 (2.8)	55	Good
2	42	1.16 (3.8)	32	Excellent

tion, almost a 60 percent savings in terms of electronic storage space is afforded by the lower sampling rate of 42 µm/pixel, a factor that becomes important when planning for a large archive of historical aerial photographs. The experiments showed that scanning faithfully preserves feature detail of the historical aerial photography, thereby allowing archiving of the original photographic prints.

Overlaying Unrectified Photographs Upon Orthorectified Photography

Once historical aerial photographs have been converted to a digital format, they can be geometrically corrected for integration with other GIS data sources. A practical test was devised to determine if sufficient ground control points could be found, and whether a polynomial transformation would be satisfactory to overlay unrectified photographs upon orthorectified photography in areas of relatively low local relief. Individual frames of historical aerial photography acquired on 16 July 1939 for a portion of McHenry County, Illinois, were scanned at 42 µm/pixel (Figure 3a). U.S. Geological Survey digital orthophoto quadrangles (DOQ) for McHenry County prepared from 1988 National Aerial Photography Program (NAPP) 1 photography were also acquired (Figure 4a). The DOQ is a 1-metre ground resolution image encompassing a geographic area of 3.75 minutes of both latitude and longitude at a source scale of 1:12,000 cast onto the Universal Transverse Mercator projection (NAD 83). DOQs are mathematically corrected so that distortions from the terrain, from the camera lens, and from the perspective view have been removed (Gaydos *et al.*, 1986, Hood *et al.*, 1989).

Because the DOQs have been geometrically corrected, it is a straightforward mathematical process to transform the scanned historical photographs to conform to the corresponding DOQs using image-to-image registration (Jensen, 1996). Registration was expedited because both sets of imagery possessed nearly the same ground resolution, 1.16 metres/pixel for the historical aerial photography and 1.0 metres/pixel ground resolution for the USGS DOQs. After a sufficient number of corresponding ground control points are located on both images, the resulting resampled and rescaled historical imagery can be overlain on the corresponding orthophotograph so that landscape changes that have occurred during the intervening 50 years can be easily identified and delineated. However, the authors found that registration of the two images is not exact; measurement inaccuracies range from less than a metre to a few metres.

Visual inspection of Figures 3a and 4a show that a significant amount of change has occurred during the 50-year time interval between the two photographs. Most noticeable is the conversion of rural farmland and wooded land to residential and commercial land use south and west of the original built-up area of McHenry, Illinois. At the lower right margin of Figure 3a and adjacent to the Fox River is a large, palustrine deep marsh (Cowardin *et al.*, 1979) characterized by two separated areas of open water, and interspersed with emergent vegetation. By 1988, the majority of this high-quality marsh had been converted to a diked and impounded, open water wetland (Cowardin *et al.*, 1979) (Figure 4b). Such conversions of palustrine wetland habitat are common in northeastern Illinois (see also Figures 3b and 4b), and the use of scanned historical aerial photography in conjunction with digital orthophotography can accurately document such landscape changes. Change in wetlands was the reason for the County of Lake's interest in acquiring high-quality copies of historical aerial photography.

Orthorectification of Historical Aerial Photography

As part of the pilot project, the authors investigated the need to orthorectify the scanned historical photography in the same manner as the DOQs in order to remove distortions and displacements. The historical aerial photography shown in Figure 3a was not rectified, but was geometrically corrected to register with the corresponding DOQ imagery. This approach proved to be adequate for applications where precise ground location is not necessary.

Examples of scanned historical photography, along with the corresponding USGS DOQ and 1:24,000-scale USGS digital elevation model (DEM) data, were prepared for two selected geographic areas that express moderate local relief within St. Clair and Jo Daviess Counties in southwestern and northwestern Illinois, respectively. These data were provided to Intera Corporation of Ontario, Canada to determine the potential cost of producing historical digital orthophotography.

Based upon their estimate, the production of digital orthophotography from *historical* aerial photography is probably cost-prohibitive. Among the factors contributing to this conclusion are

(1) Ideally, the rectification procedure requires that camera lens calibration data be provided. Such information includes the camera make and model, lens type and number, focal length, and calibration measurements. Prior to 1943, U.S. governmental agencies did not formalize camera calibration procedures. Consequently, camera reports are not generally available for the oldest historical aerial photography acquired by the U.S. Department of Agriculture (B. Johnson, U.S. Geological Survey, personal communication, 1995). If such data were available for older aerial photography, it would logically reside with the civilian companies that acquired the photography. However, many of these companies either no longer exist, have discarded older calibration reports, or have changed ownership or address and are difficult to locate.

(2) For both the aerial photography used in Figures 3a and 4a, as well as the sample data for St. Clair and Jo Daviess Counties, nearly 50 years have transpired between the acquisition dates of the scanned historical aerial photography and the DOQs developed from recent NAPP 1 and 2 aerial photography. As a result of landscape changes that have occurred (e.g., widening of roads, rural to urban/built-up land-use conversions, vegetation succession), collecting sufficient ground control points on both dates of imagery for the geometric correction procedure proved to be difficult.

(3) One example of a rectified data set incorporated three scanned historical aerial photographs (two end-lapped photographs with one side-lapped photograph). Intera Corporation furnished the rectified, historical aerial photography back to the authors for the purpose of ascertaining quality of mosaicking. The mosaicking process revealed that remaining distortions were sufficient to preclude the creation of a controlled mosaic, and that only semi-controlled mosaicking was possible. Correction of the remaining photographic distortions was deemed cost-prohibitive.

Preservation of Lake County, Illinois Aerial Photography

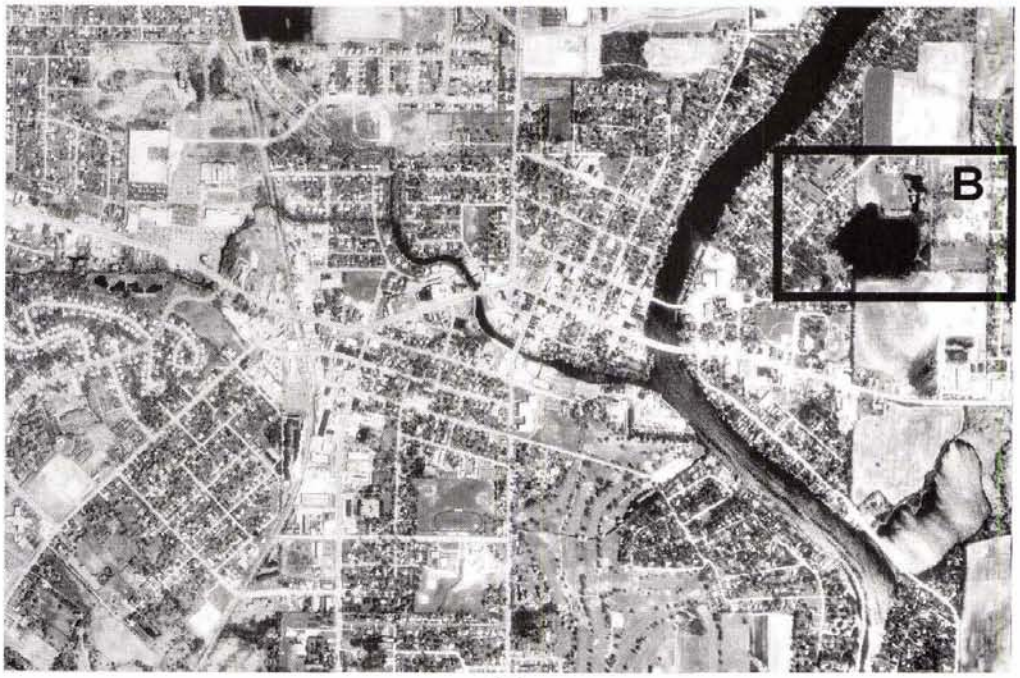
During the pilot study, 268 original historical photographs acquired in July, 1939 for Lake County, Illinois were scanned using a 42µm/pixel scan rate. Several things were learned in the course of scanning the historical Lake County aerial photographs (R. Hilton, County of Lake, Illinois, personal communication, 1997):

- The digital archive of 268 images, each of which averages 33

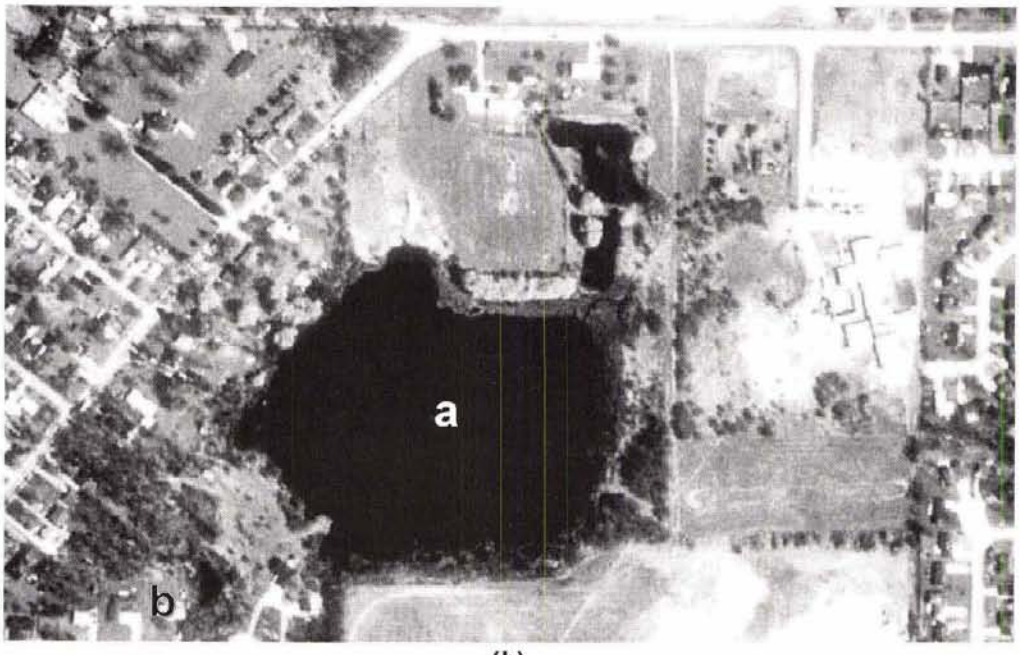
(a)

(b)

Figure 3. (a) Portion of historical aerial photograph acquired over McHenry, Illinois, on 16 July 1939. Original print scanned at 42µm/pixel (1.16 m/pixel). Area of scanned image shown measures 3,550 columns by 2,350 lines, with an equivalent ground area of 4.12 by 2.73 km (11.23 sq km). (b) Area labeled "A" on (a) reproduced at full resolution, encompassing a ground area of 0.99 by 0.67 km (0.66 sq km). Area shown was predominantly in agricultural use in 1939 and also depicts large, natural shallow/deep marshes (PEMC/PEMF; Cowardin *et al.*, 1979) at "a" and "b."



(a)



(b)

Figure 4. (a) USGS DOQ for McHenry, Illinois made from NAPP 1 aerial photography acquired on 19 April 1988 for same area shown in Figure 3a. Comparison with Figure 3a shows that numerous changes have occurred during the 50-year interval between the two dates of photography, particularly with regards to increases in urban land use. (b) Area labeled "B" on (a) reproduced at full resolution. Compare with the same area shown in Figure 3b. The original PEMC/PEMF wetland has been converted to a largely open water wetland (POWG; Cowardin *et al.*, 1979), while the smaller marsh has been drained and incorporated within a single-family housing development.

Figure 5. Historical aerial photograph acquired by the U.S. Army Corps of Engineers in 1931 over St. Louis, Missouri and East St. Louis, Illinois.

Mbytes, requires a substantial amount of storage (approximately 8,576 Mbytes). The issue of available on-line storage is exacerbated when it is desirable to make comparisons over multiple dates.

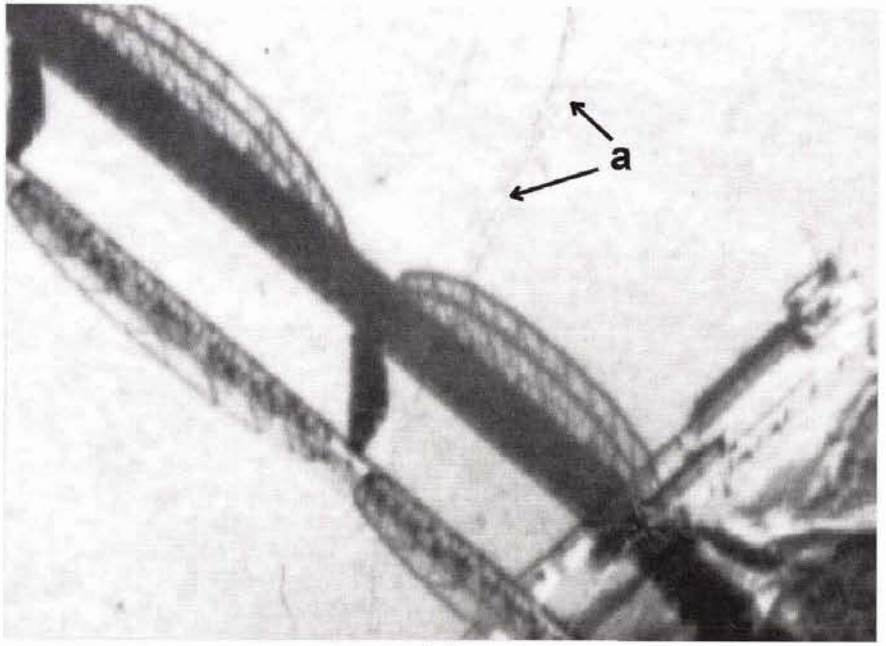
- It takes time to load and view an image using GIS software even with a 200MHz Pentium Processor workstation with 256 Mb RAM, or with a Sun SparcStation 20.
- Data were initially stored on 8-mm tape cartridges. A more convenient medium such as compact discs would be preferable. It would require approximately 14 CDS to store the Lake County archive.
- Public access is planned but hampered by the large storage needed. Sufficient storage space for on-line access will not be available until later. Temporarily, Lake County loads imagery as needed.
- The largest public usages have been for environmental work in examining property parcels for their pre-WWII land cover.

Discussion

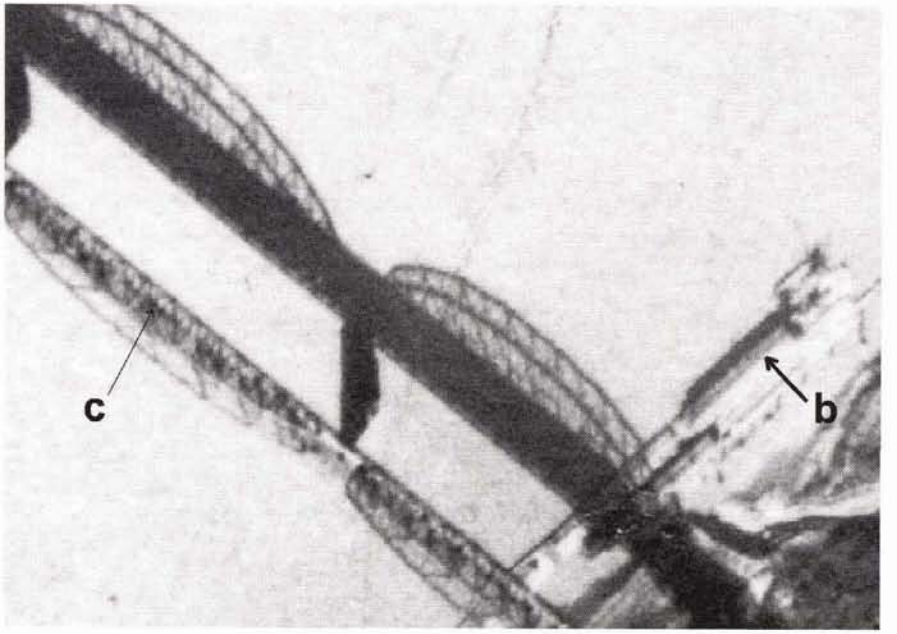
Aside from fiscal obstacles to archiving of the historical aerial photography, additional technical issues arise. These are:

Scanning Quality

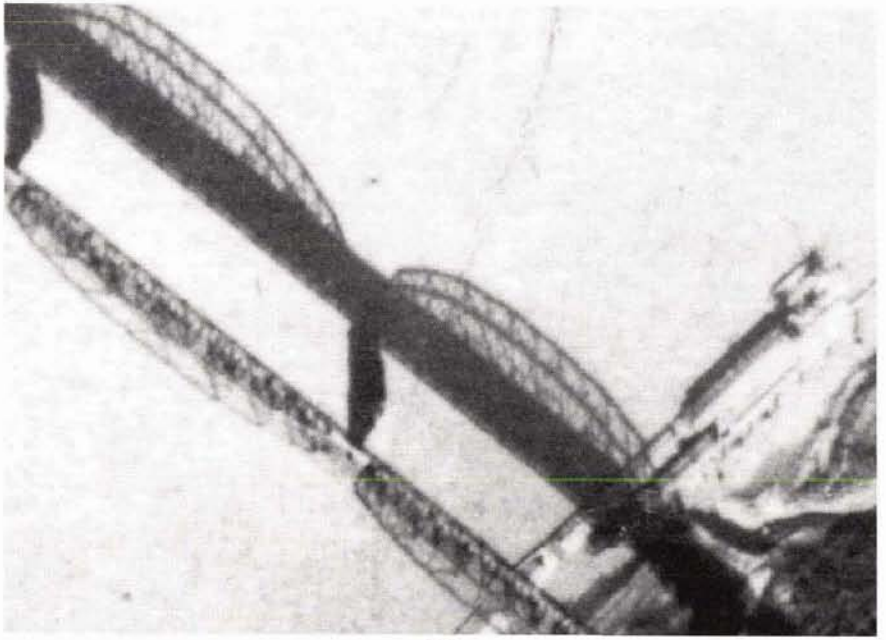
In order for scanning to accurately preserve a photographic print, the process must maintain the geometry, tonal range,



(a)



(b)



(c)

Figure 6. (a) Area labeled as "A" on Figure 5 reproduced at a 6.6× enlargement using a Microtek Scanmaker E6 flatbed scanner at a resolution of 42 μm/pixel (600 dpi). The light-toned line at "a" is an impression on the original photographic print. Compare with (b).

(b) Area labeled as "A" on Figure 5 reproduced at a 6.6× enlargement using a Crosfield drum scanner at a resolution of 42 μm/pixel (600 dpi). The edges of the roof at "b" and the bridge details at "c" appear sharper on image produced by drum scanning as compared to the image produced by the flatbed scanner in (a).

(c) Area labeled as "A" on Figure 5 reproduced at a 6.6× enlargement using a Crosfield drum scanner at a resolution of 21 μm/pixel (1200 dpi). There is little additional detail observed in comparison with (b) scanned at 42μm/pixel (600 dpi).

and all of the feature detail of the original without introducing image artifacts not present in the original print. With these factors in mind, two competing scanner technologies exist for preserving historical aerial photography: (1) flatbed scanners and (2) drum scanners.

Flatbed scanners capture imagery on a moving CCD array that samples each target area of the original photographic print in a single pass. With a fixed focal plane, flatbed scanners cannot focus accurately on the usually curved and warped surfaces of old prints. Broad areas are illuminated at the same time, which can create shadows where impressions occur on the original photographic print (Figure 6a). Finally, flatbed scanners typically can scan only at fixed pre-set resolutions, such as 85 and 42 μm/pixel (300 and 600 dpi, respectively). Options for operator intervention are minimal.

Drum scanners capture imagery through a stationary photo multiplier tube as a photo revolves on a drum. Drum scanners and attendant software allow for considerable operator intervention in adjusting contrast and restoring faded detail. Distinctions between drum and flatbed scanners include the following: (1) discreet areas are sampled several times and the results are averaged; (2) mounting techniques and an adjustable focal plane allow drum scanners to keep the entire area of a warped original print in focus; and (3) only the small area being sampled is illuminated at any one time, eliminating shadows of impressions on the original print (compare Figures 6a and 6b). Finally, drum scanners allow for scanning at variable resolutions, although excessively high resolution does not necessarily increase the detail in the resulting image.

Differences between imagery scanned at 42μm/pixel (600 dpi) by flatbed and drum scanners becomes apparent at a 6.6× enlargement (Figure 5, Figures 6a and 6b). The edges of the roof and the bridge detail appear sharper on the drum scanner imagery than on the flatbed scanner imagery even though both were scanned at the same resolution. However, there is little additional detail observed when the image is scanned at 21μm/pixel (1200 dpi) (Figures 6b and 6c). Because affordable scanning instruments have improved dramatically, comparisons should be conducted before commitment to a par-
ticular technology is made for the permanent preservation of historical aerial photography. Although not a complete comparison between scanners, Figures 6a, 6b, and 6c shows how the quality of the resulting image is also dependent upon the skill, training, and experience of the operator, as well as on the particular scanning technology (M. Smith, Scantech Color Systems, Inc., personal communication, 1997).

Need for Immediate Action

There is an urgency in preserving historical aerial photography. As described above, deterioration of the photography continues with time and each use. Loss of photographs through use, especially theft, is permanent.

Education of Administrators and Appointed and Elected Officials

Most elected and appointed officials, librarians, and staff appreciate the need for preservation, but regrettably, preservation of historical maps and photographs does not have a high priority. Unless consistent steps are taken to preserve necessary materials of all kinds, the accumulated backlogs will result in the loss of valuable materials and present even larger costs at a later date.

Cooperation of Libraries, Government Agencies, and Private Collections

Documenting and publicizing the existence and value of collections of historical aerial photography are necessary first steps to eliciting cooperation among government agencies, public libraries, and institutional libraries in order to avoid unnecessary duplication of efforts and to lead to sharing of resources, experiences, and limited finances. The Lake County project had to assemble the 1939 photographic coverage from several sources because a portion of the Library collection had deteriorated and was incomplete. Where collections exist, photography should be cataloged for ease of access as well as for preservation. Photography lent from an uncataloged collection may mistakenly be thought to be lost.

Format of the Digitized Photography

Format of the preserved imagery is an important consideration. Proprietary systems may require proprietary hardware or software for viewing or other uses. Nonproprietary systems tend to require considerable technical expertise, which may not be available from a library. Common proprietary formats for data exchange include .img, .lan, and .pix, and may require proprietary software for viewing and manipulation. The Tagged Image Format File (TIFF or .tif) is public domain and can be readily incorporated into many diverse types of software ranging from simple to sophisticated.

Distribution Medium

Choice of a distribution medium is another consideration. The evolution of storage media makes selection of a particular medium problematical. At this writing, the compact disc (CD) format is a widely used storage medium. One CD can contain 650 Mbytes, or about 19 or 20 uncompressed images of historical aerial photographic prints that have been scanned at 42 μm/pixel.

Public Access to Historical Aerial Photography

An efficient means of displaying the digital imagery is needed so that patrons can conveniently find the photos desired, examine the imagery, and make usable copies. It would be desirable for access to be available from the World Wide Web. Both would require new, sophisticated cataloging and retrieval of the photography in a semiautomated environment. Consider, for example, the relative convenience of the computer screen as an alternative to laying out individual frames on a library table.

Current AACR2 (Joint Steering Committee for the Revision of Anglo-American Cataloging Rules, 1988) cataloging rules are effective for cataloging text, but would not be useful for aerial photography. Library of Congress subject headings (Library of Congress, 1991) also are of little use in locating relevant information contained in individual frames of aerial photographs.

It must be noted that significant progress has been made regarding Internet access to aerial photography. Projects such as the Alexandria Digital Library at the University of California Santa Barbara (http://alexandria.sdc.ucsb.edu) and the Information System for Los Angeles (ISLA) Integrated Digital Archives project located at the University of Southern California (http://www.usc.edu/Library/ISLA) are developing standards-based cataloging systems that are expected to improve access to aerial photography (Hunt and Ethington, 1996.). Both projects utilize "geographical footprints" as well as conventional cataloging indices, online availability, and extensive gazetteer functions to improve access. ISLA plans to employ a "click and drag" box in order to define the geographical area of interest, display photography within the context of its geographical position, and allow users to "zoom" backward and forward in time, as well as through space in order to locate aerial photography. The ISLA cataloging method has decreased the average time of indexing by 60 percent, and the completion of related software is expected to decrease the indexing time by about 80 percent. The question of whether such access is cost-effective within the envi-

ronment of the Illinois project is being evaluated at the University of Illinois Library.

Legal Considerations

While it is not easy, or perhaps possible, to alter original photographic prints in a way that could not be detected by expert inspection, the digital copy can be changed by accident or design using readily accessible commercial software packages. To date, there is no known procedure for certifying and protecting a legal digital copy. This consideration is likely to become important when historical aerial photography deteriorates in spite of the best efforts to extend the life of the paper copy.

Summary

High-quality scanning of historical aerial photography is an appealing alternative to traditional methods for the development of a permanent archive. However, the cost of scanning Illinois' collection of pre-1950 statewide aerial photography, encompassing some 60,000 frames, is too great for the University Library to bear alone. Cost-sharing initiatives with state and local governmental agencies may be a practical method for distributing the costs to local sources thought to have the greatest need for the preservation. Support might be sought from those who have the highest frequency of use of the historical aerial photography. For example, during the period of the pilot project, the University of Illinois Library and one county governmental agency cost-shared the scanning of the oldest set of county-wide USDA aerial photography.

Digital orthorectification of historical aerial photography is cost-prohibitive at the present time. However, for areas of low local relief and on a site-by-site basis, the authors suggest that a simple geometric correction of the scanned photography using existing, current digital databases such as USGS DOQs is sufficient for GIS applications where precise registration is not necessary.

Acknowledgments

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References

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe, 1979. *Classification of Wetlands and Deepwater Habitats of the United States*, Department of the Interior, U.S. Fish and Wildlife Service, FWS/OBS-79/31, 131 p.

Gaydos, L., L. Ladner, R. Champion, and D. Hooper, 1986. The Production of Orthophotographs by Digital Image Processing Techniques, *Technical Papers, 1986 ACSM-ASPRS Annual Convention Photogrammetry*, American Society of Photogrammetry and Remote Sensing, Bethesda, Maryland, 4:241–249.

Hood, J., L. Ladner, and R. Champion, 1989. Image Processing Techniques for Digital Orthophotoquad Production, *Photogrammetric Engineering & Remote Sensing*, 55:1323–1329.

Hunt, L., and P.J. Ethington, 1996. ISLA: An Archive of Los Angeles Materials in Multiple Formats Integrated by Spatial and Temporal Referencing, *Proceedings of the GIS/LIS '96 Annual Conference and Exposition*, 19-21 November, Denver, Colorado, pp. 62–75.

Jensen, J.R., 1996. *Introductory Digital Image Processing: A Remote Sensing Perspective, Second Edition*, Prentice-Hall, Inc., 316 p.

Joint Steering Committee for the Revision of Anglo-American Cataloguing Rules, 1988. *Anglo-American Cataloguing Rules, Second Edition, Revision XXV* (M. Gorman and P. Winkler, editors), Library of Congress, Cataloging Distribution Service, Washington, D.C., 677 p.

Kolbl, O., M.P. Best, A. Dam, J.W. Douglass, W. Mayr, R.H. Philbrik, P. Seitz, and H. Wehrli, 1996. Scanning and state-of-the-art scanners, *Digital Photogrammetry: An Addendum to the Manual of Photogrammetry*, American Society of Photogrammetry and Remote Sensing, Bethesda, Maryland, pp. 3–38.

Library of Congress, 1996. *Library of Congress Subject Headings, 19th Edition*, Library of Congress, Cataloging Distribution Service, Washington, D.C., 5979 p.

Luman, D., C. Stohr, L. Hunt, and M. Smith, 1995. Preserving the Past: The Development of a Digital Historical Aerial Photography Archive, *Illinois GISMapnotes*, 13(Fall):2–9.