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Photogrammetric Cadastral Surveys and GLO Corner Restoration

Photogrammetric techniques are an alternative and supplement to conventional ground surveys; they help reduce costs and strengthen the legal position of any survey.

Introduction

The most accurate cadastral survey may be inadequate unless every effort has been made to locate and re-establish the original General Land Office Survey (GLO) corners. Finding the original evidence and re-establishing at least some of the original GLO corners will strengthen the legal position of any survey. However, reconstructing the original survey by conventional ground methods is time-consuming and costly. An alternative to conventional ground methods is through the use of photogrammetry,* which incorporates aerial photography and sophisticated measuring instruments to assist the surveyor and reduce the amount of actual work performed on the ground.

Abstract: *The State of Washington, Department of Natural Resources (DNR) has developed an operational cadastral survey procedure using photogrammetric techniques to assist the surveyor and reduce the cost of retracement, identification, and restoration of the original General Land Office Surveys. The photogrammetric technique used also establishes a Third Order (1:5,000) or better control network to reduce further the cost of completing surveys on the ground using conventional survey methods. The procedure discussed in this paper will show why all surveyors should consider photogrammetric techniques as an alternative and supplement to conventional ground methods in order to help reduce costs and strengthen the legal position of any survey.*

The Department of Natural Resources of the State of Washington (DNR) manages approximately five million acres of forest, agricultural, and range lands; marine aquatic lands; and tidelands. It is essential to know where its property boundaries are located due to the high values involved and for the effective management of this property. Many of the boundary and subdivision surveys required are located in rough mountainous terrain and are very expensive or even prohibitive. Scheduling is critical and often several surveys must be performed simultaneously. Most DNR property is also scattered in small parcels throughout the state because of the way in which land grants were awarded at the time of statehood. This "patchwork" pattern further complicates survey problems.

To resolve some of these difficulties, the DNR began experimenting several years ago with photogrammetry as a supplement and an alternative to conventional ground methods on every survey proposed.

DNR's Test Project

DNR's test project began in April, 1975 by forming a committee of six other landowners. The landowners cooperating with the DNR were Burlington-Northern, Crown Zellerbach, International Paper, Longview Fibre, Scott Paper, and Weyerhaeuser. Robert J. Shelton of Missoula, Montana was the contractor establishing the photogrammetric survey portion of the project.

* *Manual of Photogrammetry*—Third Edition, Volume I, Chapter I.

Photogrammetric Engineering and Remote Sensing,
Vol. 47, No. 2, February 1981, pp. 193-198.

DNR's objectives were to test the feasibility and application of photogrammetry for the purpose of

- Locating and restoring GLO corners from original evidence,
- Establishing a subsequent Third Order or better control base which could be used to establish section corners and perform subdivisions,
- Reducing costs while increasing production,
- Solving major problems in surveys when the original GLO Survey is questionable, and
- Developing a technique whereby survey crews could function on several projects simultaneously.

The test project consisted of 72 sections in T6N R1E and T6N R2E in Cowlitz County, Washington. Many of the section corners, along with original evidence established in the surveys of 1857-1892, were destroyed by wildfires in the early 1900s. Consequently, numerous independent surveyors trying to re-establish the original surveyed corners could not agree on their location. Corner locations differed by several hundred feet in many cases.

To the best of our knowledge, this is one of the largest (if not the largest) such survey of its kind in the country, and the first cooperative effort by several major landowners that has been successful.

Why Photogrammetry?

It was decided that these two townships were particularly suited for a photogrammetric survey rather than conventional ground methods for the following reasons:

- The project is located in rough terrain and heavy brush cover, which would have made it difficult and costly to survey by conventional ground methods;
- The original GLO Survey was questionable;
- There were up to three positions for many of the corners previously established by independent surveyors;
- There was up to 1,000 feet of error between some of the independent surveys;
- No one could agree on property line or section line locations;
- None of the landowners could afford to resurvey the entire two townships by conventional ground methods;
- Survey crews could work on this project as time and seasons allowed; and
- None of the previous surveys was established on the Washington State Plane Coordinate System.

The Photogrammetric Procedure Used for the Test Survey

A cooperative agreement was negotiated and accepted between the major landowners during the summer of 1975. Total agreement required considerable discussion due to past difficulties and the differences in corner locations between independent surveys. However, an agreement was reached and everyone agreed to accept the results of the photogrammetric survey, to share the workload, and to supply the contractor with all necessary information. Three potential contractors were interviewed by the committee. The criteria used to select the contractor were

- Experience and expertise in photogrammetric survey and corner restoration techniques;
- Costs;
- Non-resident but licensed to survey in Washington;
- No conflict of interest in any of the lands on the project site; and
- No dealings, past or present, with any of the landowners involved.

These criteria were extremely important to assure each landowner that the survey was totally unbiased and fair. Very high land and timber values are involved, and many trespasses are expected to surface as a result of the survey. The committee negotiations and contractor selection process were successful. Work on the project progressed smoothly with few technical problems.

Actual work on the project began in February, 1976 with the targeting, establishing a primary control network, and tying previously found GLO corners to the primary control (see Figure 1). Two 2-man crews set a total of 515 targets using plasticized 20-inch wide butcher paper. The butcher paper was placed on the ground so as to form a 20 foot cross and was weighted with rocks. A ½-inch by 21-inch rebar and a plastic cap were placed in the center of each target (see Figure 2). Each target was given a serial number, identified with aluminum tags, and recorded in the field books. The route to each target was flagged for easy recovery. About 70 of the targets were placed on or near recovered monuments and each of these targets was surveyed on the ground and tied to 15 primary control point targets. The remaining targets were placed in the general location of each section corner and ¼ corner (see Figure 3).

The criteria for placing these targets were (in order of priority)

- Placement so that a primary control point could be seen,
- Placement so that one of the other corner targets could be seen, and
- Placement of a second backsite target when a control point target or another corner target could not be seen.

As a result, two targets were placed near many of the corners because of the heavy brush cover, mountainous terrain, and heavy tree cover.

The photography was scheduled to be flown on or about 15 March 1976, but was delayed by inclement weather. The project site was finally flown on 26 April 1976. Three strips of east-west photography were flown by Montana Aerial Pho-

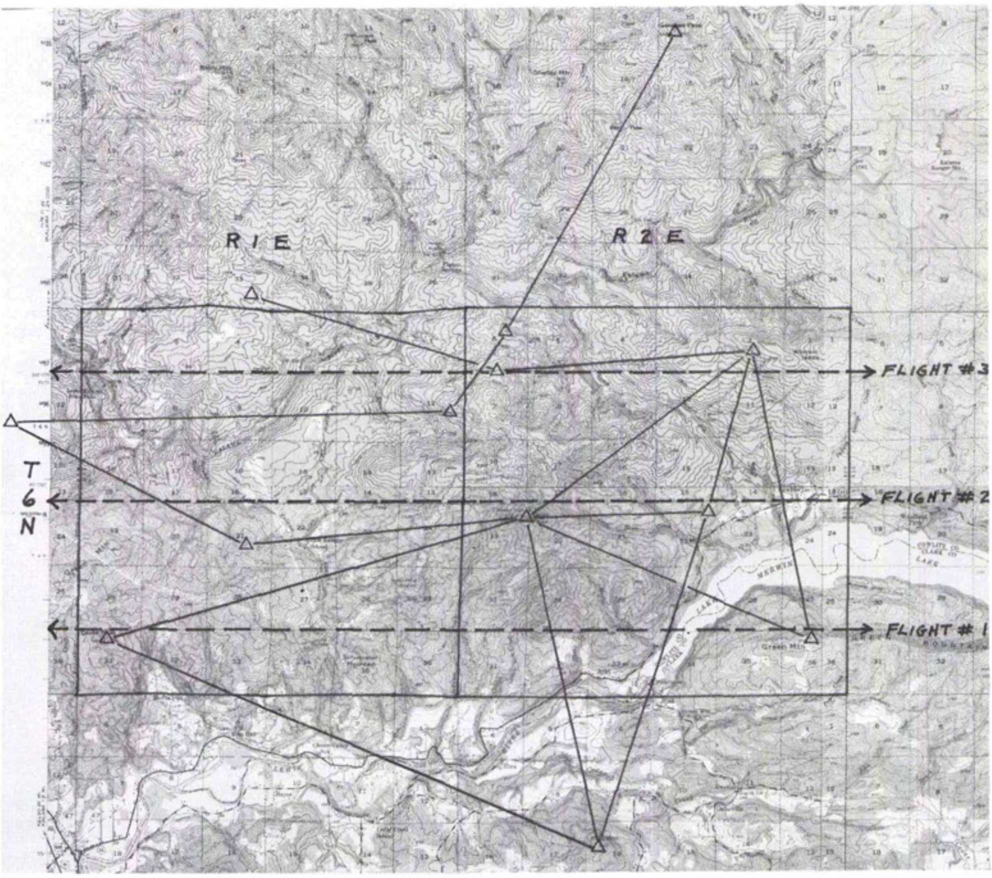

FIG. 1. U.S. Geological Survey quadrangle map showing distribution of the primary control and flight lines of the photography flown.

tography per the following specifications (see Figure 1):

Camera:	WILD RC8
Focal Length:	6 inch
Scale:	1:18,000
Endlap:	80 percent
Sidelap:	22 percent
Negatives:	Black and White

An additional flight was flown on the same flight lines at 1:24,000 scale with an 8¼-inch focal length lens in order to produce 1:4800 scale planimetric maps for this project.

By carefully planning the positions of the targets, 97 percent of the targets were easily identified on the photography. The high percentage of identified targets is particularly noteworthy because the low sun angle caused long shadows, timber at some locations was over 100 feet tall, and the targets were out in the open for over a month due to weather delays.

After the negatives and prints were inspected and accepted, the targets were annotated on the 1:18,000 prints. The targets to be used for control were tabulated with Washington State Plane Coordinates, and vertical values, and were delivered to DBA Systems, Inc., in Florida for aerotriangulation. DBA Systems, Inc., performed the

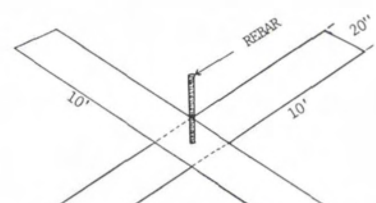

FIG. 2. The above illustration shows the size and pattern of the targets placed during the DNR Test Project. The panels were placed at right angles to form a cross with a 20-inch by 20-inch white center. The ½-inch by 21-inch rebar was driven into the ground through the exact center of each target.

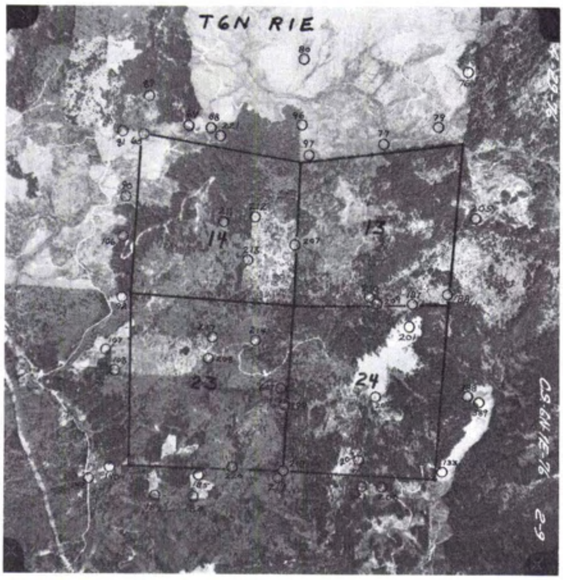

FIG. 3. Aerial photo showing the distribution of targets on four sections within the two townships described and the character of the land surveyed.

analytical aerotriangulation using the 1:18,000 negatives and a simultaneous bundle adjustment. The position accuracy obtained during the aerotriangulation was expected to be 0.5 ft relative accuracy across the two townships and no more than 0.9 ft positional (absolute error) error against the datum.

The maximum residuals of the computed values obtained during the aerotriangulation against the surveyed values was 0.3 ft. When compared with values which were measured on the ground and withheld to edit the aerotriangulation, the accuracy of DBA's work was found to be within 0.5 ft of the datum in all cases. The relative accuracy between targeted positions checked best when photo-computed coordinates for the primary control were used instead of actual control values. This substantiated the hypothesis that relative error is less than absolute error. However, the surveyors found it very difficult to check for positional errors of this magnitude with the Second Order survey methods used during this project. This further substantiated the need for photogrammetric surveys on rough, brushy, mountainous terrain.

Planimetric base maps at 1:4800 scale were prepared showing all of the control and the targeted positions. Planimetric details, along with the GLO terrain calls from the original GLO notes, were compiled on these maps using a Kelsh Plotter. Corner search plots were computed and plotted on the maps, which assisted the surveyor in locating original corners on the ground.

The maps were updated as corners were found, and new search plots for other corners were determined from the new information. If the search failed to produce a corner, a double proportioned corner was re-established and monumented after agreed upon by all parties affected.

Accomplishments on the Test Project

The corner search on the ground, using the search plots and information compiled in the Kelsh Plotter, produced 17 original corners in T6N R2E. No original corners have been found in T6N R1E, but then the ground search has not been completed in that township. Figure 4 shows some typical corners found in this part of Washington.

The photogrammetric portion of the project is complete. The computed search positions make it possible for the first time to plan and execute a thorough ground search for the remaining GLO corners. The established photogrammetric control base also makes it possible for the first time to complete the survey on the ground with continuity between independent surveys on the Washington State Plane Coordinate System.

All of the landowners who cooperated with the DNR on this project are impressed with the results and some are considering other surveys using photogrammetry.

All of the positions determined by photogrammetry and tested by the DNR have been found to be of Third Order accuracy or better.

Advantages and Benefits Determined During the DNR's Photogrammetric Test Survey

There are many advantages and benefits of the photogrammetric survey technique which will assist the surveyor and significantly increase accuracy, save time, and reduce costs. However, each survey project must be weighed to determine if the photogrammetric technique is the best procedure. Not every project should be surveyed using photogrammetric procedures, but they should be considered as an alternative during the planning stages of every project, even if surveying only one section.

The following is a summary of some advantages of photogrammetry as determined during the DNR's test survey:

- Error is not accumulative because the positional error in a computed position is rotational around itself and does not accumulate from point to point;
- A Third Order or better survey can be obtained even under the roughest of conditions;
- It is easier to place a survey on the State Plane Coordinate System and it encourages the use of the System;
- It helps keep surveyors out of trouble by providing more facts and information;
- It reduces the time-consuming portion of the survey, such as the time spent clearing survey lines, and it reduces the number of miles to be surveyed;

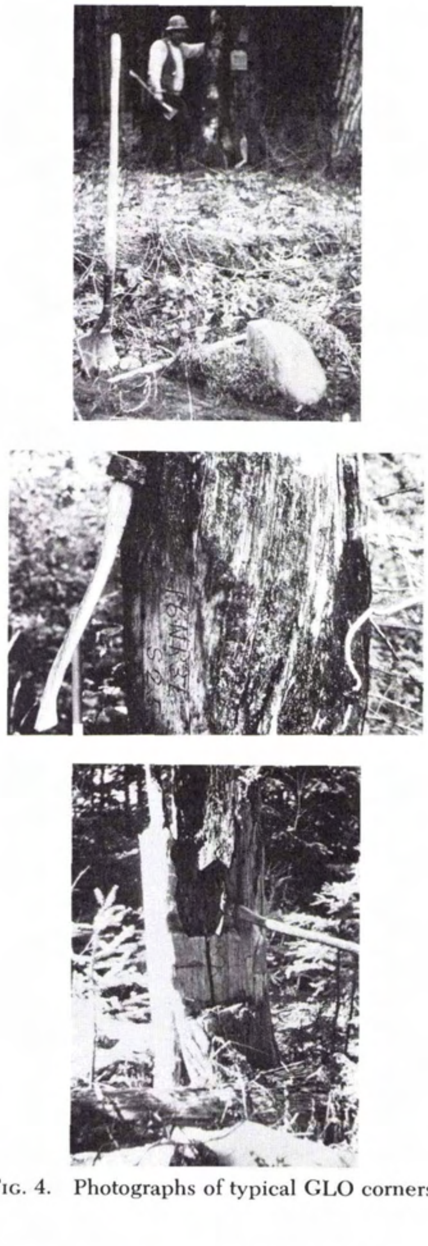

FIG. 4. Photographs of typical GLO corners.

- More work can be accomplished with existing personnel;
- Photogrammetry provides an easier method of calculating positions, which reduces the number and length of control lines to be run on the ground;
- Survey ties are easier to obtain and photogrammetry reduces the cost of survey ties on the ground;
- It is easier to obtain a quicker overall picture and to determine what needs to be done;
- Much of the work normally performed by the surveyor on the ground can be accomplished by the photogrammetrist in the office; and
- Once the initial photogrammetric portion of the survey is completed, the project can be put on the shelf and completed on a "need basis."

THE FUTURE OF PHOTOGRAMMETRIC SURVEYS IN THE DNR

As a direct result of the test survey project's success, DNR now has an ongoing photogrammetric cadastral survey program. All survey requests will be analyzed to determine if photogrammetry is the best method, regardless of the size of the project.

DNR produces 1:4800 scale topographic maps with 20 foot contours to assist in timber sales planning and management. The original GLO notes will be plotted on these maps during compilation in order to assist the surveyor in locating the original GLO corners prior to a cadastral survey. This information will help determine the scope of the survey to be performed and reduce the number of survey lines to be run. The surveyor and the photogrammetrist working together can determine the scope of the photogrammetric procedure; thus, the survey may be finished on the ground any time the surveyor deems necessary.

THE LEGAL ASPECTS OF PHOTOGRAMMETRY

A cadastral survey established with photogrammetric procedures can be registered as a legal survey when standard land survey procedures and accuracies are maintained. Photogrammetry is just another tool available to the land surveyor, but one which can be more accurate than ground survey methods under certain conditions. The surveyor makes all the final decisions on the ground for each position, as is done with conventional survey procedures.

CONCLUSIONS

Surveys performed utilizing photogrammetric techniques require less time and will be more accurate and complete because the surveyor has more information and facts to assist him in his work.

Photogrammetric techniques have been tested by the DNR and found to be sufficiently accurate. Medium to large jobs cost less, and more work can be accomplished with existing personnel.

Probably few surveyors realize the full potential of the photogrammetric technology available to them today. As shown in this paper, some significant progress has been made in the DNR, through the use of photogrammetry, to reduce costs and get more work done without increasing personnel. The photogrammetrist only supplies the surveyor with more and better information to help make more intelligent decisions on the ground. I believe that the cadastral surveyor and the photogrammetrist can work together as an effective survey team.

The courts are demanding that everything possible must be done to recover the original GLO Survey from original evidence found during the cadastral survey. Photogrammetric procedures used in the corner search and restoration help answer the court's demands. In other words, the surveyor has not done everything, in many cases, unless he has used a photogrammetric survey and search procedure. For instance, many of the original corners found during the DNR test project were walked over several times by previous surveyors, but were not located until a search position was resurrected by photogrammetric means from the original GLO notes.

Photogrammetric cadastral surveys will never become synonymous with conventional survey practices unless the photogrammetrist accepts the burden of proof and provides explanations in terminology which non-photogrammetrists can understand. However, in turn, the surveyor must be willing to accept and try out the procedures developed.

In the final analysis, if we do not use or consider photogrammetry as an alternative procedure in cadastral surveying, we are not doing everything possible to make good decisions and to reduce costs.

Acknowledgments

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