*Photogrammetry in Cadastral Surveying**

J. E. KING,
Chief, Cartographic Section,
Division of Engineering, U. S. Forest Service

ABSTRACT: *Cadastral surveying is an important element of Forest Service cartography. The author for many years has directed developmental projects aimed at a photogrammetric solution of the cadastral survey problem.*

The principal steps in procedure and results are explained for early experiments on the Bienville and Chippewa National Forests, with a more detailed discussion of a current test on Tahoe National Forest. The obvious requirement of coordinated control and increased accuracy has been met by the use of a first-order camera-plotting instrument combination. Correlative with the actual test work, certain recommendations on control and survey photography scales are presented, and field control and identification procedures and requirements are suggested.

EVERY now and then there comes a time when overworked words like stupendous, colossal, and gigantic are far too weak and inadequate to describe a particular event or situation. Such is the case when attempting to find a word, or words, which can describe the importance and impact of photogrammetry on cadastral surveys. Let us simply say that in it lies the only hope for efficiently and economically resolving the increasingly major problems of our land ownership.

The limitations of time for this paper make difficult, if not impossible, treating this subject intelligently without sacrificing accuracy and thoroughness. However, I hope the brief dissertation will provide useful and interesting facts with regard to our experience with photogrammetric cadastral surveys, and also will stimulate your thinking.

How does the Forest Service fit into the cadastral picture? Through the back door, so to speak, by virtue of its responsibility of managing and administering 180,000,000 acres of National Forest lands, located in 40 States, Alaska and Puerto Rico. Figure 1. These lands represent 10 per cent of the total area of the Continental United States.

Along the 250,000 miles of property boundary between National Forest and other land ownership, there are thousands of individual landowners with whom it is necessary for the Forest Service to live as a good neighbor. The security of both the government and the individual is intimately bound up in the ownership of these lands; the Forest Service no longer can disregard the urgent need for accurate and adequate property line determination, restoration and perpetuation.

Of necessity, and within the limits of its authority, the Forest Service has been actively engaged in developing and putting into effect a practical and acceptable method of photogrammetric cadastral surveys. Although procedures have been directed mainly toward retracement surveys, the value of the method for original and resurveys is readily demonstrated.

In Denver, almost exactly twenty years ago, I presented to a group of engineers my news and views on the application of photogrammetry to various engineering activities—principally on the use and value of aerial surveys for preparing precise topographic maps. Perhaps some of those engineers are attending this meeting. What a blast of hoots and boos that speech brought forth! I was virtually run out of town and ostracized from the profession.

* Presented at the 1956 ACSM-ASP meeting in Denver, Colorado, October 2, 1956.

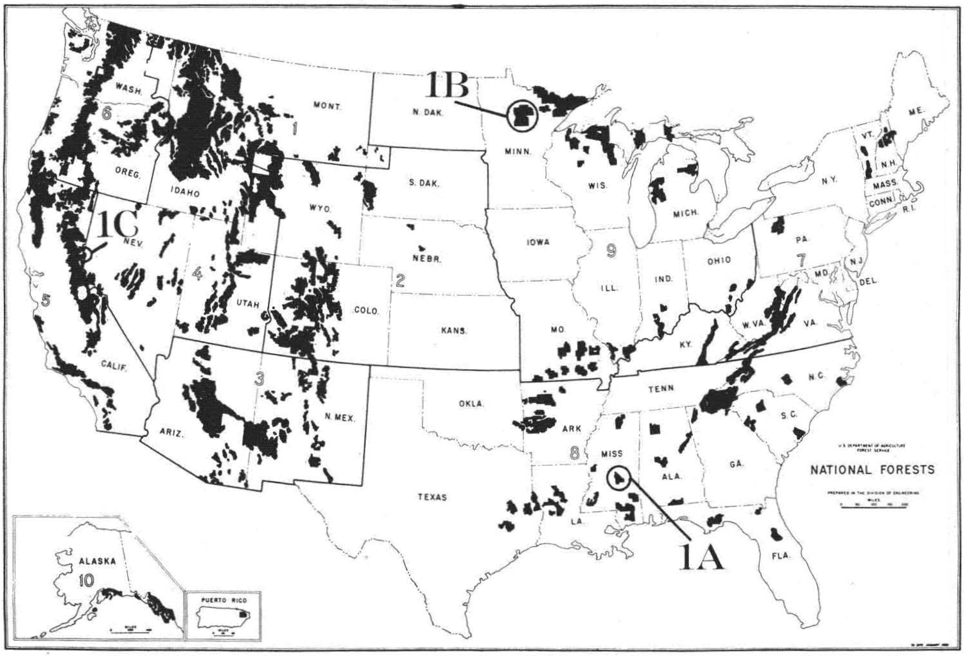

FIG. 1. National forests.

But today! Some of those who then were the most vociferous jeerers now cheer the loudest; they are counted among the most staunch supporters and advocates of ideas I presented twenty years ago. Undoubtedly this paper will bring forth hoots from some of the listeners. If so I hope that you will permit me to remain in town.

Until very recently, cadastral surveys have been executed almost exclusively by ground procedures, employing conventional traverse methods. These are always slow and costly. But now we have a critical manpower shortage. The result is that the Forest Service has been unable to keep abreast of its land ownership problems, let alone get on top of them.

There has been a lack of proper publicity of the technical advances of photogrammetry. The result is widespread unfamiliarity with methods now employed and with the potentialities of comparatively new photogrammetric techniques. This situation is largely responsible for a lot of the reluctance or prejudice against the employment of photogrammetry for cadastral surveys.

THE BIENVILLE FOREST EXPERIMENT

Culminating a number of years of speculative thinking and kicking around the photogrammetric cadastral potentiality, the Forest Service, on February 14, 1948, set its aerial survey wheels in motion on an experimental survey on the Bienville National Forest in the State of Mississippi. 1A Figure 1.

The purpose of this project was to develop a photogrammetric method for resolving the ever-increasing problems of acquisition surveys, boundary marking and trespass cases. The graphic approach to the application of aerial survey to the cadastral problem in Mississippi, utilizing the Kelsh plotter and large-scale stereotemplets, was, at that time, the apparent answer. In brief, the system employed included:

1. New vertical photography at scale of 1:15,840. During the test, various other types and scales of existing photography were tried and found inadequate. In the test five-diameter enlargements of the 1:15,840 photographs were utilized.
2. Field identification of all section and quarter-section corners.
3. Preparation of examination prints by standard sectional subdivision on enlargements made from the oldest available photography.
4. With the aid of examination prints,

the investigation of ground evidence and determination of necessary action for locating each forty-acre corner and for the perpetuation of property lines.
5. Preparation of the final plat.

This project was completed early in 1951 with several significant conclusions. The system will afford very definite but limited value in cadastral operations in areas similar to the Bienville Forest. It is definitely usable for certain types of boundary settlement. In actual practice on the Mississippi project, a peaceful and satisfactory agreement was reached with all but two property owners whose occupancy constituted a long standing trespass upon government land. The method promises significant savings in time and cost in boundary location and settlement, particularly in areas similar to Mississippi, when old and new photography are available for rigorous comparisons for conformity with state law requirements.

Despite the success in settling land disputes on the Mississippi area, an essential element was lacking. The procedural data obtained did not provide for reducing the findings to geographic positions. In other words it was infeasible to produce accurate descriptions of line in terms of bearings and distances. Even on the large-scale plats (1:3,168 or 20″=1 mile), discrepancies in position were found to vary from 4 or 5 feet to 15 and 16 feet. The court and legal profession either were most reluctant, or flatly refused, to accept a property boundary described simply from map positions or graphic locations thereof.

The Chippewa Forest Experiment

Although the Bienville test was largely successful for the intended purpose, Forest Service cadastral problems required a much more precise and comprehensive technique. So in May 1951 we moved into the Chippewa National Forest in the State of Minnesota. (1B Figure 1.) This area was chosen for reasons of economy, and to provide for testing in a terrain and cover of considerable contrast to that in Mississippi.

Essentially the techniques and procedures used on the Mississippi project were employed on the Minnesota test. That is, the Kelsh plotter—stereo-templet-graphic-approach, with certain refinements and modifications which our previous work had indicated as desirable. The area selected was considered representative of average resurvey requirements and was covered by aerial photography of scales of 1:15,840, dated 1947 and 1:20,000, dated 1939.

Procedure on the Minnesota test was briefly:

1. A diligent search for all section and quarter-section corners, and photographic identification of all corners or data pertinent to the location thereof.
2. The establishment of supplemental horizontal control for increasing the accuracy of subsequent planimetric maps.
3. The construction of a planimetric map, scale of 1:15,840, in $7\frac{1}{2}'$ quadrangle units and establishment on it of all recovered land office-survey corners, or information pertinent thereto.
4. The construction of a cadastral plat incorporating all recovered field-survey data and completion of the land net.
5. Using the plat as a guide, conducting a second search for unfound corners. This entailed transit traverse of lines, using the courses as determined on the plat.
6. The adjustment and completion of a plat from field data and complete standard subdivision of sections.
7. The monumenting of property, meander, quarter, and section corners in the field, and obtaining agreement of positions by adjoining owners as required.

Again in spite of extreme care in all operations, there were excessive errors in the graphic determination of angles and distances. The results of the test proved conclusively that any graphic solution to this procedure could not be relied upon.

It should be pointed out, however, that this method once more demonstrated its effectiveness in accomplishing savings in time and cost of retracement surveys. Many corners were found which otherwise would have gone undiscovered, and although the project resulted in field work excessive to that anticipated, the amount was far less than would have been required by conventional methods.

The Tahoe Forest Experiment

The last procedural gasp was expended on the Tahoe National Forest in California,—a final try. This third area presented a still different pattern of cover, topography and land ownership. This test was initiated in March 1953 utilizing the then available Forest Service photogrammetric equipment, namely: the Kelsh Plotter, stereo-templets, and conventional 9″×9″ aerial photography at a scale of 1:10,000. The operations soon indicated we would wind up with results similar to those obtained on the two previous areas. Procedures and usable data were modified and incorporated into subsequent tests on the same area, hereinafter discussed.

The Modified Tahoe Experiment

We were now satisfied that for our photogrammetrical cadastral work, nothing short of the highest specifications in instruments and specialist experience would be acceptable in each phase of the survey. This applies equally to the photography, field control, photographic interpretation, stereophotogrammetric equipment, field check, and final drafting. Nothing but the best from the photogrammetric and cadastral engineers and their equipment is acceptable if adequate standards are to be maintained.

The essentiality of precise and top quality photography cannot be overemphasized. This is the heart of any photogrammetric procedure and upon it largely depends the extent of necessary field operations, which, of course, take the biggest bite into the financial pie. Together with precise navigation of the photographic flights, the aerial camera is the decisive factor in obtaining the essential photographic quality.

Our first approach to our cadastral survey, then, was the procurement of an aerial camera which would afford the maximum in photography in image definition, distortion freedom, optimum illumination, and uniform and correct overlap. The answer was the Zeiss-Aerotopograph's aerial survey camera RMK 21/18. Figure 2.

Zeiss-Aerotopograph for several years has been conducting extensive experiments on cadastral surveys, and, prior to their presentation of the subject at the annual ASP-ACSM meeting in 1955, the company provided the author with a rather comprehensive report of these operations. Although the Company's methods were not applicable to our cadastral problems, the basic technique and equipment (matched RMK 21/18 camera and C-8 Stereoplanigraph) appeared to be the needed ingredients.

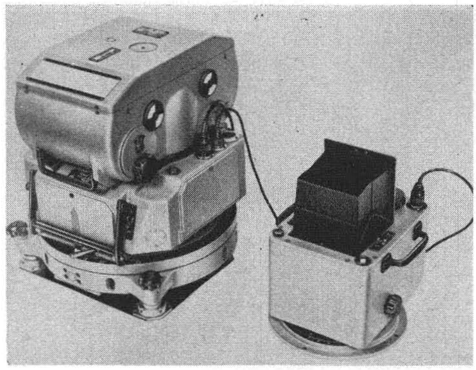

Fig. 2. Zeiss aerial survey camera RMK 21/18.

As far as concerns photography, our previous experience had convincingly shown that several basic factors were essential. For the cadastral survey, *the camera must be matched with the metrical characteristics of the stereoplotting instrument and employ an 8¼″ or 12″ normal-angle lens.* We had demonstrated definitely that *wide-angle, convergent-photography, and that taken with focal lengths of less than 8¼″ would not be acceptable.* Of course, in the interests of economy, wide-angle photography for control purposes is still desirable.

Zeiss-Aerotopograph offered the Forest Service the use of the RMK 21/18 camera and C-8 Stereoplanigraph for the proposed test purposes. The modified Tahoe project was launched in July 1955.*

It should be pointed out that although this paper specifically discusses our photo-cadastral objectives and findings, the Tahoe project was targeted as proving grounds for advanced photogrammetric application to several other types of engineering survey including earthwork and dam-site survey, cross-section and profile-

* Acknowledgement is herewith made of the excellent work and cooperation of both the Forest Service personnel in California, and the Zeiss organization, throughout the Tahoe tests. —*The Author*

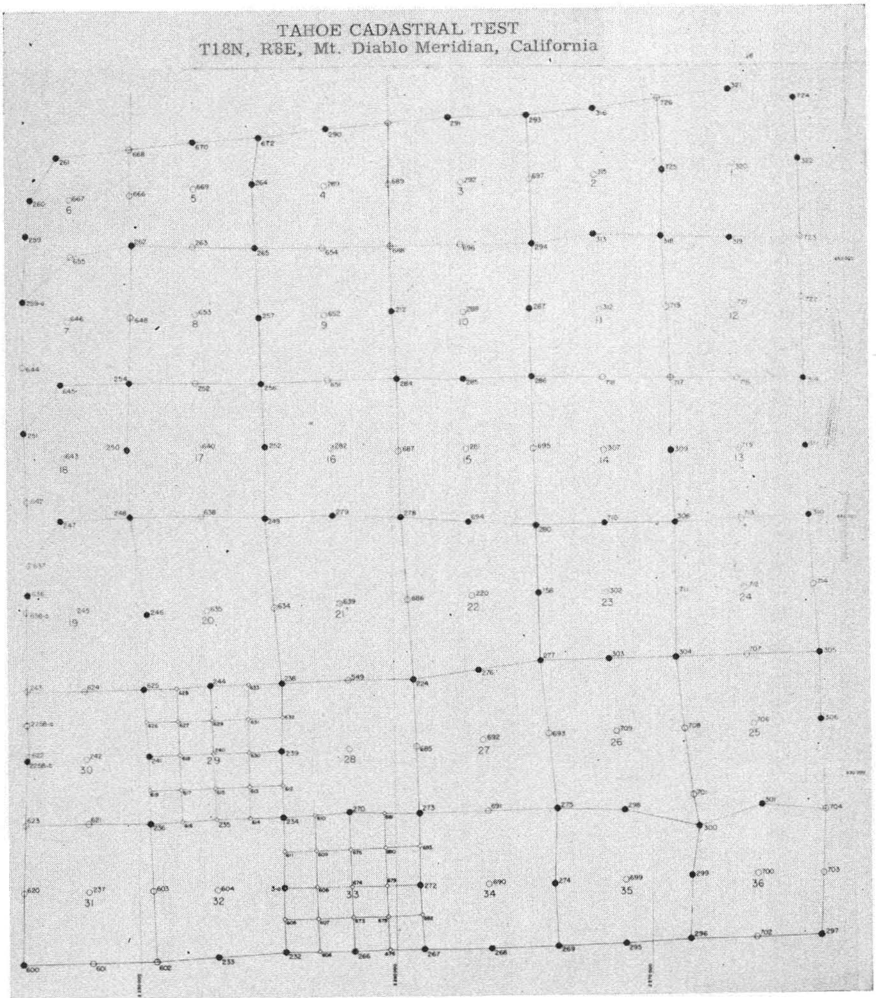

FIG. 3. ● = Found corners. ○ = Corners to be restored from picture points.

line; bridge-site survey and plot-plan. More will be made known from the results of these tests at a future date.

Township 18 N, Range 8 E, Mt. Diablo Meridian, (1 C Figure 1), in the Tahoe area was used in this test, this being the area upon which the original 1953 operations had been conducted. On-the-ground reconnaissance indicated for the cadastral survey the desirability of photographing the area at scales of 1:27,000 for control purposes, and 1:15,840, 1:10,000 and 1:5,000 for ensuing cadastral operations.

Prior to photography, a diligent search was made jointly by the Forest Service and the Bureau of Land Management engineers for all quarter-section and section corners within the township. Figure 3. BLM personnel verified all corners found. All of these which would appear on the photographs were pre-marked with various types of targets, of a size compatible with the resolution of the photography, to afford comparisons of their recoverability and effectiveness. Where it was determined that the corner would not be visible on the photographs, offsets were measured by bearing and distance to a location which would be discernible and so marked. Figure 4.

In order to provide ties to state plane-coordinates, all photography was flown north and south, the 1:27,000 scale coverage (control photographs) requiring three flight strips for the township. Forest Service triangulation was established to meet

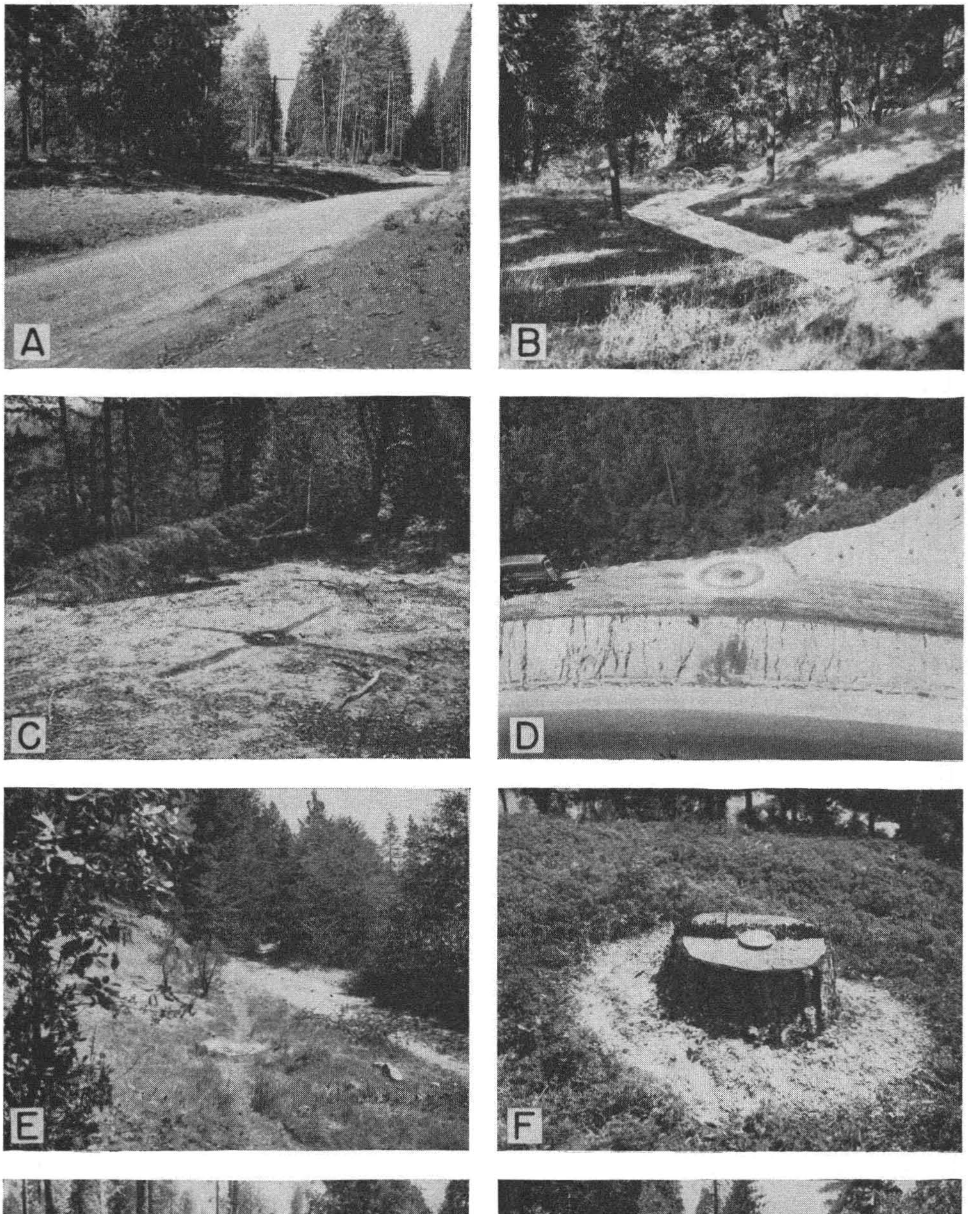

FIG. 4. Illustrations of ground markers.

EXPLANATION OF FIG. 4

A. Painted white cross in road. Marking contrasts nicely with darker surface. Location is open and not affected by shadow pattern.
B. White-limed "L" with 10 inch pie-plate at apex. Pie-plate is supported on stakes to clear pipe monument. Visible on photos, but shadow pattern makes it hard to identify.
C. Ten-inch pie-plate supported on hub; circle and cross colored with black powder commonly used to color cement. Effective where background is white.
D. Ten-inch pie-plate; 2 concentric circles of white lime. Excellent for small-scale photography.
E. Ten-inch paper pie-plate; 3 foot square of black tar paper; 6 foot square of white lime. This marking not as effective here as in (H) due to variation in ground coloring.
F. Ten-inch aluminum pie-plate on center of stump; white circle of lime around stump. Dark ground cover makes good contrast.
G. Twelve-inch aluminum pie-plate; 3 foot disc of black tar paper; 6 foot circle of white lime. Very effective.
H. Ten-inch aluminum pie-plate; 3 foot square of black tar paper; 6 foot square of white lime. Very effective.

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the requirements of the Stereoplanigraph, all stations being based upon four Coast and Geodetic Survey stations encompassing the township. Angles were turned with a Wild T-2 theodolite and sufficient positions were read to provide second-order accuracy. Figure 5. Ties to Coast and Geodetic Survey level lines were made for all stations; their elevations to 1929 mean-sea-level datum can be considered as of third-order accuracy.

On the south ends of the first and third flight strips, a quadrilateral of triangulation was established and two stations in each strip at the north ends thereof. Near the midpoint of each of these two strips, an elevation was determined. No control was established for the second, or middle, strip of photographs. As in the case of recovered land corners, all control points were pre-marked on the ground so as to appear on the photography. This consti-

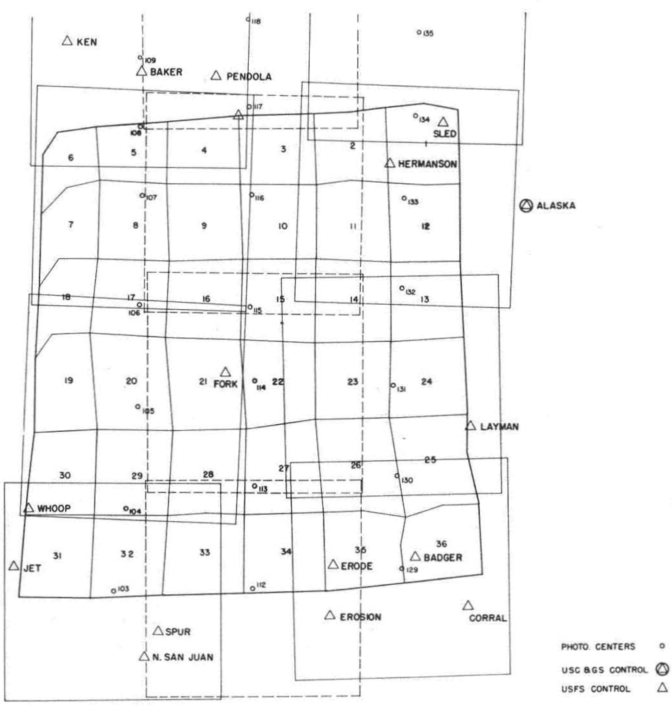


FIG. 5. Control diagram and 1:27,000 photo index T. 18 N., R. 8 E., Mt. Diablo, Meridian, Calif.

tuted all of the ground-control required for the cadastral survey.

This information, with four sets of photographs, descriptions of markers, field notes, and attendant data, were taken to the Zeiss plant in Munich, Germany, for completion of the stereoplotting phases of the project.

A C-8 Stereoplanigraph (Figure 6), two highly trained operators, and three computers were assigned to the job, and ca-

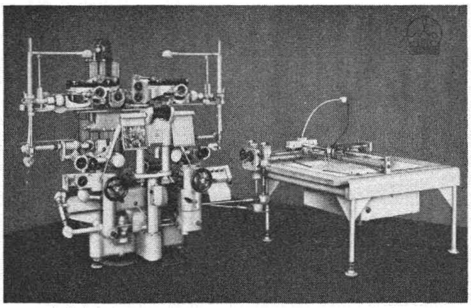


FIG. 6 Zeiss C-8 stereoplanigraph.

dastral operations were started on September 14, 1955. The first order of business was bridging the control across the township by means of aerotriangulation on the 1:27,000 scale photography in the Stereoplanigraph. Complete spatial triangulation between ground-control was established on the area, establishing control points for each model and determining state plane-coordinates thereof. The triangulation and adjusted net were accomplished to the highest order of accuracy possible, based upon the Coast & Geodetic Survey second-order control. It is of interest to note that the first trial run, starting with the quadrilateral on the south end of the first strip, closed on the triangulation at the north end with a six foot error.

Comparative tests made in the Stereoplanigraph with the 1:15,840, 1:10,000 and 1:5,000 scale photography to determine the most practical working approach to the subsequent cadastral operations, gave the nod to the 1:10,000 scale. The complete cadastral survey, then, was accomplished with this photography. Based upon predetermined control from the 1:27,000 scale photography, state coordinates were established for all corners recovered in the field. Coordinates for unfound corners were determined during the process of aerotriangulation, by providing the position of the approximate corner location and a close grid of three to four witness points which are easily identifiable, both on the photographs and on the ground. Points such as small rocks or bushes, stumps, etc., were chosen to permit use as hubs in subsequent field survey operations. Figure 7.

The entire township was surveyed in this manner, resulting in state plane-coordinates for all section and quarter-section corners, section centers, witness corners and sixteenth corners of two sections therein, all of which were adjusted to second-order triangulation "brought down" from the 1:27,000 photography. Computations were completed including bearings and distances from witness points to corners, and on November 7 that phase of the cadastral survey became history.

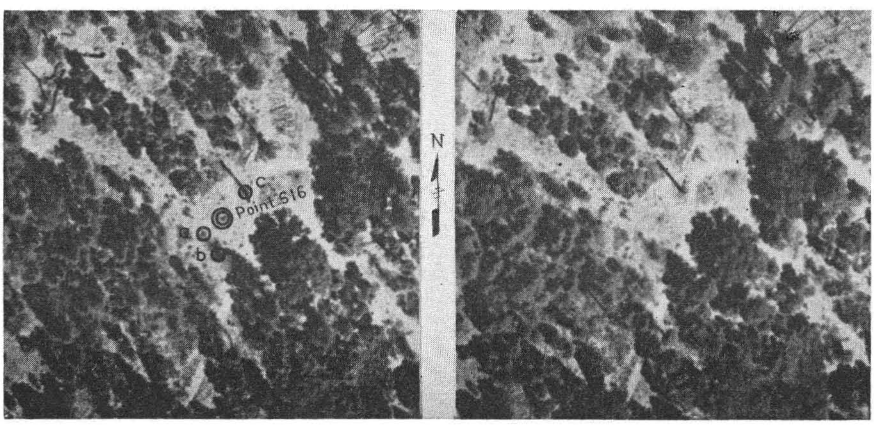


FIG. 7. Stereogram showing point 616 and witness points *a*, *b* and *c* (see Figure 10).

On completion of the Stereoplanigraph operations, the procedure resolved into one of final computations and final field-survey operations. Brought back to the States were the complete data, including a set of C-8 notes, with adjusted state-coordinates for every found corner, nonrecoverable corner and witness corners thereto, centers of sections and sixteenth corners of two sections within the township—all adjusted to the second-order triangulation established from the 1:10,000 photography. Figure 8.

Number	*Y* in Feet	*X* in Feet
610	29,055.7	57,282.8
a	021.4	269.5
b	078.3	293.2
611	27,854.2	55,577.4
a	744.1	598.0
b	811.2	659.9
c	964.6	465.2
612	30,003.1	55,525.7
a	29,922.1	531.7
b	30,000.7	631.2
c	30,014.7	476.3
613	29,972.6	54,138.9
a	969.4	094.5
b	944.3	122.6
c	935.9	165.8
614	28,654.6	53,890.4
a	652.1	909.0
b	669.8	875.7
c	592.2	907.2
d	626.3	849.1
615	29,913.7	52,729.5
a	834.5	728.5
b	884.2	770.4
c	909.9	803.2
616	29,063.1	51,718.2
a	047.4	698.0
b	031.9	712.0
c	091.5	738.2
617	30,076.4	51,869.0
a	075.1	851.3
b	089.1	923.5
c	096.9	867.3
618	31,036.5	51,783.9
a	30,922.6	766.5
b	31,162.8	677.0
c	30,705.1	829.6
619	29,718.2	50,285.9
a	752.0	217.6
b	678.7	222.5
c	702.4	312.5
620	26,285.7	45,603.9
a	335.4	601.8
b	239.0	585.9
c	198.1	668.3

FIG. 8. Tabulation of stereoplanigraph coordinate readings.

CADASTRAL SURVEY NOTES
STEREOPLANIGRAPH C-8 MEASUREMENTS

TOWNSHIP: T 18 N, R 8 E

MERIDIAN: Mt. Diablo

STATE: California

PLANE COORDINATE ZONE 2

SEC. 29
(X indicates corner)

POINT NO. 616 PHOTO NO. R2-L2-26

Description of Point: Point is small bush, west side of road, and on west slope of ridge.

Description of Witness Points

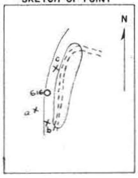
a. small bush

b. small bush

c. tree (no limbs)

d.

SKETCH OF POINT



COORDINATES

Point Number	Y in feet	X in feet	True Bearing	Distance in feet
616	629,063.1	2,251,718.2		
a	047.4	698.0	S52° 43′W	25.6
b	031.9	712.0	S11° 48′W	31.8
c	091.5	738.2	N53° 43′E	34.7
W 1/16 Cor 29/32	628,645.6	762.2	S5° 27′E	419.8

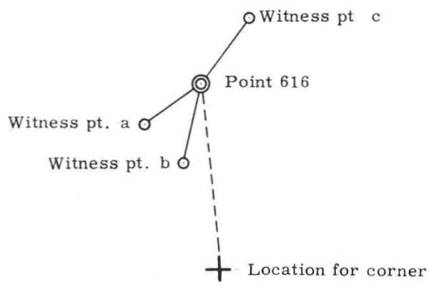
Operator Hampe Recorder King Date 10/10/55 Computed by Cornish Date 1/19/56

FIG. 9. Cadastral survey notes. Stereoplanigraph C-8 measurements.

In brief, operations now boiled down to:

1. The computation of bearings and distances for all witness points. Figure 9.
2. Using survey data of ties from targets to found corners, the computation of state-coordinates of found corners.
3. From coordinates of found corners, the computation of coordinates for unfound corners. (This was performed by the Bureau of Land Management.)
4. The computation of bearings and distances from photogrammetric reference points to points determined as the corner in the preceding operation.

The data here provided are then taken into the field and used as a basis for offsetting the cadastral information by conventional survey methods. Figure 10. This simply entails occupying the photogrammetric reference point, orienting from solar observations or witnessing corners, turning bearings computed from BLM corner location, and monument corners. From state plane-coordinates, compute true bearings and distances for township survey, resurvey, or retracement, Figure 11, and complete final plat.



Set instrument at Point; sight on one witness point (other witness points may be used as checks); turn angle as indicated by computed bearing to corner· measure distance and set corner.

FIG. 10. Locating corner from photo point.

On-the-ground accuracy tests of the Tahoe photogrammetric cadastral survey are presently under way by the Coast & Geodetic Survey, the results of which are not yet known. These tests will demonstrate that attainable accuracy with this equipment and procedure is limited only by the desired accuracy itself, and will be used as a yardstick for determining the course to take for accomplishing specified accuracy results. Whatever may be argued on this subject, there is no question that *insofar as transformed photogrammetric coordinates and coordinates of the same points surveyed by ground methods are concerned, this system and modern, first-order stereoplotting machines are entirely capable of meeting the most exacting accuracy requirements.*

It is no longer a case of "what accuracy can you obtain?" but "what accuracy do you want?" Although even the most practical tests on accuracy can be misleading, since conditions vary greatly from area to area, the findings of the Tahoe test should closely indicate the probable consistent accuracy which can be achieved from the procedure when utilizing dual 1:27,000 and 1:10,000 scale photography of the same characteristics used in this area. *Should circumstances require greater or lesser accuracy of final results, the problem is purely and simply one of either increasing or decreasing the photographic scale, with*

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CADASTRAL SURVEY LINE COMPUTATION

Township: T 18 N/S, R 8 E/W Meridian: MT. Diablo State: California

Plane coordinate zone: 2 Computed by AER Date 6/28/56 Checked by ____ Date ____

	COORDINATES Y in feet	X in feet
Beginning Corner 31/32 6/5	623,291.9	2,250,524.6
Ending Corner 1/4 cor 32/5	623,419.9	2,253,031.9
Difference	128.0	2,507.3
	Latitude	Departure

BEARING

Departure		Latitude		Tan. Grid Bearing		Grid Bearing		Grid Corr.		True Bearing
2,507.3	÷	128.0	=	19.588 281 3	=	N 87° 04' 39".12	±	33' 30"	=	N87-38-10E
				Sin 0.99869944						
				Cos 0.05098454						

LENGTH

$\sqrt{\text{Latitude}^2 + \text{Departure}^2}$		Length in feet				Length in chains
16384.00 + 6286553.29	=	2510.565	÷	66	=	38.039

FIG. 11. Cadastral survey line computation.

corresponding implementation of procedural operations.

Discussion

One could report countless examples of attained accuracy from extensive tests carried out more or less recently by our European neighbors. In Holland, for instance, tests conducted by the Ministry of Public Works gave a difference over 60 measured points of $4\frac{1}{2}$ inches between the photogrammetric coordinates and the coordinates of the same points determined by conventional ground survey. Tests conducted by Zeiss-Aerotopograph in Germany gave a mean differential of 3.6 inches between over 1,000 distances determined by field measurements and corresponding photogrammetric measurements based on flying heights ranging from 4,200 to 6,900 feet. Another example are the figures based on the work of the Swiss Department of Cadastral Survey which show that at a flying height of 3,500 to 10,000 feet above ground, a mean error of ± 6.6 inches is obtained.

So we are really *concerned with the practical realities of the cadastral problem as a whole, rather than attainable accuracy. The latter is strictly routine.*

Our experiences with photogrammetric cadastral survey have taught us—quite frequently the hard way—many do's, don't's, and must's. Attention is again called to the fact, that although the Forest Service is not concerned with unsurveyed areas, *the photogrammetric method* used on the Tahoe test *has many advantages in unsurveyed lands.* With no old corners to hunt, the work is far less expensive and goes much faster. Furthermore, in independent operations, such as in an isolated school-section survey, the technique ideally lends itself to laying out an independent section and setting it in the middle of a township without the necessity of marking on the ground any other part of the township.

Scale of photography depends upon the accuracy required. The working photography, from which the actual survey is made, should be of the scale of 1:10,000 or larger depending on the objectives of the job. It is *essential that photographs be taken with the proper lens, focal-length and scale for the job* at hand. Under no conditions should existing photography be used where there is the slightest doubt as to its adequacy for the cadastral purpose. As in the case of equipment, far too often the attempt is made to use second-order photography for a first-order job, simply because it is available. Decision as to the required photography should be left to the expert in this field—swivel-chair selection defeats the project before it starts.

As is common to all aerial photographic projects, such *film and filters* should be selected as will *most efficiently satisfy the requirements* of the area being covered.

The importance of adequate targets cannot be overstressed. Extreme care must be taken in marking points on the ground, and the chosen type and size of targets should be such as will result in maximum effectiveness in the procedure and equipment employed. Studies are currently being made of the efficiency of the various kinds of targets used on the Tahoe test. Also the possibilities of portable targets for such use are being explored. Only skilled personnel should be employed who know field conditions—target and ground contrast, what size, color and design will best be resolved on the photographs, life expectancy of different targets, wild life conditions of the area, etc. Wherever practical, pre-marking should always be made on the corner itself; where not, precise photo reference points will suffice.

As in any other photogrammetric survey, *advance planning of cadastral operations is of the utmost importance.* Areas as large as possible should be approved for maximum economy. This holds true for both control and photography.

Horizontal control must be of second-order or higher accuracy, and all stations must be of number and placement determined by the requirements of the stereoplotting equipment. In no instance should control be used which was established to meet the requirements of procedures and equipment incompatible with the cadastral method. *Requirements for field notes* are no less than those for the usual ground survey. Adequate notes and complete diary must be maintained.

The importance of photo-identification needs no elaboration. This operation should be in the hands of a skilled photogrammetrist.

The results of the corner-search phase of the job largely depend upon the efficiency and soundness of the closely integrated operations which follow, as well as the project as a whole. *Search for corners is one of the most expensive, time-consuming and important steps in the survey.* Although photogrammetry materially assists in expediting this function, each and every corner is a problem of its own. Only a cadastral specialist with photogrammetric training should be employed for this purpose. It may be well to point out that the current Tahoe testing will provide certain time-consuming data on corner search, but will not provide comparative cost statistics. No amount of testing can give that information for obvious reasons.

Ties to corners should never be made by running stub, or open-ended, lines from reference point to corner. They should be instrumentally closed traverses. No compass. The procedure of using witness corners for azimuth is favored over solar observations.

Photography, when taken with the new Topar lens, or one of similar characteristics, not only can but *should take advantage of days when skies are overcast* This serves the dual purpose of eliminating shadows and increasing the probable photographic flying days to as much as 50 per cent on many projects. It is *essential that long focal-length lenses be employed on areas in which stands of large timber are predominant.*

We are thoroughly convinced that, for sound management use, it is a stern fact that the *state plane-coordinate system is essential* to effectual over-all operations. Obviously, however, satisfactory results will be provided by any convenient system.

A real problem exists in present methods to reference corners. The practice of blazing and scribing trees for witnessing corners belongs back in the horse and buggy days. It is incredible that this procedure is still accepted today. Trees die and are lost or are burned over or are logged over. Such reference marks are highly unsatisfactory. Cadastral reference corners hold just as much significance and importance as those required in referencing high-order control, and these points should be established with similar technique and precision. Various methods to reference corners are being studied, such as the use of buried metal which would be recoverable by dip needle. A second problem is that of land corners being destroyed by Federal, State and private contractors during the operations of various construction activities. Though some of this is naturally unavoidable, a lot of it is occasioned by carelessness and disregard of the importance of these corners. *Adoption of the use of state plane-coordinates for location of corners will go a long way in resolving the problem of restoration of disturbed or destroyed monuments.*

It is significant to note that in the photogrammetric cadastral survey procedure, when running boundary between corners on the ground or marking line, it is *unnecessary to mark the entire township*—mark only as needed. Monumentation of land corners must be executed in accordance with governing state and federal laws. A word of warning in this respect:—private engineers are not authorized to monument corners except under the advice and direction of a licensed land surveyor or the Bureau of Land Management, depending upon the jurisdiction involved. Cadastral surveys on Public Domain lands must always be made by the Bureau of Land Management, or if on lands which have passed out of Public Domain, by a state licensed land surveyor. The latter holds true whether the surveys are executed by the government or by contract.

A quite serious situation is reflected by the acute shortage of cadastral engineers. Due to the complacency and the thinking of some people that we have long been on top of the land survey problem, *the cadastral engineer is practically non-existent. The modern approach requires* a new kind of cadastral engineer—*one with training along photogrammetric lines.* Photogrammetry makes use of other skills and abilities to cope with our land survey problems, and it is no longer necessary for the land surveyor to carry the whole cadastral load. The aerial survey sets him free to devote the proper time and effort in the field of his speciality.

Cognizant of the ever mounting problems of land ownership in which the interests of both government and individual are so closely integrated, and the continued inability to keep pace with them, the unquestionable answer to these problems offered by the use of photogrammetry in cadastral survey firms up our thinking into a definite pattern.

This pattern takes shape in the form of a *joint undertaking by* the *Bureau of Land Management, state licensed land surveyors* *and the Forest Service.* For the immediate present, and until we can get on top of the land ownership situation, the responsibilities of the major functions of the procedure would be spread in accordance with the authority involved, and according to the availability of the required qualified engineering personnel. The responsibility for all operations relevant to corner search, verification of the positions of non-recoverable corners and corner monumentation is, of course, in the Bureau of Land Management; all other operations in or adjacent to National Forest lands are the responsibility of the Forest Service.

This is our present thinking and we are convinced that it is sound. However, the attractiveness and ideal applicability of the method to contractural arrangements must be given serious consideration. The weaknesses and objections so prevalent in contracted cadastral surveys, executed prior to 1910, are not a factor in the present technique, as it can be readily seen that a rigid finger can be kept on all operations of the aerial survey at all times. In the interest of time, efficiency and economy the possibility of contract must not be overlooked.

Whatever direction the wind blows, however, we can no longer plod along on the ground with a chain, when photogrammetry can do the job with more accuracy and with half the cost and time.