Aerial Mapping in Areas of Heavy Ground Cover

IRWIN STERNBERG, District Location Engineer, Department of Highways, Tucson, Arizona[1]

This is a discussion of a study begun by the Washington State Highway Department for the purpose of investigating possible methods of securing large-scale aerial mapping of high accuracy in areas of heavy ground cover.

The paper covers work performed in the Fall of 1955 with the assistance of K. B. Wood and Associates of Portland, Ore., by means of mobile plotting equipment set up in the immediate vicinity of the area to be mapped and a small field crew equipped with portable radios in constant communication with the mapping unit so as to furnish necessary spot control as needed during the compiling operation.

● PRODUCTION of a large scale aerial contour map to an acceptable degree of accuracy is not a complex problem in an area where little or no ground cover is encountered. By use of modern precision equipment, proper "C" factor, competent operators, and with strict attention to weather conditions, it becomes a comparatively simple matter to obtain the accepted standard accuracy of a maximum one-half contour interval variation in 90 percent of the contours plotted.

However, with all methods in use at the present time it is necessary to be able to see at frequent intervals the actual image in the photographs, of the ground to be mapped in order to obtain a degree of accuracy agreeing with or comparable to the above.

Where there is heavy ground cover, such as is encountered in the heavy coniferous forests of the northwestern United States and in similar regions, the ground is completely obscured over large areas and assurance of attaining the above degree of accuracy becomes increasingly less as the density and area of the timber cover increases. The fact that these forests are predominantly evergreen minimizes any advantage gained by photographing the area when trees are bare of leaves.

Frequently such heavily timbered areas are precisely those where accurate, large-scale contour maps are desired. Consequently a number of methods have been proposed and tried, but so far few if any whereby a high degree of accuracy could be definitely assured.

The most common of these methods, by estimating the height of cover and making the proper correction during plotting operations, is at best only approximate. A degree of accuracy to approximately one-half the height of cover is all that can be expected. Any attempt to secure greater accuracy by this method usually does not materialize. Where trees are of heights reaching 100 ft and more and, particularly where these heights vary considerably, such accuracy is, of course, of little value for the purpose for which the maps are generally desired.

Attempts to secure a greater degree of accuracy by actual measurement of cover in the field and measurement by photogrammetric methods during the plotting operations have generally failed due to inability to secure accurate data in sufficient quantity to serve the purpose.

There has been considerable experimentation along various lines by some of the larger aerial survey organizations to solve this problem satisfactorily, such as by using extended stereoscopic coverage, utilizing sun angle with shadow images, making

[1] Formerly, State Location Engineer, Department of Highways, Olympia, Washington

multiple flights, varying flight height and other methods all of which are efforts to more accurately measure height of cover or to increase the number of points where true ground images can be seen. Various degrees of success have been realized, but generally where heavy ground cover occurs weather conditions are poor, resulting in considerable delay in securing the necessary additional photography of a quality necessary to attain these results.

In the northwestern part of the United States, particularly in the coastal areas, many factors offset accuracy besides the timber problem. The principal one is the limitation of good flying weather. Heavy fogs along the coast obscure the terrain for long periods, rains are frequent and sometimes of long duration, low cloud formations are of frequent occurrence. In addition, precipitous canyons and high, sharp ridges cause extremely varied lighting conditions with accompanying heavy shadows even at noon.

The combined result of heavy timber and brush cover with adverse lighting conditions often results in photographs with less contrast than is found under more favorable conditions.

Two or more flights over the same area at different times of the day will frequently minimize heavy shadows in canyons. This method, however, requires the setting up of separate stereo-models and it also fails to a great extent where canyons run almost due east and west, which they most frequently do in the west coastal area.

It appears then that a logical approach to this specific problem is a method whereby stereo-compilation, combined with supplementary field control during and in conjunction with the actual compilation process, can be developed.

At the suggestion of Mr. K. B. Wood, president of K. B. Wood and Associates of Portland, Oregon, an experimental project was set up by the Washington Highway Department in the Fall of 1955 in which stereo-compilation would be brought into close coordination with field mapping. As Washington has no photogrammetric equipment of its own it was necessary to negotiate with Mr. Wood to perform the necessary work in connection with this experiment. Mr. Wood had done considerable work for Washington in the past and was himself concerned with the lack of accuracy obtained in this type of terrain with the usual methods of mapping. An area was desired which would impose problems of adverse condition both as to character of terrain and heavy forestation whereby the above methods could be fairly evaluated.

The site selected was immediately south of the Snoqualmie National Forest in Lewis County, approximately 12 mi west of Morton. Twenty-five percent of the area was covered with a 200 year old stand of virgin Douglas fir timber, 50 percent with a dense stand of alder in combination with an understory of heavy brush, and 25 percent was open fields. It was considered desirable to have part of the area in open fields for a direct comparison of accuracy. The area was cut transversely by a steep-sided canyon running almost due north and south and approximately 300 ft deep. In addition the Tilton River, a precipitous stream, about 100 ft wide, ran in an east-west direction through a canyon some 400 ft deep along the south edge of the strip to be mapped.

It can be seen therefore, that the area selected was a difficult one to map—perhaps too difficult as far as terrain was concerned—but the extent and variety of cover was ideal for the purpose in mind.

Secondary State Highway No. 1-K traverses the northern third of this section throughout its length and afforded easy access to the area. It was also a help in expediting primary control by transit traverse, which was considered desirable for this particular problem. The control was made at third order accuracy and was tied directly to the Washington Coordinate System which is based on the Lambert Grid. The strip, varying from 2,600 ft to 4,000 ft in width and 4¼ mi in length, was mapped at a scale of 1 in. to 200 ft with a 5 ft contour interval. The extent of the area covered was 2.54 sq mi or 1,622 acres.

The following procedure is taken directly from Mr. Wood's report which he submitted on completion of the project:

"In order to obtain the best possible coordination between stereo-compilation and field completion work, a three-projector multiplex machine was set up in a 24-ft

steel trailer, equipped with 2-way radio so the multiplex operator could be in immediate touch with the field crew for spot checking areas on the photography where interpretation was difficult. In this manner also the compiler was able to operate as an office engineer for assembling and combining field sheets where ground mapping was accomplished. Consequently his time was fully utilized, even though the field work lagged behind the stereo-compilation operation on many occasions. Work was started in the Fall of 1955, and completed in January 1956. The weather during the course of the operation was typical of fall and winter west coast conditions, with a good deal of rain, some snow and some extremely cold weather.

Detailed procedures were as follows:

1. Aerial Photography. The area was flown in two separate strips at a scale of 1:6000, with a 6-in. precision mapping camera.
2. Ground Control. Ground control consisted of traverse run through the center of the area tied to primary traverse station 46, Washington 1912 on the west end, and tied for azimuth only by solar observation on the east end. Attempt was made to run the traverse not along existing roads, but through the center of the heavily timbered area, giving additional tie-ins for field mapping. Levels were run along the existing highway and closed in a loop back along the bottom of the Tilton River, giving good wing point control for levels and also tie-in points at numerous spots for field work. Levels were also run along the traverse, providing a vertical tie in the center of the project.
3. Aerial Triangulation. Prior to going to the field the project was set up on a multiplex long bar and the entire project was extended. Although scale points existed from field work on almost every model, it is usual procedure with this company to run through stereo-triangulation on multiplex in order to check the picture pointing and to set up additional scale controls on every model.
4. Compilation. On November 25, the portable multiplex unit and the compilation crews, consisting of four men, went to the field and a set-up for the portable unit was found where good communication was available to all parts of the area. The timber and ground cover conditions logically caused the work to fall in three categories:

a. Open fields and areas where 100 percent stereo-compilation was possible. (This work could have been done at the office plant in Portland.)
b. Areas where exact interpretation of the ground was extremely difficult. The usual procedure in these areas was to stereo compile the entire area, dropping good scale and vertical points on good photo image points on the ground for tying in field work. The field crew would then run strips between these points, correcting the topography where the stereo interpretation was in error. In other areas, field strips were run prior to the compilation and the photo compiler would use the field strips for orienting and adjusting his interpretation of the ground.
c. Areas of 175- to 200-ft timber. In these areas no stereo work whatsoever could be done except to drop points along the edges of the area for purposes of tying in the field mapping.

The field work was done by use of a staff compass line between either photo control points or ground control points. For distance, the chain was used in some cases and other cases where the distances between controls were not too far, a Wild range finder was used and the distances adjusted on tying into final control. An Abney level was used for purposes of carrying levels on the field strips. The accuracy of this type of field procedure was found to be within map accuracy wherever the distance between tie-ins, either to photogrammetric control or ground control, was not in excess of 1,500 ft.

Because of the unusually bad weather conditions, in most cases field sketching was not done. A set of field notes with spot elevations was carried in the field book and the topography plotted and interpreted from these field notes. There is no question but that the work could have been done more rapidly and possibly with slightly better accuracy, had field sketching been attempted. However, with continuous rain and

snow, it would have been very difficult to maintain a sketch board in the field for a very long interval of time. The stereo-compilation work was completed on January 10, 1956.

5. Drafting. Drafting in accordance with standard State of Washington specifications was undertaken as soon as the compilation work was completed, and the work was delivered to the State of Washington on January 20, 1956. The cost of undertaking this work was, of course, excessive because of the fact that it was an experimental operation. Numberous procedures had to be developed, some of them retained and some of the rejected. In terms of man-hours, a total of 1,228 man-hours of work was expended on the job. This can be reduced to 289 man-hours per lineal mile, or 484 man-hours per square mile, for obtaining representative results. Due to the extremely rugged nature of the terrain and extreme brushiness of the project, strictly standard map accuracy was not obtained on the job. A total of 7 profiles were run by the State of Washington on the project, and the results of these profiles are as follows:

Accuracy results testing topography (based on 226 measured points on seven independent profiles):

Mean error	2.42 feet
Maximum error	9.00 feet
90.7% within	±5 feet
71.8% within	±2.5 feet

The interesting thing to note in regard to these profiles is that there is very little difference in accuracy between the relatively open semi-brushy areas which were done primarily with stereo-compilation, and the heavily timbered areas which were done primarily with fairly crude field methods. It is felt by this company and others with experience in the northwest timbered areas, that under conditions such as these, results better than this are almost impossible to obtain. It is also difficult, even in field work to ascertain in some places exactly where the ground is. Those who are familiar with west coast conditions realize that in walking on the ground one is often walking from two to five feet above the ground, on old windfalls and brush piles. A precise delineation of the mineral soil profile prior to a clearing operation, in many cases, is virtually impossible."

Cost

Cost of preparing maps on this one section ran approximately double what it would have cost using standard methods of computation. Somewhat cheaper costs could be expected on a larger project, and during a more favorable period of the year.

The actual cost of photography, preparing the maps, tying the primary control to the Lambert Grid, and all necessary supplementary field control, was $7,768.86 for the the 2.535 sq mi covered. To this should be added $1,650.00 spent by the state for test profiles, making a total of $9,418.86. The cost per square mile was $3,715.53 or $2,216.20 per lineal mile for a strip averaging 3,000 ft in width.

Projects over similar terrain mapped by regular aerial survey methods ran considerably less, but these were all to such a dubious degree of accuracy as to be worthless except for reconnaissance purposes. A fair estimate of performing this same work by usual aerial survey methods would be about $2,000 per square mile exclusive of the supplementary cost of checking. This is approximately one-half of the actual cost per mile of this experimental section. It should be remembered too that this was an isolated project of small size. Understandably such a project would cost considerably more per mile than one five or ten times as long.

Conclusions

Mr. Wood's conclusions as regards to possible accuracy that could be obtained over this particular area are concurred in by the writer. In other areas of less rugged terrain, or with a more uniform ground suface and with more refined methods of field work, a greater degree of accuracy might be attained.

It can be said that the primary objective of this survey, which was to obtain close coordination between stereo-compilation and field completion, was obtained. Many kinds of combinations in field and office work were easily possible to work out under these conditions. The use of two-way radio between the office and the field was not used as much as originally anticipated. Inasmuch as the compilation office was within a mile or two of the field operation, and the field crews checked in at noon for lunch at the compilation office, frequent contact was easily possible without the use of the radio. It was also found that the packing of a two-way radio in some of the brushy areas was sometimes excess baggage, although in other cases it was very desirable from a safety point of view.

Perhaps the most important principle learned in the course of this job was the need for the training of specialty men, both in compilation and in field work on this type of terrain. Those who are not familiar with northwest terrain and brush conditions cannot always understand this problem. Some engineers, with the proper training, can get along well with caulked shoes and conduct reasonably accurate engineering field operations. Others are simply not adapted to these conditions and are not suited to undertake this type of work. There are many places on this type of ground where the slopes are in excess of 75 percent, and the brush cover is such that a man cannot see more than ten feet in any direction. It is necessary also for the field crews to get over all of the ground in such areas, as there are many hidden draws and hidden springs, benches, cliffs, etc., which cannot be discerned from aerial photography, yet they are very critical from a design point of view.

The method shows promise and deserves further experimentation. It has proved to be one method whereby an aerial map of useable accuracy can be assured over difficult terrain and where heavy ground cover is encountered.

The area selected was extemely difficult to map under any condition and with any method. Without doubt, refinement of method, a more favorable period of the year and an area of greater extent would cut the average cost of mapping on this basis an appreciable amount.