of the maps have been published. It is felt that the data being obtained will be extremely valuable in timber, range and watershed management, assessment, and other uses.

So far there has been considerable demand for the maps produced by the Survey. Within the National Forest areas, the Regional Office and the individual forests have put the work maps to use in preparing working circle management plans, land exchanges, etc. Several private individuals and companies have put the Timber Stand maps to work in connection with sampling for volume estimates, preparing management plans, locating logging roads, and many other uses.

In concluding this discussion of the Forest Survey activities in California, I might re-emphasize the fact that the whole sampling system and production of maps is based on the use of aerial photos. In addition, the photos are used extensively in the field by both the plot sampling crews and the field mappers, as a means of orientation and to facilitate all phases of the field work.

THE USE OF AERIAL PHOTOGRAPHS IN TIMBER CRUISING ON THE NATIONAL FORESTS*

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AERIAL photographs are being used more and more in timber cruising work on the National Forests. Before going into further detail, however, I should like to present some of the background which, from technical and administrative standpoints, affects and sometimes limits the use which we make of aerial photos in cruising work.

From 75 to 80% of National Forest lands in the Pacific Northwest are covered with vertical, single-lens aerial photographs, and this photography is available for our use. This coverage has been accomplished by a number of agencies. It varies considerably in age, quality, and scale. Scales range from 1:40,000 to 1:10,000 with the bulk being 1:20,000.

As necessary and as funds permit, this existing photography is being supplemented by rephotographing the older inferior coverage and by undertaking new coverage. We customarily contract our aerial photography to private bidders.

The Pacific Northwest Region of the U. S. Forest Service, with headquarters in Portland, embraces 19 National Forests located in Oregon and Washington. For timber management purposes, for planning and for making and administering timber sales, the 19 forests are divided into 92 management units called working circles. Twenty-nine of these working circles are located in the ponderosa pine subregion east of the Cascade Summit, and 63 are located in the Douglas-fir subregion on the western slope. Within the 92 working circles, there are nearly 14 million acres of forest land on which the available annual allowable cut is nearly 2.5 billion board feet. Our actual cut, which has been generally increasing as transportation systems are extended, is now around 1.5 billion board feet. After advertising, an individual timber sale is awarded to the highest bidder. Each year we are now making approximately 2,500 individual timber sales.

Obviously the amount of timber resource involved and its importance to the economy of the Northwest calls for considerable planning which in turn

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must be based on inventories of sawtimber volume and growth predictions for each working circle. Also, in advance of advertising, each individual sale area must be carefully planned. Thus the timber survey work on the National Forests divides itself naturally into two general kinds: surveys for management plans, and surveys for timber sales. I shall now proceed, therefore, to divide part of my paper between these two general kinds of surveys.

MANAGEMENT PLAN SURVEYS

For a given working circle, these surveys are aimed at providing the information necessary to predicting growth, computing allowable annual cut, preparing a cutting budget, planning the location and sequence of sale areas, etc. In their simplest form these surveys provide the following items:

1. A forest type map of the working circle.
2. A site quality map of the working circle.
3. A sawtimber volume estimate for the working circle.

The question is: How can aerial photos be employed in gathering this information? To begin with, a management plan survey would not be undertaken unless complete coverage of the working circle is available in usable photography on a minimum scale of 1:20,000. Oftentimes it is necessary for us to initiate new photography or rephotography of projects to achieve suitabe photography.

Presuming that photography is available, contact prints of the project are assembled for field use. When circumstances permit unrestricted choice, we prefer that these prints have semi-matte finish and that the paper have a grain or "bite" which facilitates writing with colored pencils and erasure on the photos, without indenting the emulsion.

The so-called "effective area" of each photo in the project is delineated on each photo. We customarily use each photo in our work, splitting the overlap and side lap between adjoining photos. The lines formed thereby bound normally a rectangular area which includes the central portion of each photo and which we refer to as the effective area of that photo. By using all photos as instead every other one, we feel that we are assured of better results because our work is confined to the minimum central portion of each photo where distortion and error due to topography, tip, and tilt are a minimum.

Obviously the effective areas of some photos will be partially outside the working circle. On such photos the boundary line of the working circle is precisely drawn under mirror stereo viewing, by drawing lines along the topographic features, such as rivers, roads, etc., which often form the boundaries of management units. Sometimes land lines form such boundaries, and in such cases it is necessary to sectionize the photos in order to delineate the project boundary.

Forest type lines are next marked on that portion of every effective area which is within the project area of the survey. In doing this, the aim is to delineate every contrasting type which is 10 acres or more in size. All of each effective area that is within the project is delineated. This assures the entire working circle being systematically typed during the course of the work. Type lines on one photo are drawn only to the effective area lines where they match with type lines drawn on neighboring photos, which in turn are drawn only to their respective effective area lines.

We regard the job of delineating forest types on aerial photos as a combination office and field job. The forest type classification scheme which we now

employ recognizes three factors: (1) Stand size class; (2) Species combination; and (3) Density of stocking. Sometimes all three items can be satisfactorily interpreted in the office from the photos, using lens stereoscopes, but most of the time we must supplement the office work by observations made in the field. In effect, the results of our practice are that we go as far as we can in the office—to the extent that the quality and scale of photography and the complexity of the stand will permit. Sometimes this resolves itself into a matter of delineating all contrasting conditions in the office by putting lines on the photos between different stand size classes and density classes, and then with photo in hand we visit each such delineation on the ground, to complete the forest classification by observing species composition. When pure stands are involved, such as lodgepole pine or ponderosa pine, we can quite reliably identify forest types completely by photo interpretation alone.

Quite often contrasting conditions which are delineated on photos in the office do not turn out to be changes in forest types when observed in the field; instead, they are found to be due to changes in site quality. While in the field completing our identification of forest types, we customarily make height and age observations, so that each type delineated can be classified as to site quality. As you well know, site quality can be accurately determined in any one sample tree, but to map site quality is something else. To meet this problem we have resorted to the trick of letting forest type lines be the boundaries of site quality classifications. A given type may comprise more than one site, but as has been mentioned, when changes in site are sudden, the line of delineation is identifiable on the photos, and the type can be accurately split into two or more site quality classifications. When changes in site are gradual, we of course must use our best judgment in defining limits.

How do we get at the problem of securing board-foot estimates of sawtimber volume? We have a dual need in this respect. First, we want a volume estimate for the working circle which has known reliability as far as sampling error is concerned. Secondly, we want the volume estimate to be broken down as to locality within the working circle, or in other words, we want "in place" estimates.

We employ statistical theory to compute the number of sampling units which we must cruise so as to obtain a volume estimate which in two times out of three will be $\pm 5\%$ of what we would have obtained if we had made a 100% cruise of the working circle. We have arbitrarily agreed that a sampling error of 5% based on one standard error per working circle is tolerable.

In order to select the sampling units and to locate and go to them on the ground, we employ aerial photographs. All photos whose effective areas contain a portion of the working circle, and which by photo interpretation are judged to contain sawtimber, are chosen and numbered consecutively and put in a pile. Then by lottery a photo is drawn and taken from the pile. A transparent dot grid is then imposed onto the effective area of this photo, and by lottery again a dot representing a sampling unit is selected. If the dot falls in sawtimber, it is pricked and labeled as a sampling unit location. If it does not, the photo is returned to the pile. This procedure is repeated until the required number of sampling units are pricked on the photos.

In order to travel to a given sample unit location on the ground, the cruiser takes the photo and goes to some reference point, such as a road junction, stream junction, or a single tree in a meadow which is identifiable both on the ground and on the photo. At the location of the reference point, he obtains from the photo a bearing and a distance to the pricked sample unit location.

Then by following a compass course and pacing, he goes to and cruises the sample unit. In actual practice the job of going to sample units and of completing the forest type classification work on the photos is done concurrently in the field. In addition, concurrently with both these jobs, the cruiser follows the practice of making ocular estimates of stand per acre for each island of sawtimber which he had delineated by his forest type classification work. This is the trick employed in order to secure the so-called "in place" estimates. Admittedly, the job of making ocular estimates is subject to error, but the results are surprisingly effective and useful in management planning.

When all this field work is completed, the type-site density delineations that have been made on the photos are transferred by various plotting devices to a 2-inch to the mile planimetric base map which has been prepared from the aerial photos. On this map, the type delineations appear in reasonably accurate size and shape so that areas can be determined and type acre statistics compiled for the working circle. In turn the total acres of sawtimber obtained thereby are used to expand both the volume estimate obtained from sampling, and the volume estimates obtained by making ocular observations. The sum of the ocular estimates is then compared to the working circle estimate obtained by sampling, and if the two differ by more than the sampling error, each "in place" ocular estimate is adjusted proportionately until the two volume figures are in balance.

TIMBER SALE SURVEYS

The second kind of timber survey to which I have referred is our so-called "sale surveys." The aim of these is to provide the necessary information for making and administering timber sales. The typical items required as the result of such surveys are as follows:

1. Volume estimate of timber to be cut.
2. Log grade recovery estimate of timber to be cut.
3. A map of the area showing topography, sale boundaries, cutting unit boundaries, proposed and existing transportation routes, forest types, etc.
4. Stand structure information for use in determining methods of cutting.

Aerial photos are invaluable to the field man as a scouting tool for use in making preliminary plans for a sale. By being able to observe forest types, topographic features, etc. on the photos, a lot of arduous and time-consuming foot travel can be saved in the process of planning a prospective sale. Other than this, the greatest single contribution of aerial photographs to sale surveys is through their use in preparing topographic base maps of the sale areas.

The kind of plotting equipment available to us, and the usual scale of photography which we have at hand permits us to provide 4-inch to the mile maps showing 25 or 50 foot contours. In exceptional cases on proposed sales where topography is very difficult and where it is a limiting factor in logging, such maps are not always adequate and we must resort to ground procedures in order to get more detail on larger scales. In addition, we must continue to use ground techniques wherever our aerial photo coverage is inadequate or missing. Nevertheless, we are doing a lot of sale area mapping each year.

You have perhaps noted that in describing our cruising work, no mention has been made of an attempt on our part to estimate timber volumes directly from photos. I wish to enumerate some of the obstacles to our doing this:

1. There are a number of things to secure for which we must go into the field.

Therefore, direct volume estimates would save us very little. We must usually go into the field in connection with our surveys to complete the forest classification as to species composition, to secure log grade information, to secure stand structure, etc.

2. We need estimates by species, and, in complex mixtures such as occur in the Douglas-fir subregion especially in southern Oregon, the various species cannot be successfully identified on photography which is mostly on a scale of 1:20,000.

3. Net volumes are needed as a result of our surveys. In many locations we have defect and cull factors which sometimes amount to as high as 50% of the gross volume. We cannot judge cull and defect from photos.

4. The crowns of some sawtimber size trees are below the general canopy of the forest; therefore we cannot secure reliable tree counts from aerial photos.

5. Our stands are so dense, especially on the west side, that we cannot see the base of trees; therefore we cannot reliably determine tree heights by measuring shadows or by using the parallax wedge method. A complicating factor in this regard is the fact that most of our area involves mountainous terrain which in turn results in tremendous changes in photographic scale within short distances on a photo.

6. We have no evidence that there is a close correlation between crown width and tree volume in most of our conifers.

7. We are a far-flung organization employing hundreds of men who must do their work in extremely variable conditions. Training in photo mensuration techniques would be a big job.

CONCLUSION

In closing I wish to say that for us the possibilities of estimating volume per acre for photo delineations of stand size density classifications seem to offer more opportunity than attempting to secure the volume of individual trees. We regard this as a possibility only for types which are comprised of one species of low uniform defect. Lodgepole pine stands may be susceptible to this kind of treatment.

USE OF AERIAL PHOTOGRAPHS IN THE INVENTORY PHASE OF THE FOREST MANAGEMENT JOB*

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IN THE past ten years there have been tremendous advances made in the use of aerial photographs in the forestry and engineering fields on the West Coast. At first, aerial photos of forested areas were a curiosity, but soon their utility for reconnaissance purposes was recognized. Foresters then began using them for forest typing and topographic mapping; and before long we probably shall see them used in what may well be their most intensive forestry use, photo-cruising.

The theme of this meeting has been particularly interesting and encouraging. Speakers have stressed what has been and is being done with the aerials, rather than relating nebulous thoughts of what is supposed can be done with them. This approach is especially valuable in establishing faith among the industry, and should lead to greater use of aerials in connection with forest properties.

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