PHOTOGRAMMETRY AND FOREST TAXATION

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INTRODUCTION

THE use of aerial photography in conducting forest inventories is by no means a new topic for discussion. However, new techniques and combinations of techniques and equipment are being developed to meet special situations. The purpose of this article, then, is to outline a new method used in the appraisal of forest property, and to bring it to the attention of others who may have to meet a similar situation.

THE SITUATION

Along with other real property in Oregon, there are several million acres of privately owned timberland, which are subject to ad valorem taxation by the State and Counties. During past years, the assessment of this timberland has been based either on a county cruise, a hasty reconnaissance, the personal knowledge of the Assessor or upon arbitrary rates per acre. These assessments have often remained static on the tax role for several decades, with little adjustment other than for depletion or for blanket changes in values, which were usually applied to all property. In those same years, the immature stands grew to maturity and became valuable, and unmerchantable species at the time of the county cruise took on value with the changes in utilization standards. But the assessed values remained as of old. Why haven't these values been adjusted to fit the changes in the forest stands? The chief reason is that the counties didn't have, and still don't have, the trained workers nor the funds to hire commercial firms to conduct periodic surveys of the timberlands. The situation, then, has grown into the need for an accurate, low-cost method of making an inventory of private timberlands for ad valorem taxation.

REQUIREMENTS OF THE INVENTORY

The first considered and often the most important requirement of the inventory is that it be accomplished at low cost. This is of prime importance to the budget board of most counties who have to cut expenditures to satisfy the public and yet provide for the necessary civil functions. The second requirement concerning the method is that it be completed in as short a time as possible.

From the viewpoint of the technician, the most important requirements are those of accuracy of results and practicability of operation. Any inventory of timberland in Oregon can hardly escape covering very rough country; therefore, the method must be practical and must yield results with accuracy in keeping with the resource being inventoried. Accuracy must be obtained in locating ownership lines with respect to the forest resource, and in measuring the acreage of various land classes. This coincides with the first need of an appraisal for taxation, which is a determination of the location and extent of the property to be appraised.

DEVELOPMENT OF THE METHOD

Upon investigation of the several means available, it was seen that the use of aerial photography would provide a method to meet all the requirements. Consideration was also given to the fact that aerial photos in themselves would not

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provide all the answers, and that they had limitations and disadvantages. A program of study and experimentation was then set up, and the various types of equipment, photographs, materials, and techniques were worked with until a reasonable line of action was developed. To see how the method would stand up under actual conditions, a small project area of 20,000 acres was chosen and the inventory steps worked out completely. From this school of hard knocks was derived the basic techniques and the method which is described on the following pages.

THE METHOD

The process developed is, in brief, one of constructing a new base map with field survey and photogrammetric techniques, transferring planimetric detail and timber type outlines from the photos to the base map with a plotting instrument, and finally making volume estimates from field measurements and the aid of the photos. The trial project brought out the fact that the photos used must be contact prints of vertical photography at about 1:12,000 scale, and that the principle of radial triangulation must be used in making the planimetric maps. Details of the method are as follows:

PROCURING PHOTOGRAPHIC COVERAGE

In keeping with the economics of the situation, photographic coverage has been secured by cooperation with private individuals and with State and Federal agencies, and also by letting contracts to aerial survey companies. In many cases, prints from negatives owned by the Forest Service, Soil Conservation Service, A. A. A., Army Engineers, etc. are purchased, when they are of recent date and of suitable scale. It has been found in this type of work that it would be more profitable to contract for new coverage than to use available photography which is over two years old. The cost of additional field work in using old photos more than makes up for the cost of new photography.

Procurement of coverage by contract with a flying agency is governed by detailed specifications written into the contract. These specifications include date and time of flight, direction of flight, altitudes, type of film and camera, lens length, side and end overlap, allowable crab and tilt, photographic paper, method of printing, flight indexes, time extensions, penalties and many other details necessary to a successful contract. In any case it is more necessary to get good quality coverage than to save in costs. It is also more important to have full area coverage than to cut costs by omitting small areas. The omission of small areas will cause more troubles in securing survey control than would be saved in photo costs.

THE PHOTOS

The desirable photos are taken in parallel flight strips with an average of 60% end lap and 25% side lap, with no more than 3% tilt. Photos from a camera with 12 inch lens and between-the-lens shutter are necessary. Use of a 12 inch lens is desired since it produces photography with less distortion, and because the photos are to be used only for planimetric mapping. The photos are taken at a flight elevation over the ground surface which will yield an average photo scale of 1:12,000. Often this means that the elevation of portions of flight lines or of different flight lines must be increased to get the proper overlap and scale over high ridges and mountains. To be suitable for the combination of survey and forest inventory work, the photos must be made when shadows are the shortest, when there are no clouds or other atmospheric interference, when there

is no snow on the ground, and when conditions in general are the best for photo interpretation. Panchromatic film is used with whatever filters are necessary to aid in cutting out atmospheric interference; there has been no opportunity for experimentation with film-filter combinations. The contact prints are made on double-weight water-proof paper of as many contrast grades as necessary to produce photos of uniform contrast and tone. Waterproof paper is used because it has smaller dimensional changes in the printing and drying process, and because it will stand field conditions much better than the matte or semi-matte papers. It is used in double weight for the same reasons. Since for economy sake, one set of prints is used through all the field and office work, the prints must be durable and be treated with care. One trouble has been experienced with the waterproof paper and that is the peeling of the emulsion around the edges of the photo. This has been overcome by placing binding tape around the edges of the photos.

PRELIMINARY STEPS WITH PHOTOS

To save time in later steps, the photos are first grouped by square township areas, and the township and range designation are lettered on each of them with waterproof ink. They are then placed in township file pockets and arranged geographically. The principal point and conjugate principal points are marked and encircled with red waterproof ink. This is not absolutely necessary, but it makes the photos easier to use in the field in picking control points and survey markers. Many times, a small index of the placement of photos by flight line and photo number is made for each township. This aids in the use of the photos until the worker is thoroughly familiar with them.

THE GROUND CONTROL NET

The purpose of the ground control system is to provide a network of accurately located points which serve as tie rods to fasten all the survey area together. The location of all points is known, and the distance between them is calculated; by having these control points, all distances and areas between and among them are held to a constant scale in transferring photo detail to a base map on which the control points have been plotted. The control points may be triangulation stations, traverse stations, public survey markers or any extension or combination of these systems.

In order to save the expense of running survey lines, the survey notes and data of all sorts have been gathered from other agencies. These agencies include the U. S. Coast and Geodetic Survey, U. S. Geological Survey, U. S. Army Engineers, all branches of the U. S. Department of Agriculture, State Highway Commission, County Engineers, power companies, railroads and many others. Control on a recent project, covering 500 square miles of timberland, was secured from the survey run by the State Highway Commission in locating two major highways, from triangulation points set by the U. S. Geological Survey and by a little triangulation and traverse run by the men doing the work. The cost of securing control on this job was but a fraction of what it would have been if data had not been collected from the other agencies. One of the cheapest methods of securing control has been found to be by running transit-stadia traverse. This method is suited to the rough terrain and conditions encountered, and fits the standards of the inventory. Considering the instruments, the element of time, the money available and the requirements of such a forest inventory, it is felt that a map which locates features within 50 feet of their true ground position is entirely satisfactory.

The number and placement of the control points is that necessary to hold a slotted-templet layout to its true position. This means, in general, that a control point is necessary at each end of each flight line, and at a few locations along the edges of the area. Control point location is modified to fit the shape of the area, the terrain, present surveys, direction of photo flights and other conditions as they arise.

As the ground survey is conducted in the field the control points are marked on the photos. This brings up a rule-of-thumb which is that all control points must be placed where they can be positively identified on the photo. The points are marked on the photos with a fine pin hole, with the aid of a stereoscope or magnifying glass. The accurate marking of these points on the photo is as important to the method as is the turning of angles or the measurement of distances correctly in running control. The ground control points on the photos are encircled with green waterproof ink.

LOCATION OF SURVEY CORNERS

The field work of locating section, quarter and donation land claim corners can be carried out either before or after running the ground control. In some respects, it would be best to locate section corners before running control, so that in the process of running control the section corners can be tied in. Either way it is done it requires about the same amount of time and effort.

The purpose of locating section corners and spotting them on the photos is to record the ground position of the corner with respect to its surroundings. This is one step toward assurance that properties will be placed in their correct ownership. Not every section corner in a township is located because it would probably be physically impossible, and also because it is not absolutely necessary. About 15 to 20 section corners are located throughout the township. Again it is necessary to locate corners which can be spotted with accuracy on the photos. With 1:12,000 photography and the aid of a magnifying lens stereoscope or small magnifying glass, it is possible to locate corners with respect to individual trees, snags, small bushes, large rocks, logs, bare spots, telephone poles, fence corners and innumerable other objects visible on the photo. The most difficult spots are in a stand of timber where there are no openings, but only thousands of tree crowns all of which look alike on the photo. The corners finally located are marked on the photo with a pin hole and a cross of black waterproof ink. The back of the photo is marked to show the identity of the corners.

When the photos are taken into the field and especially into brushy, rough timber country, they are carried on a metal or wood clip board, so the edges are not broken from them. In rainy weather the photos are carried in an envelope of heavy, transparent acetate. In this way they are visible and are protected from moisture. With waterproof prints and waterproof ink, the photos do not suffer much from a little rain. They will not stand an all-day soaking in wet brush, however. During hot, sunny weather carrying prints face down on the clip board is the practice, to prevent unnecessary curl of the prints from the heat.

PHOTOGRAPHIC CONTROL POINTS

To complete the system of points necessary to the slotted-templet layout, the system of photo control points known as "wing" or "pass" points is next set up on the photos as an office procedure. These points serve approximately the same purpose as the ground control system, but instead tie adjacent pictures throughout the area to each other, at image points common in areas of both side

and end lap. They are selected on the photos as prominent objects which can be punched and marked accurately without trouble. This sounds easy, but in rough country covered with unbroken timber stands, it is not easy to place such points and to transfer them accurately to the other photos as is required. The "wing" points are transferred from one photo to another with the aid of a magnifying stereoscope. They are pin pricked and encircled with blue waterproof ink. This in itself is not a small job when 350 square miles are covered in one layout.

OUTLINE FOREST TYPES ON PHOTOS

The purpose of making the forest type-map for the inventory is to classify the forest growth and land areas. The classification system is as follows:

Non-forest Lands

- Agricultural Lands
  - Tillable
  - Non-tillable
  - Brush, stump pasture
- Non-commercial, Rocky Areas
  - Rivers, Lakes, etc.

Forest Lands

- Commercial Timber
  - Old Growth
  - Second Growth
  - Immature Stands
  - Reproduction stands
- Non-commercial Lands
  - Most Hardwoods
  - Brush
  - Fern hillsides
- Deforested Lands
  - Burned
  - Logged off

The system provides further for a breakdown by tree species and a method of symbols to show on the map the exact classification of each different land area and the species and age classification of each timber type.

The outlining of forest-types on each photo is a small part of the project, yet it is one of the more important steps in the entire process. This work is, in effect, mapping the various forest-types on the photo. It is basically a process of outlining differences, instead of scanning the photo for predetermined types and outlining them if found. In other words, typing the photos is the outlining of areas which appear to be homogeneous. Thus each type or classification will be homogeneous whether it be a cultivated field, brush patch, stand of douglas fir timber, etc. In outlining types, differences in stand volumes, tree species, stand height, stand ages, crown density, forest site, topography, etc. are the factors which may make types appear different, and cause them to be outlined. No attempt to name individual tree species in a mixed stand, or to tell the volume of any stand, is made from inspection of the photo. Usually, however, the difference in species of pure stands, and differences in age classes, can be readily identified from the photo. The separation of tree species, determination of volume, stocking and other details of the timber stands are left for the later field work. However, with this technique it has become possible to classify nearly all the land areas, by inspection of the photo in the office. This work is usually aided by the use of a magnifying, lens-type stereoscope, and is possible only after the worker has spent considerable time in the field with the photos. From then on, it is a matter of photo interpretation, and the use of detailed knowledge of the forest in correlation with the shapes, tones, textures and shadow patterns found on the photos.

In typing, no minimum acreage of type is set. That is to say, no type of less than 10 acres, for example, will be outlined. Instead, all the differences, within reason, are outlined. A four acre patch of timber in a section of brush will be

outlined; also a three-quarter acre bare spot in a dense stand of timber. Patches of oak and alder will be separated from second-growth fir, and so forth. In other words, the forest features are outlined as they are found. To some, this may seem to be hair-splitting and unnnecessary work. In practice it works very well. This technique makes possible accurate volume estimates with far less field work than in common practice, and provides the basis for an accurate appraisal of the forest values.

The type outlines are drawn with a fine pointed pen, with blue waterproof ink. The blue ink seems to show up better over heavy stands of timber and dense shadows than does other colors, and makes the job of transferring type lines easier. Usually, it is of little advantage to type the photos while in the field, because only a limited view of the land area and timber can be had from any one location on the ground. Some work may be done from the highest peaks, but it is not worth the extra trouble to climb there. The most advantageous position would be from helicopter, but, since the photos are taken from the air, there is no advantage in that method. Typing in the field may be used to advantage in training personnel or in gaining experience in new country.

The entire surface of any one photo is not typed, but only that portion around the principal point, and to midway of the overlap from adjacent photos. Thus, a type may often extend from one picture to another. The stereoscope is used to type in the overlap to prevent omission or duplication of areas.

Figure 1 shows a typical photo with type outlines and all necessary control points.

THE MAP BASE

Over small units of one to four townships the map base is laid out on a good piece of detail paper. Usually a rectangular grid is laid out, and the control points plotted on it from calculated latitudes and departures. The map scale is laid out at 1:12,000, which is a convenient working scale, and which will make a township map about 36 inches square. This scale also provides sufficient space to map the actual forest types within a forty acre unit, and provides a very workable map on the township basis for the assessor's records.

On larger areas where one layout has taken a space of nine by twelve feet, a rectangular grid was laid out on enameled plywood, and the plotted control points were transferred from it to detail paper in about township sized pieces which are convenient to handle under the radial plotter.

The slotted templets are made of good quality bristol board. The points are pricked through the photo to the templet, and are labeled on the templet by using green marks over the ground control points, blue over the "wing" points, red over principal points and black for section corners. This is the same color scheme that is used through all processes. Each templet is also marked to show the photo number and flight direction. The marks are placed so they cannot be punched out in the process of slotting the templets. The use of these marks and color scheme greatly facilitates the templet-layout.

After the templets are satisfactorily laid out and adjusted to the ground control net, a punch is run through each templet stud, and the location of every point is marked on the map base. As the templets are taken up, these points are again marked with their respective color, the photo centers with their number, and the section corners with the proper designation.

Since several section corners were placed on the map base by the templets, it is possible to lay out the section net of the township. This is done to scale from the original survey notes and plats. Having the section and "forty" lines on the

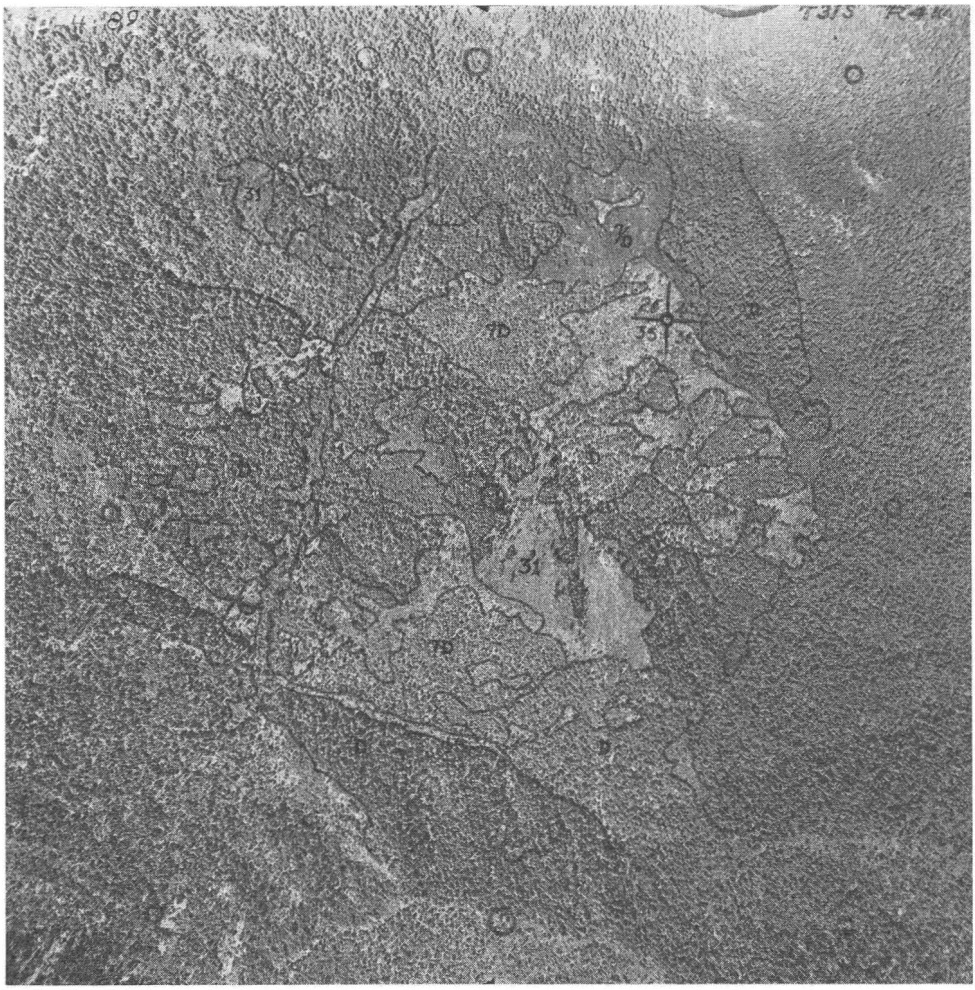

FIG. 1. Vertical Photo of Douglas Fir Region in Western Oregon showing timber type lines, principal points, control points, and a section corner. The type symbols are: 7/D Immature Fir, 7D Second Growth Fir, D Old Growth Fir, 31 Brush.

map base is helpful in transferring detail from the photos, especially when a change of forest type occurs along such a line.

With the marking of all the control points, wing points, principal points and section lines, the map base is complete and ready for the process of transferring detail from the photos to the map. The grid system has served its purpose, and will not be a part of the finished map.

TRANSFERRING DETAIL FROM THE PHOTOS

Two general types of transfer devices were available for this job. One used single photos; the other employed stereoscopic images and the principle of radial triangulation. The first type of device was not suitable because distortion could not be eliminated, and because accuracy exists only over level ground, and with photos having very little tilt. The occurrence of level land in the forested areas of Oregon is so rare that this fact alone prohibited the use of that type of device. Many of the second type of devices were eliminated because of their

cost and because they were suitable to more uses than the transfer of planimetric detail.

In selecting the instrument, consideration was given to the factors of accuracy, speed of operation, ability to compensate for scale deviations, ability to adjust from the basic photo scale, preparation necessary before use of the machine, time necessary to train personnel for operation, size, portability and cost. It was decided that the Kail Radial Planimetric Plotter would fulfill the requirements.

In practice, stereoscopic pairs of pictures are placed on the photo tables, and the plotter is oriented over the proper control and "wing" points on the map base. After adjusting the plotter so that the scale of the photos fits the scale of the map base, the operator then transfers all forest type outlines, creeks, roads, fields, section corners and other land marks from the photos to the map base. It requires about six days to transfer the detail over an entire township.

The photos are not typed on the plotter because the detail cannot be observed closely enough with the optical system. The operator has to concentrate only on orienting the instrument and accurately transferring the information. The forest types are transferred with accuracy and with no rounding off in shape

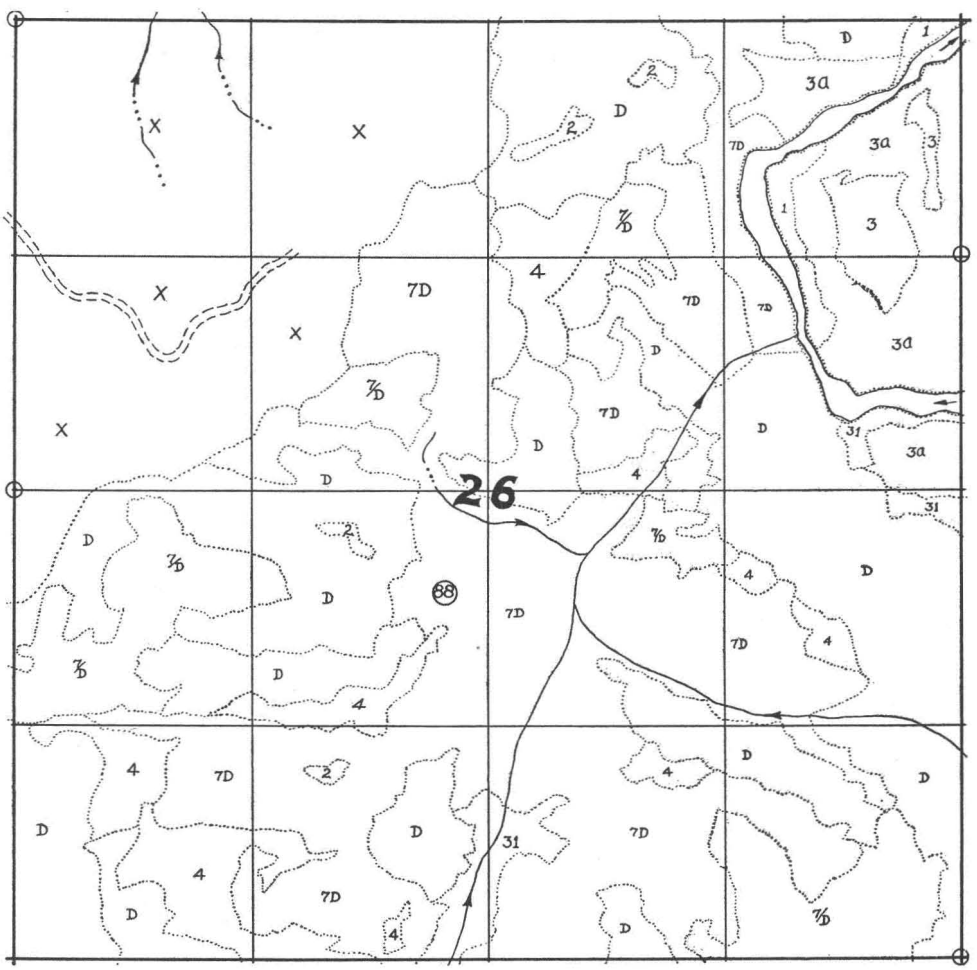

FIG. 2. Portion of Forest Type Map.

because any change in type means a change in area or an error in location with respect to ownership. As the photos are worked, the operator checks the photo detail closely with the map, to make certain that all type lines are completed, and that creeks do not run up hill or on the wrong side of a road. On this pencil copy, the roads are drawn in red and the creeks in blue, to avoid confusion between the forest type lines and the other detail.

THE FINISHED MAP

A black-ink tracing is made on tracing cloth from the pencil copy. Here again it is necessary to trace the detail exactly as it is found, and to make no changes unless they are corrections. The forest type lines are traced as dotted lines so they will not be confused with the other features. Other detail is traced and represented by conventional symbols. All details are traced in ink except the section lines (to be inked later) and these are made in pencil. Most of the classification symbols are placed in the types, but a few doubtful ones are left until the field sampling is done. The tracing is completed with a proper title and legend.

From this tracing are made direct black-line prints. These are used as field copies and work sheets in the field sampling.

A square section of a map is shown in Figure 2.

FIELD SAMPLING

The construction of the planimetric type map fulfills the requirements of an inventory for determination of the location and extent of the resource, and leaves the job of determining quantity and quality. In this job the photos are only an aid. But what an aid! They have already shown the location of nontimbered areas, the streams and ridges, and the means of access to various areas. They have cut the footwork to a fraction of that necessary in conventional methods. They have made more accurate volume estimates possible with comparatively little work and expense.

The field sampling consists of taking a copy of the type-map and the photos into the field where a predetermined number of sample plots are taken in each of the merchantable timber types. For the merchantable timber the volume by species is determined. In immature stands, the relative stocking and quality is determined, and measurements are taken from which growth predictions may be made. The volume estimates are not made by "forties," as is done in the conventional cruise, but are made for the separate type, even if it cuts across several "forties." This technique gives accuracy with a smaller sample, and saves a great deal of time in not correlating the sample plots with survey lines. The collected data are kept by section, "forty," type location and photo number. Special care is taken to correlate the data with the photo location for future study.

In the process of making the volume estimates, new section corners are located, and the detail of the map checked for accuracy. The remaining doubtful type symbols are checked and placed on the map. The field check also brings to date the logging done since the photos were taken.

In the office again, the ink tracing is completed by making the necessary changes and inking the section net. Several prints of the tracing are made for general use, and a cloth-backed print is made for the county assessor's records. A blue-line Ozalid print, backed with cloth, is given to the assessor, as the map on which he keeps record of the ownership names and boundaries. The individual township square maps are arranged geographically and are bound in a large volume. The purpose of reproducing the tracing by the Ozalid process is to obtain a copy of the original detail which has the original, accurate scale. It is

important to have the cloth-backed map with accurate scale so that areas and distances can be measured directly from it, and so that names and boundaries can be marked and erased repeatedly with little damage to the map. The tracing is preserved so that progressive changes in the forest cover and land classification can be recorded on it, and a new office record printed from it at convenient intervals.

SUMMARIZING THE INVENTORY

Now that the map is finished, the field sampling made and the volume of merchantable timber in each type calculated, the next task is to summarize all details of the inventory on convenient and proper forms. These forms provide space to show for each ownership, by forty acre subdivisions, the acreage of each land class, the quality class and acreage of immature timber, the volume by species of merchantable timber, and also provides space to apply values to the total of each land class and to thus prepare the data to go on the tax roll.

To fill out these forms, it is necessary to take the timber volumes from the sample plot data sheets and to measure the acreage of each separate type as it is shown on the map. The job of measuring the acreage of each type is accomplished with a dot grid. This grid is a series of etched dots on transparent acetate so placed that the square formed by four dots represents one-half acre at 1:12,000 scale. The type areas are measured on the map, by so placing the grid on the map that the lines of dots fit uniformly within the boundaries of the "forty." Then, the number of dots falling within each type are counted, and the number converted to acres. If a dot falls on a type line, it is given one-half the value accorded a dot. By this method areas can be measured to the nearest one-quarter acre. This method is sufficiently accurate for timber lands, and is in keeping with the accuracy of other phases of the inventory.

CONCLUSION

The situation of static forest land taxation has been met, and is being altered by a low cost method of using aerial photography as an aid to making an inventory for the appraisal of the forest lands. The use of aerial photography reduces the inventory cost of from fifty cents or one dollar per acre, to ten or twenty cents per acre, and makes available more accurate information in less time.

NEWS NOTE

NEW CLOTH ENDS NEED FOR NEGATIVE IN REPRODUCING ENGINEERING DRAWINGS

According to a news release of the Eastman Kodak Co., the conventional negative step used in making cloth reproductions of engineering drawings can be eliminated by the use of Kodagraph Autopositive Cloth, a new photosensitized cloth developed by the Company. Like other "Autopositive" materials, Kodagraph Autopositive Cloth produces a positive copy directly from a positive original drawing. It may be handled in normal room light and is exposed on conventional blueprint or direct-process machines or a vacuum printing frame. Not only does elimination of the negative result in savings in time and materials, it also produces a cloth reproduction free from the distortion introduced by the use of paper negatives. The new cloth is highly translucent, assuring rapid production of quality shop prints, and may be drawn in on either side, using ink or pencil. It is available in 30- and 100-foot rolls in the following widths: 20, 30, 36, and 42 inches.