THE APPLICATIONS OF PHOTOGRAMMETRY TO FORESTRY IN CANADA*

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Abstract

The applications of photogrammetry and photo-interpretation to certain phases of forestry operations are discussed. These are the determination of (1) volume and availability of merchantable wood, (2) success of reproduction, (3) area of cut-over land and the area and volume of the residual stand, (4), assessment of damage caused by fire, wind, insects and disease, (5) location of logging roads, (6) logging plan, and (7) water delivery system. Most of the information so obtained is transferred to planimetric maps.

The volume and availability of merchantable wood is determined by delineating timber type areas within 1.14 to 2.11 per cent accuracy by two methods cited—(1) tree heights by parallax or shadow measurements accurate to a standard deviation of ±7 to ±11 feet for individual measurements on 1:15,840 photography, and (2) density on a comparison photo-interpretation basis accurate to a standard deviation of ±13 to ±23 per cent and which is considered to be not sufficiently accurate. Other methods of determining density offer better results.

For reproduction surveys the areas can be delimited with greater accuracy at reduced cost, but the success of reproduction is unsatisfactory due to difficulties of detecting the presence of deciduous species, identifying coniferous species, and an accuracy of only approximately 60 per cent in the one case cited for stem counts of coniferous species.

For the determination of cut-over area and of the residual stand, the use of aerial photographs is superior as to accuracy and cost. Although the density of the residual stand is more difficult to determine than of an undisturbed stand, a good comparison of the pre-cutting cruise and the actual cut can be obtained.

The extent and severity of damage to the stand by fire, disease, insects and wind can be determined more accurately because of extensive spot damage of varied intensity over large areas in some cases, if the photography is made for the specific purpose.

For all-weather roads photogrammetry can be used very effectively in determining the location most favorable from the standpoint of construction difficulties, gradients and costs.

It is suggested that topographic maps based on sufficient vertical and horizontal ground control and on photogrammetric methods be made in laying out logging chances.

The use of aerial photographs for pre-drive planning and for current drive information is in the early stages of development and use. It is possible to determine the capacity of the river, necessary improvements of the river, and measures necessary to supplement the normal river flow to insure success of the drive. Aerial photography flown during the drive permits determination of the state of the drive at any time and the immediate measures necessary to insure its success. After pulp wood is in booms a more accurate count can be made than by counts on the site.

The primary reasons for using aerial photographs in conjunction with attendant ground surveys in the forest operations cited are to obtain better and more current results at the same or less cost and in less time.

Ethan D. Churchill

I. Introduction

A. DEFINITION

PHOTOGRAMMETRY is defined by the American Society of Photogrammetry as the art or science of obtaining reliable measurements by means of photography. As it is defined in terms of measurements, its application is naturally limited to measurements in forestry—that is, forest surveys.

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There are many reasons for making surveys in practising forestry but they may be divided into two groups: those intended to give information about the forest itself, and those intended to give information about the methods of logging the forest.

B. TYPES OF SURVEYS

Under the strictly forestry surveys we have the following surveys:

1. To determine volumes of available wood,
2. To determine the success in establishing a new crop—that is, regeneration surveys,
3. To determine cut-over areas and residual stands,
4. To assess the damage caused by fires, high winds, insects and fungi.

For logging purposes we have:

1. Road location surveys,
2. Logging plan surveys,
3. Water delivery surveys.

There are many other types of surveys, but those mentioned have one thing in common, which is better results for the same cost can be obtained if photogrammetry is applied to them. In the remainder of this paper will be explained briefly what each type of survey involves, and how photogrammetry is, or can be, applied to it.

II. Surveys to Determine Wood Volume

A. INTRODUCTION

Just as in land surveying, there are various classes of surveys distinguished by the accuracy required of the result. While there is much less agreement between foresters than between surveyors on the boundaries between these classes, it is believed that a large measure of agreement can be obtained on the following three:

1. Reconnaissance surveys
   Accuracy required: ±10% by volume on 500 square miles,
2. Inventory surveys
   Accuracy required: ±10% by volume on 100 square miles,
3. Operating surveys
   Accuracy required: ±10% by volume on 7 square miles.

While the range of permitted error is the same in all cases, the area over which permitted varies greatly. This follows directly from the fact that the units with which the timber cruiser must deal, namely trees, are infinitely variable. Even in what the forester calls an "even-aged" stand, the trees will vary up to 15 years in age, 10 feet in height, and 10 inches in diameter. In addition, the shape of the trunks, the clear length, the bark thickness, and the wood fiber yield will vary. And most variable of all will be the amount of defect.

To meet this situation the forester calls upon the science of statistics, and deals in averages obtained from samples of various kinds—systematic, random or selected.(5) According to the purpose of the survey, he spreads his samples over units of varying sizes. If only general information is required, these units will be the watersheds of large rivers, in the neighborhood of 500 square miles. If more detailed information is required for long-range planning, they will be spread over smaller units of perhaps 100 square miles, corresponding to the watersheds of tributary rivers. If detailed information is required on a "camp chance" to be operated the following winter, the same number of samples will

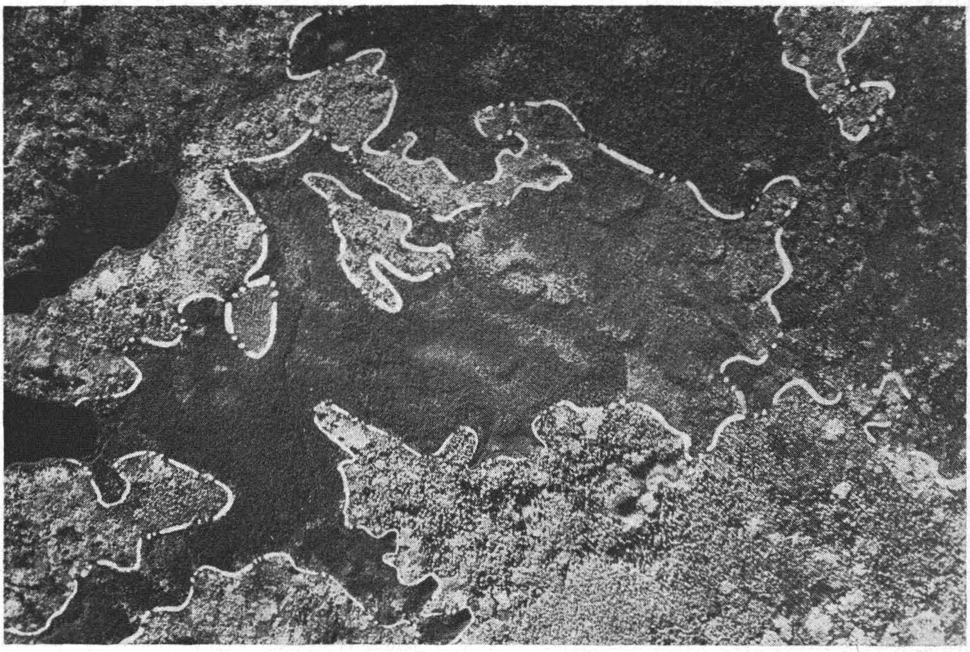

FIG. 1. A fall photograph at 1,320 feet to the inch, showing the type areas as outlined by the interpreter. (Department of Lands & Forests, Ontario.)

be taken in an area of about 7 square miles. As long as a given number of samples is taken and the same variability is encountered, the same accuracy of estimate will be obtained, because there will be the same opportunity in each case for the plus and minus variations to cancel out.

There are three kinds of measurements involved in applying photogrammetry to making a timber cruise—the *measurement of area*, the *measurement of tree heights*, and the *measurement of stand density.*

The measurement of area involves first of all the transfer of the forest type areas from the photograph to the planimetric map, with simultaneous corrections for scale differences between map and photograph, scale changes and displacements due to variations in ground elevation within each photograph, and distortions due to tilt. This transferring is done with an instrument such as the Duoscope (3), Seelyscope (7), Sketchmaster, or Anharmonic Rectifier (8). Figure 1 shows the type areas marked on the photo and Figure 2 the map resulting from the transfer of similar areas. When the areas have been transferred and adjusted, their measurements are obtained by means of dot-counting or by using a planimeter of either the polar or photo-electric type. For an area of 211 square miles mapped at 1 mile to the inch, Nash (2) quotes an accuracy within 1.14% for the polar planimeter and 2.11% for the photo-electric planimeter.

Tree heights are obtained from the measurement of their shadows or images on the photographs (4). Shadows are measured directly to the nearest thousandth of an inch and images may be measured either directly or by their parallax. With photographs at a scale of 1,320 feet to the inch, single height measurements give a standard deviation of ± 7 to ± 11 feet. Figure 3 shows a winter photograph which is nearly ideal for the measurement of coniferous tree heights.

For reconnaissance surveys, stand density is obtained by estimates of experienced interpreters. For inventory surveys, it is estimated by the comparison

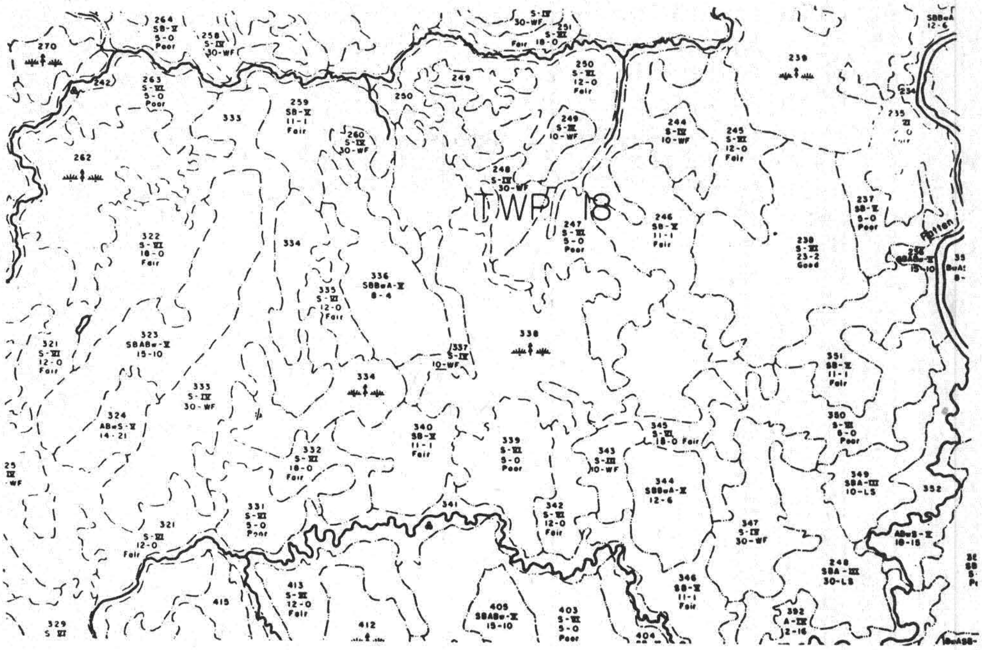

FIG. 2. A portion of a completed forest inventory map.

of similar known stands in the same forest section. The latter method has been used for operating surveys but it is not sufficiently accurate. Single estimates show a standard deviation of ± 13 to $\pm 23\%$ of full density. A tree counting, or crown closure method, promises better results.

III. Regeneration Surveys

The aerial photograph has two great advantages in regeneration surveys.

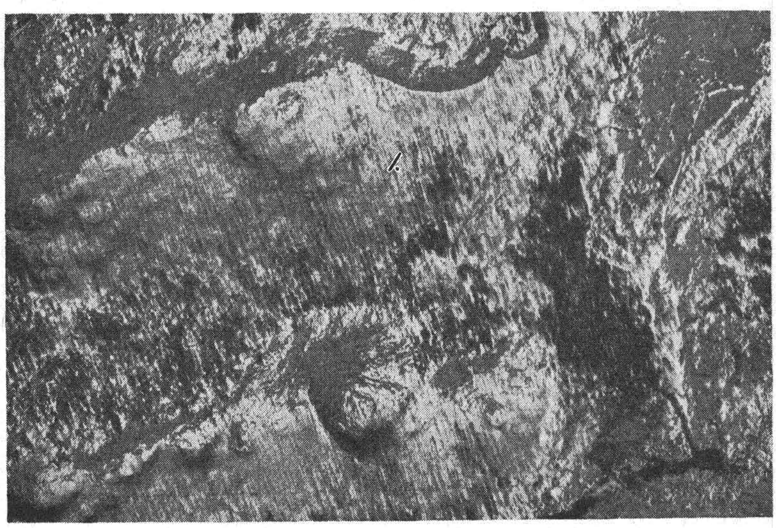

FIG. 3. A winter photograph taken at 600 feet to the inch. The images and shadows of the conifers can be seen particularly well against the snow background and in the absence of the hardwood leaves. See especially near the number (1).

The first is that through its use a large part of the costly field work can be eliminated. The second is that it provides the best possible basis for mapping the areas of various degrees of stocking. It is only a matter of outlining them on the photograph and transferring them to a base map, as in forest surveys for timber volumes. Without photographs, extremely inaccurate mapping results unless a great deal of money is spent on this phase of the job alone.

There are two disadvantages in using aerial photographs for regeneration surveys. First of all, it is doubtful that the presence of any deciduous species could be discovered in the technique that will be suggested. And secondly, it is very doubtful whether the individual species of conifers could be distinguished. In regard to the first, this disadvantage can be completely disregarded in Canada. Over very large areas hardwood species are not cut, and in the areas where they are cut, regeneration is so abundant that it constitutes no problem and no surveys are necessary to determine its abundance. The second disadvantage—the impossibility of distinguishing coniferous species—is more serious. It can, however, be overcome by a field examination of a small proportion of the area studied on the photographs.

The chief factor to consider in working out a method is the small size of the seedlings which it is desired to measure and to count in the photographs. It is therefore essential to do everything possible to obtain maximum resolution. First of all, this means the largest possible scale. But if the use of the standard air camera is desired, the scale is limited to about 200 feet to the inch by the image blurring caused by the movement of the aircraft during the interval that the shutter is open. The Sonne camera compensates for this, but it is preferable to retain the 9″×9″ format for ease of handling in interpretation; until this compensation is generally available in the new survey cameras, scales smaller than 200 feet to the inch must be used. A further limitation to increasing scales is the economic one. By asking for extremely large scales the cost of photography could be so high that it would be cheaper to make the survey entirely in the field.

The next step, then, would be to consider how we could increase the contrast between the seedlings and their background, and thereby obtain greater resolution. A simple answer is to plan so that photography will take place immediately after the first snowfall of the winter. This would give a white background for the dark coniferous seedlings without burying any but the seedlings which had germinated during the year. If considered important in a given survey, their numbers could be determined the following spring at the same time as the field sampling to determine coniferous species is done.

With this maximum contrast and with high quality photography, the resolution would be close to 0.1 feet on the ground at a scale of 200 feet to the inch, which would allow counting of all but the smallest established seedlings. Even if compelled to accept photography at 600 feet to the inch, a count could be made of everything 0.3 feet in diameter or larger and the numbers of seedlings smaller than this could be obtained by a limited field examination.

An opportunity for testing this technique in all details has not yet been available, but an example can be given of such a survey carried out under disadvantageous conditions. This was a survey of a plantation described in another connection by B. J. Smith (6) and which, because it lay well off the main routes of travel, had not been visited for some years.

Photography of the area was obtained for another purpose at a scale of 600 feet to the inch in the early spring. Snow lay almost everywhere except on the sand plain on which the plantation stood—a simple application of the time-tested law of the innate cussedness of inanimate objects. The contrast was accordingly very poor between the spruce seedlings of the plantation and the wet soil sparsely covered with the brown vegetation of the preceding season (Figure 4). On a tone scale which runs from black to white in ten steps, there was only one step difference. Accordingly, even at 600 feet to the inch, the resolution was estimated at only 3 feet. It proved to be even less.

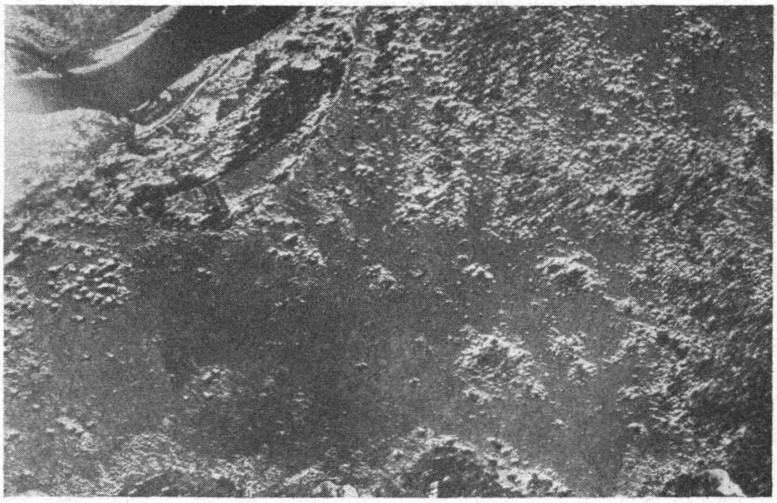

FIG. 4. A view of a spruce plantation. The young trees are planted in regular rows in all the openings visible, but because of their similarity in tone to the background, they can only be seen with difficulty even in the original photograph.

Seventeen one-acre plots were laid out on the photographs and the trees on them counted. The average count was 400 trees per acre. A subsequent ground check showed that there were actually 700 trees per acre of all sizes. Assuming that the crown width of these seedlings to be equal to their height, this meant that nothing under six feet in diameter had been counted since there were 325 trees per acre five feet in height or less. Had the area been larger, it would have been possible to use this relationship to complete the survey from the photographs, but the initial samples were sufficient for the survey.

IV. Cut-Over Surveys

Cut-over surveys are required by organizations engaged in woods operations for the purpose of revising their inventory at the end of each season, and also as a check on the accuracy of the estimate of wood made prior to the beginning of the operation.

If piece-cutters could be held to exact areas and if cruises could be exact, there would be much less need of cut-over surveys. But with several hundred men working individually over an area of bushland of three or four square miles, supervision is very difficult. Between the rounds of the foreman and control man, individual cutters have ample time to get out of line, particularly if the timber looks better just over the boundary set for them! Also in pulpwood cutting, each man is making a strip road and cutting the trees along it as he goes; when the time comes that his camp has reached its quota for the season, cutting stops just where each man is. In addition, there are always patches of timber which are always left behind because defective or too small to cut.

As a result, the boundary of a cut is very ragged and difficult to survey (Figure 5). Until the advent of aerial photographs, the standard method was to

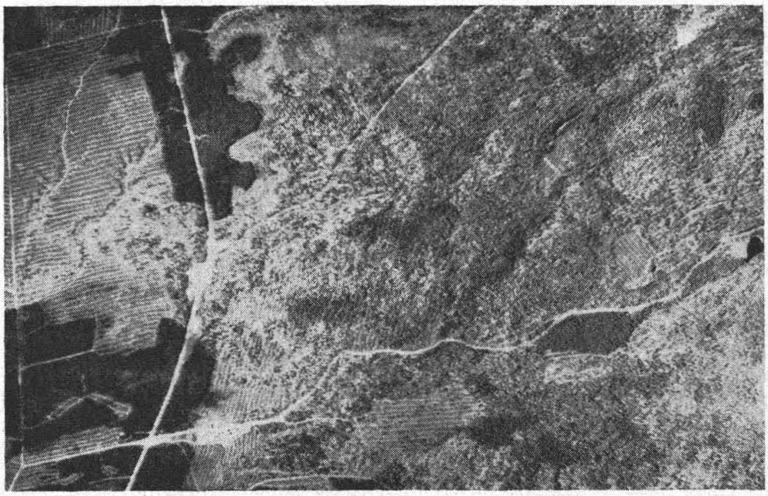

FIG. 5. A photograph of an area cut over for pulpwood. The light parallel lines are the strip roads from which the brush is cleared to allow the removal of the piled pulpwood. Note the difficulty of establishing a boundary between cut and uncut stands in the central portion of the photograph. (Department of Lands & Forests, Ontario.)

pace or chain distances and take bearings with a staff or hand compass. Even this was time consuming and the results could not be very accurate. In the past this inaccuracy was of little consequence because the available planimetric maps were often not as accurate as the cut-over mapping. But now that reasonably accurate planimetric maps are becoming available almost everywhere in Canada, an improvement is being made.

The aerial photograph is the only cheap means of making this improvement. Large scale (600 feet to the inch) vertical photography of the areas cut each season is not a very expensive proposition and the cut-over mapping done by interpretation of the photographs and by transfer to accurate planimetric maps is in every way superior to that produced by the old method. It is even rumored that when a certain cut-over area mapped by the old method was plotted on an accurate planimetric map, it was discovered that 3,000 cords had been cut from the waters of one lake! Of course, the rumor has been denied.

With accurate cut-over mapping it becomes desirable to estimate the *residual stand*, for only in this way can the estimate prior to the cut be accurately checked. It is impossible for the cruiser to decide in advance exactly what will be merchantable in the eyes of the camp foreman and the cutters, particularly if several years elapse between the cruise and the cut. In the borderline cases, the difference of a year or two in the growth of a stand, or in the progress of disease, insect attack, or blow-down, may change the picture entirely. A change in the economic cycle may also affect a decision as to what is merchantable and what is not, for in periods of depression, cutters will work in stands which they would not consider in periods of prosperity.

Accordingly, in planning a cruise, it becomes necessary to set definite size specifications a little lower than the smallest size the cutters are likely to touch, so that the residual stand after cutting will represent the difference between the cruise and the cut, and an accurate comparison can be made.

The method of making the estimate of the residual stand follows the methods outlined for the original cruise, with measurements of area made from the map, and measurements of the heights and densities from the photographs. In this case density is more of a problem because of its high variability.

V. Damage Surveys

A. SURVEYS OF BURNED AREAS

The surveying problem in mapping the areas of burns is much the same as for cut-over mapping. The boundaries are indeterminate because areas of complete burn intermingle with areas of partial burn, and the intensity of burn often tapers off towards the edges (Figure 6). The tracings of the boundaries on the ground is therefore a difficult and time-consuming process, and because of the lack of control, the result is often very inaccurate.

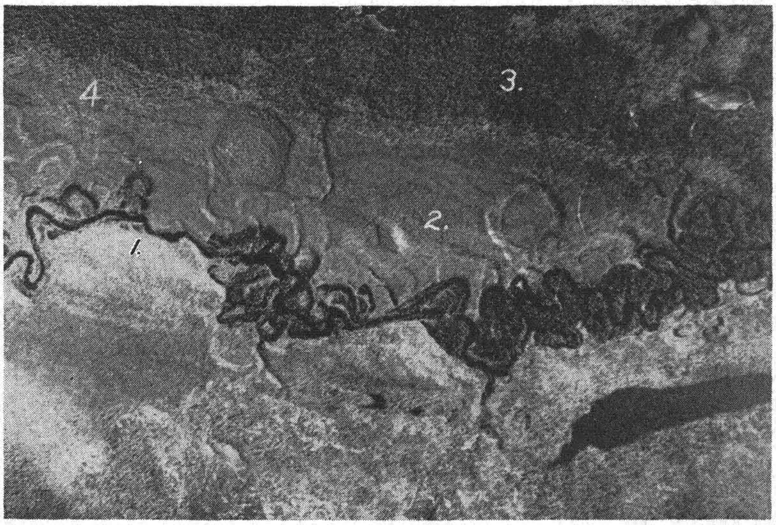

FIG. 6. The edge of a burned area. Note at: (1) A completely denuded area; (2) Dead standing timber with patches still surviving; (3) Unburned forest; (4) Gradual transition to unburned forest. (Department of Lands & Forests, Ontario.)

If aerial photography of the area is obtainable after the fire, not only can the boundaries be accurately mapped, but the whole area can be divided into sub-areas which were heavily, moderately or lightly burned. However, at least a year should elapse between the fire and the photography; otherwise the extent of the damage will be underestimated because of the damaged trees which die slowly in the less intensively burned areas.

B. SURVEYS OF AREAS DAMAGED BY DISEASE OR INSECTS

For stands damaged by insects or disease, not only are the boundaries indeterminate, but there are many isolated spots separated from the main area by considerable distances. In some instances, such as where the spruce budworm has attacked the balsam in stands of yellow birch and maple, the whole area of damage is an aggregate of these spots. No survey made without using aerial photographs could hope to be even approximately accurate without the expenditure of great sums of money. The photographic method however can supply an accurate survey at reasonable costs if photographs at a scale of 600 feet to the inch or better are used, and if it is possible to wait until the attack is well over and all seriously injured trees have died and shed their leaves. The large scale of photography is necessary to show up dead conifers which are difficult to distinguish from undamaged trees at smaller scales while they retain their fine branches.

C. SURVEYS OF AREAS DAMAGED BY WIND

Wind damage to forest stands, particularly to over-mature stands such as from a large proportion of Canada's merchantable forest, is more frequent than most people realize. Like insect and fungus damage, the effect is often spotty and even in the spots hit, the damage may only be partial. It would be almost impossible to survey the damage on the ground because of its scattered incidence, and also because of the extreme difficulty in making a way on foot through blow-down areas. Once more photogrammetry provides a ready answer. If the damage is severe where it occurs, such as after violent storms, even medium scale photographs (1,320 feet to the inch) will provide the basis for an estimate. Where the damage varies in intensity—this is usual—larger scale photography will provide much greater accuracy. The method is to estimate the residual stand in every case, using area determinations from details transferred to a planimetric map, and height, density, and species determinations from the photographs.

VI. Road Location Surveys

More and more, modern pulpwood and lumber operations are coming to depend on all-weather roads. To keep costs to a reasonable figure these roads must avoid steep gradients, much rock cutting, and swamps requiring more than a minimum of fill.

Where photographs are not available, expensive trial lines must be run on the ground or costly mistakes will be made. Everyone who has worked in the bush has heard stories of the road that ran in a semi-circle for eight miles around three sides of a swamp when there was a good route along the fourth side three miles long. Unfortunately, there is a basis of truth in most of such stories. Among many instances, I will mention a case where a practical logger laid out a road location for a pulpwood operation following a road which had been used for a much earlier pine cut. A young forester, using only a stereoscope and photographs at 1,320 feet to the inch, was able to pick out another route, which cut off three miles. With road costs varying between $3,000. and $40,000 a mile, this meant a nice profit on a few hours work.

The method used for road location varies with the importance of the road and the photogrammetric equipment available. For winter roads, a straight stereoscopic examination to determine the most likely routes, followed by a field examination, will suffice. A two lane all-weather gravel road intended for hauling will require parallax determinations for all grades with a stereo-comparagraph or similar instrument, or better, a complete topographic map covering the possible routes.

VII. Logging Plans

In laying out a camp chance for logging, the logging engineer has a complex problem on his hands if the topography is as rough as in most of Quebec, the Maritimes, and parts of Ontario, and British Columbia. To keep his costs within a competitive range his hauling must be down-hill, but avoiding excessive grades, the areas of heaviest timber must be the shortest distance to the main road, and all the timber must be reached with the least length of road. To a very large extent at present, this problem is handled by walking and re-walking the chance with the camp foreman until both have the picture in mind. That this is not satisfactory is shown by the readiness of alert logging engineers and camp foremen to use aerial photographs and a stereoscope, or in the case of the Sault Division of Abitibi, to use vectographs.

It is believed that the complete answer to this problem will be found in the preparation of topographic maps for each camp chance. With enough vertical control to horizontalize the plot, a map could be produced with a stereo-comparagraph that would permit the logging engineer to lay out the operation for his foremen and to be sure that he had the most economical plan. With the full advent of high-lead logging just introduced in Eastern Canada, detailed logging plans prepared by photogrammetric methods will become essential.

VIII. Water Delivery of Wood

The applications of photogrammetry to the *water delivery of wood* is in its early stages, but it has such great possibilities that the author is convinced that it will develop as rapidly as the idea can be sold to the operating staffs of pulpwood and lumber companies.

The first possible use of aerial photographs is in assessing the *capacity of the river*. In most cases the normal flow of the river, even in the spring freshet, is insufficient to carry the required cut, and tributary lakes must be dammed so that extra water can be released at various points along the main river as the drive progresses. The area of the tributary lakes can be obtained from a good planimetric map, but because contour maps are lacking in most cases, photographs are necessary to determine the extent to which each lake can be raised and the volume of water that can be stored. Aerial photographs can also be used to assess the need for enlargement and clearing of outlet creeks, the suitability of dam sites, and the existence of special obstacles such as railways or public roads which might be flooded if the water were raised beyond a certain point.

The second place for using aerial photographs in preparing driving plans is in *assessing the amount and cost of improvement* necessary in the river. From the photographs can be determined the amount of clearing of rock and fallen trees; the points at which low banks require glance booms, or side piers, to keep the wood in the stream; and opportunities for constructing cut-offs to shorten and straighten the river.

Photographs at any available scale will give much of this information. In one case where the author had an opportunity of working in connection with a driving plan, the only photographs available were at a scale of 2,640 feet to the

FIG. 7. A stretch of river showing various obstacles to driving pulpwood: (1) Rocks; (2) Shoal; (3) Low banks.

inch. Even with these it was quite possible to interpret rocks and shoals in the river bed, and low banks (Figure 7). Had it been necessary, the areas and possibilities of raising water levels of the tributary lakes could have been determined with a fair degree of accuracy. However, much larger scale photography is desirable.

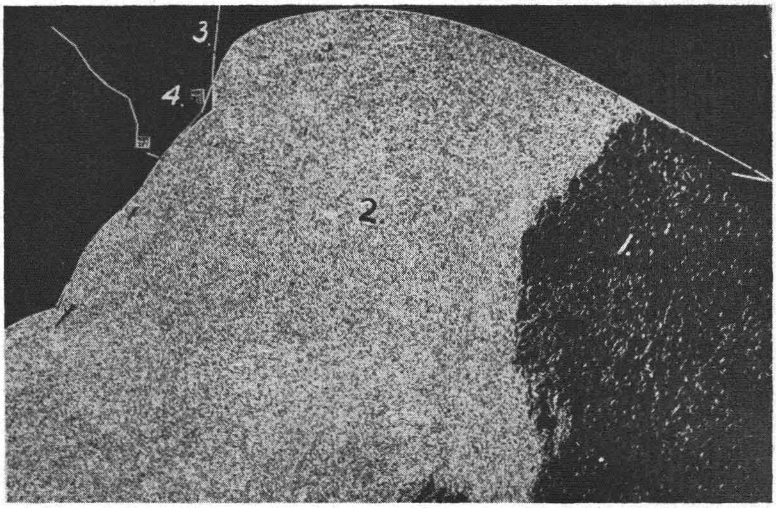

FIG. 8. A boom collecting pulpwood as it floats downstream: (1) Pulpwood moving into the boom; (2) Pulpwood already collected by the boom; (3) A section of the boom itself; (4) Piers to which the boom is moored. (Spartan Air Services Limited.)

If photography can be obtained especially for the project, the cost would be relatively little since a single flight over the length of the river to be driven would cover the entire area necessary for stream improvement studies at scales as large as 200 feet to the inch. Most tributary lakes could also be covered by a single flight at this scale; if this were done, very little field work would be required.

When drives are long and difficult, photographic coverage could be used to give a rapid report on the state of the drive at any time. The number of logs or sticks of pulpwood in any part of the river could be readily determined and remedial measures taken if necessary.

The number of pulpwood sticks in booms was counted on photographs as early as 1919 by W. Kahre (1). The value of the photographs for this purpose is that they freeze the sticks in one position, and eliminate all the confusion of movement which makes ordinary counting only a rough estimate (Figure 8).

CONCLUSION

The foregoing has touched upon some of the applications of photogrammetry to forestry in both the strictly forestry and in the operating field. In both the author sketched not only the present uses of photogrammetry, but those to which he expects it will be put within a few years. There are many other present and possible uses, but these are believed to be the principal ones.

REFERENCES

1. Kahre, W. *Woodland Review*. June, 1949.
2. Nash, A. J. "The Photoelectric Planimeter." *Surveying and Mapping*, April–May–June, 1948, Volume 8, pages 64–69.
3. Seely, H. E. "The Duoscope." PHOTOGRAMMETRIC ENGINEERING, Volume 7, 1941, page 18.

4. Seely, H. E. "Determination of Tree Heights from Shadows in Air Photographs." Aerial Forest Survey Research Note No. 1, Forestry Branch, Department of Resources & Development, Ottawa, 1942.
5. Sammi, J. C. "The Application of Statistics to Photogrammetry." PHOTOGRAMMETRIC ENGINEERING, Volume 16, December, 1950, pages 681–685.
6. Smith, B. J. "Silvicultural Work at the Sault Ste. Marie Division." *Woodland Review.* January, 1950.
7. Spear, G. A. "The Seelyscope." Forest Air Survey Leaflet No. 4, Forestry Branch, Department of Resources & Development, Ottawa. 1949.
8. Trorey, L. G. "A Map in a Day." *The Canadian Surveyor,* Volume 8, No. 6, Pages 9–24. 1944.

AERIAL SURVEY AND OIL EXPLORATION

A STUDY IN ORGANIZATION

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ABSTRACT

The author presents his experience in organizing and conducting an aerial survey and oil exploration in Peru by means of aerial photo-interpretation and field study. He describes a method of preliminary organization and air reconnaissance procedure in order to obtain full advantage of aerial photogeological interpretation prior to final field mapping. The various necessary steps, such as a review of existing trimetrogon photography, preliminary aerial reconnaissance, final air coverage of selected areas, photogeologic interpretation, plotting, etc. are described. The author used specially trained photogeologists to do the interpreting, with field geologists using this information as a base for final mapping. His experience showed that three photogeologists could interpret approximately 15,000 square miles, on a scale of 1:40,000 in about one and a half years. The photogeologic interpretation was reproduced on photo scale tracings for use by the field parties which permitted the planning of field studies, but did not eliminate the need for the surveying of detail sections. The finished compilation of field and photogeologic interpretation and geophysical data were photographically reduced from the photo scale to either a 1/100,000 or 1/200,000 map for use as a base map for the geologic reports. The final step was the reproduction of regional structural maps at a scale of 1:500,000 or 1:1,000,000.

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THE application of aerial mapping to oil exploration is so widely adopted and its techniques are so well known that little can be added in that respect. However, in the author's opinion the organizational aspect of the problem has not received the attention which it deserves.

This paper therefore describes how an aerial survey can be integrated into an exploratory organization so that all of its branches will derive the greatest benefit from it.

An aerial survey, if properly planned and applied, can be a very efficient tool for directing an exploration campaign. In many exploration ventures of the past, aerial surveys were decided upon and initiated considerably later than the start of the geologic field work. Accordingly the results of the photo-interpretation became available only after they were no longer required in the field.

In an unmapped or inadequately mapped area, an aerial survey has two aims: firstly to supply the topographic base for geologic mapping and geophysical surveys; secondly to supply a coherent structural picture to serve as a guide for the movements of geologic field parties engaged in stratigraphic studies and structural mapping.

In areas which are well known topographically, the problem of course is