PROCEDURES FOR AERIAL SKETCH MAPPING AND VOLUME DETERMINATION OF FOREST INSECT INFESTATIONS

by

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Victoria, British Columbia

Forest Service Internal Report PM-PB-4

September, 1982

Not for Publication

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Summary

This report outlines the procedures for aerial sketch mapping and volume determination of certain forest insect infestations. The procedures outlined in this report have been applied to bark beetle infestations in the Cariboo Forest Region.

The objective of this report is to contribute to the standardization of forest insect survey procedures in British Columbia. Standardization of survey techniques in this Province will lead to a more accurate appraisal of forest insect problems which will, in turn, allow dollars and manpower to be allocated with increased efficiency to priority areas.

Reviews and comments on this report are welcomed, and should be directed to the Protection Branch, Victoria.

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1. Introduction

During 1981 British Columbia Ministry of Forests staff at Williams Lake conducted an extensive aerial forest insect survey. Ministry personnel systematically surveyed 6.0 million hectares of the Cariboo Region and mapped 244,000 hectares (3.2 million cubic meters) of insect infested timber (Taylor 1981). During this survey, damage caused by mountain pine beetle[1], spruce beetle[2], and douglas-fir beetle[3] was identified and mapped. Results were used by District, Regional, and Branch personnel for a number of purposes including direction of salvage and control operations, establishment of an accurate data base, and development of a survey technology. The results obtained provided accurate area estimates and underestimated volumes (Taylor 1981). The survey methods outlined in this manual have potential use in mistletoe, root disease, and forest insect defoliator surveys.

The purpose of this report is to summarize useful techniques used during these aerial surveys. This report outlines the procedures involved in aerial surveys in more detail than reported by Grimaldi and Mitchell (1981). In addition, techniques for deriving area and volume estimates are shown in this report. Standardization of forest insect surveys could be achieved if these techniques are adopted throughout the Province. Standardized insect surveys will lead to a more accurate identification of forest insect problems which will allow dollars and manpower to be allocated with increased efficiency to problem areas.

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[1] Dendroctonus ponderosae, [2] Dendroctonus rufipennis, [3] Dendroctonus pseudotsugae

2. Flight Organization

This section outlines some of the details that should be taken care of at least two months before the sketch mapping project begins.

2.1 Coordination of Agencies

The first step in a sketch mapping project is to arrange a planning and organizational meeting of District, Regional, and Federal Pest Management staff. An important objective of this meeting is to pick a suitable project and to decide on priority areas and species (trees and insects) to be mapped. A suitable project could consist of mapping a Forest Region and concentrating surveying in areas where local knowledge points to substantial forest insect damage.

Another important part of this meeting is to ensure that Provincial and Federal mapping efforts are not duplicated. Other technical details of a proposed project which should be discussed include training and aerial sketch mapping schedules. Training and mapping schedules may have to be arranged around district and regional personnel work loads.

2.2 Selection of Personnel

Two persons are necessary for each mapping flight, one each from a Regional and District Office. To ensure uniform mapping across the region, the same Regional person should be involved with each district flight.

The Regional mapper will help district personnel to plot infested areas correctly (See section 4.3) and thus ensure uniform mapping.

Personnel selected for sketch mapping should be capable of enduring flights of at least five hours. They should also be able to distinguish between the colours red, green, yellow, and grey. Mapping personnel must be comfortable in the air to produce good maps. Some personnel get nauseous after short flights and they should not be designated sketch mappers.

2.3 Aircraft Selection

Fixed wing aircraft can be used in all but very mountainous terrain, where helicopters may be necessary. Fixed wing aircraft used in sketch mapping should have at least four seats and be capable of flying at speeds of 70 to 80 knots. Retractable landing gear will give sketch mappers an unhampered view of the ground. A Cessna 172, for example, fits the above criteria.

Helicopters used in sketch mapping should have four seats and bubble side windows will make mapping easier. It should be noted that helicopters may only be practical in situations warranting their use. Limitations may be related primarily to cost considerations.

All use of aircraft should be coordinated by the Protection Air Operations Coordinator in the region concerned.

2.4 Personnel Training

A short training program should be conducted to familiarize mapping personnel with their responsibilities in the air (Grimaldi and Mitchell 1981). Responsibilities of various personnel are discussed in section 4. A training area should be selected and sketch mapped to determine infestation percentages. To establish accurate standards this area should be ground truthed[4] so that air-to-ground comparisons can be made. The training area should cover two 1:32,680 forest cover maps and should represent the full range of attack frequencies as shown in Table 1. Sketch mapping proficiency will be achieved when personnel can select the correct mapping symbol 75% of the time under good mapping conditions. This is the level of proficiency that was obtained in the Cariboo Forest Region in 1981.

Table 1 Standard Mapping Symbols for Forest Insect Infestations

Symbol	Attack Frequency	Trees Attacked(%)
X	Single tree	—
L	Light	1-5
M	Moderate	6-30
H	Heavy	31-100

2.5 Map Preparation

Maps should be prepared at least two months in advance of the actual mapping project, as this is a very time consuming task. The colour, trim, and completeness of coverage should be checked. Coloured maps make navigation easier because sketch mappers can concentrate on

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4 Ground truthing should consist of field work designed to classify the infested area into a percentage of attack (See Table 1).

identifying attacked trees. Only the types shown in Table 2 (Provincial Cartographic Manual 1974) should be coloured.

Table 2 Types to be Coloured on the 1:32,680 Forest Cover Maps

Types to be Coloured	Colour
Lowland brush of non-merchantable value	Grey
Land under cultivation	Brown
Swamp or water	Light Blue
Areas logged or not satisfactorily restocked	Yellow
Open range, alpine, and meadow	Purple

Susceptible timber types should not be coloured. Colouring these types makes maps cluttered and hard to read. Time is better spent updating maps for disturbances (mainly logging disturbances). Out-of-date or improperly coloured maps make navigation difficult.

Proper colouring will help speed up the process of locating infested areas, thus saving aircraft time and allowing personnel to more accurately locate an infestation on a map. A properly coloured and updated map will also help one become oriented and stay oriented, especially in areas of large or similar timber types.

Maps should be trimmed to get rid of excess paper on the edges to make handling easier in the aircraft. This is also a good time to check completeness of coverage and make sure that there are two copies of sketch maps for each area to be sketched in.

As described by Grimaldi and Mitchell (1981), the two map scales used for aerial detection are:

i) 1:31,680 forest cover maps (40 chain per inch); and

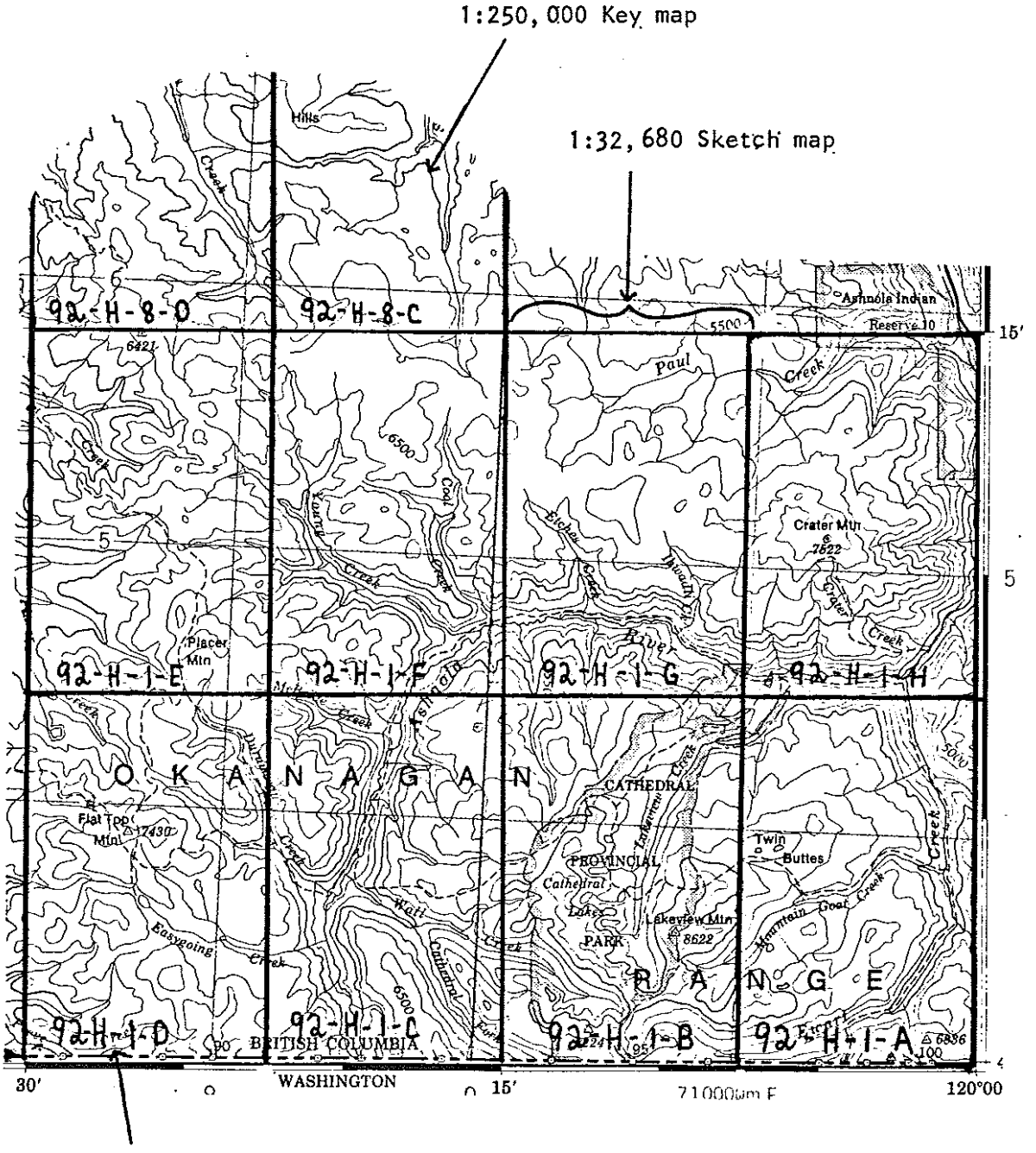
ii) 1:250,000 colour topographic maps (4 miles per inch)

The 1:31,680 forest cover maps are used for mapping infestation boundaries and isolated individual attacks. The 1:250,000 map, prepared prior to each flight, is used as a key map. On it all 1:31,680 map sheets are outlined and labeled as shown in Figure 1. This arrangement enables the observers and the pilot to plan the flight and to quickly and accurately locate areas where infestations are to be mapped. As each set of maps is completed, the key map is used to arrange the next set of maps.

For infestation mapping a scale of 1:31,680 is one of many scales that can be used for detailed mapping. The scale 1:40,000 has also been used. Use of map scales smaller than 1:40,000 is not recommended because at these scales considerable time is spent trying to accurately locate attacked areas on a map. Scales smaller than 1:40,000 may be used if either attack areas are scattered or only a broad overview of pest conditions is required.

Figure 1

Arrangement of Infestation Maps (1:31,680)
on the Key Map (1:250,000 colour topographic map)



Standard National
Topographic System
Map Label

3. Daily Flight Preparation

This section will outline equipment and weather requirements for each sketch mapping flight.

3.1 Equipment

Check each day prior to leaving the office that the following equipment is on hand:

i) Sketch maps

ii) Key maps

iii) A large supply of sharpened red pencils (Omnichrome ^{R} is the recommended brand) to map infested areas.

iv) A Forest Service radio to report both position (every 30 minutes) and fires to the regional air operations base.

v) Personal survival equipment.

3.2 Weather

Checking the weather is an essential part of pre-flight preparations. Regional meteorological staff should be consulted to ensure there is good visibility and a cloud ceiling of at least 400 meters. Air conditions tend to be unstable after 1:00 p.m. so try to arrange mapping flights in the morning. In early morning flights the low sun angle is a factor that can be alleviated by using ambermatic sunglasses or by carefully scheduling flights for mid-morning departures.

4. Flight Procedures

In this section several aspects of flight procedures will be discussed. If the procedures described in this section are followed, there will be systematic coverage of each 1:31,680 map over the desired survey area.

4.1 Layout of Flight Lines for Fixed Wing Aircraft

When fixed wing aircraft are used, Regional and District mappers should map the same area from the right-hand side of the aircraft for the following reasons:

i) For heavily infested areas two people are needed to map thoroughly. One person alone cannot pick up all the attack.

ii) For sparsely infested areas, both individuals can help pick out attacks.

iii) For standardization of mapping across the region, the regional sketch mapper should help district mappers select mapping symbols. See Table 1 for the mapping symbols.

In heavily infested areas the aircraft should fly four times over each map sheet (a map sheet has a scale of 1:31,680 in this example), as shown in Figure 2. Each pass should be made slightly overlapping the previous flight path so that mappers will be able to see areas previously under the aircraft. Passes should be made at slow speed, 70-80 knots and the aircraft should be high enough (minimum altitude of 400 meters) for mappers to see approximately one

third of the map. If the aircraft is too high, it is difficult to accurately map attack areas, and if too low, it is difficult to stay oriented.

In sparsely attacked areas, the speed of the aircraft can be increased to 100 knots and the number of passes reduced. Only two passes may be necessary as shown in Figure 3.

Figure 2 Arrangement of Flight Lines for Fixed Wing Aircraft Over a map sheet in heavily infested areas

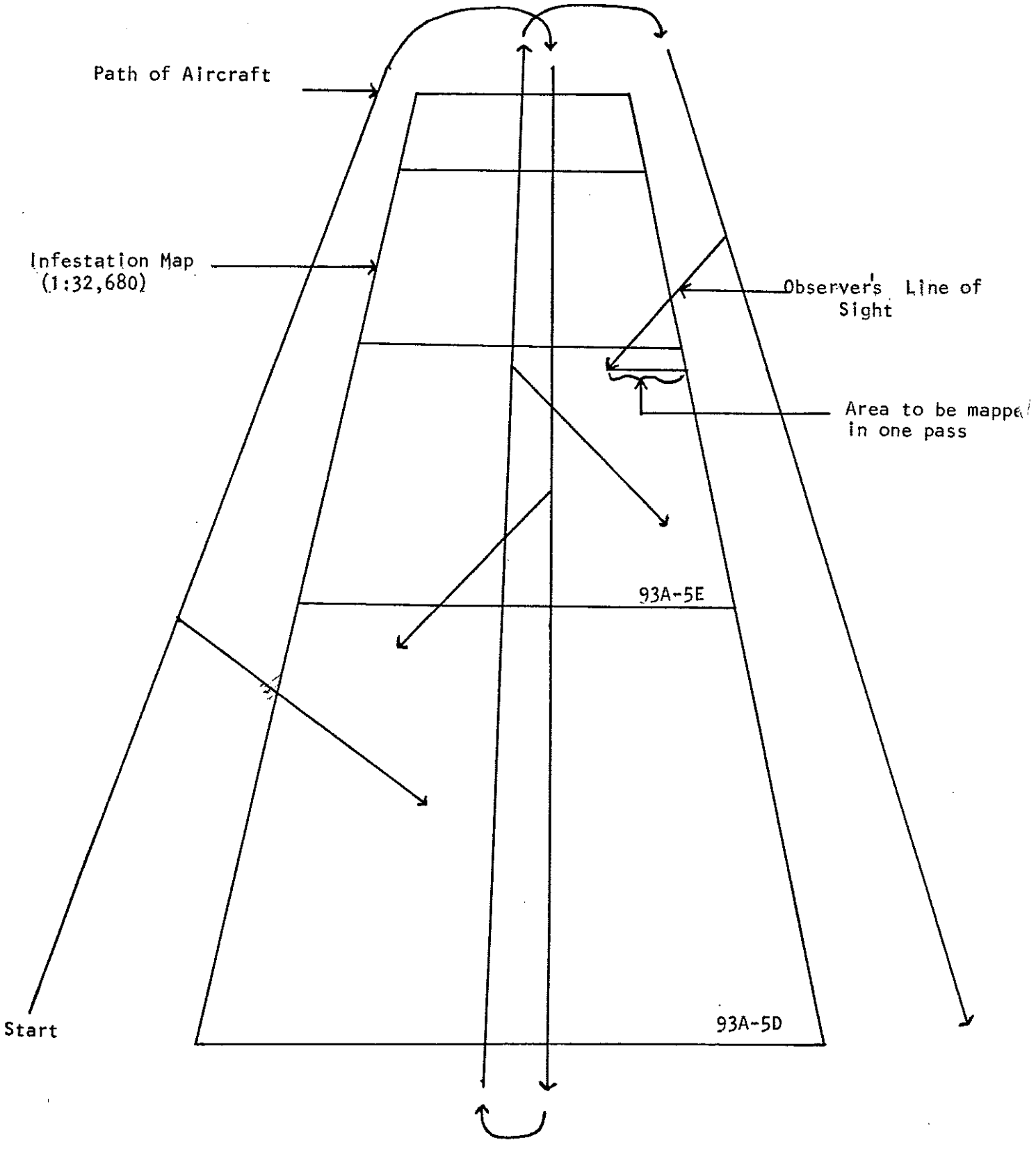
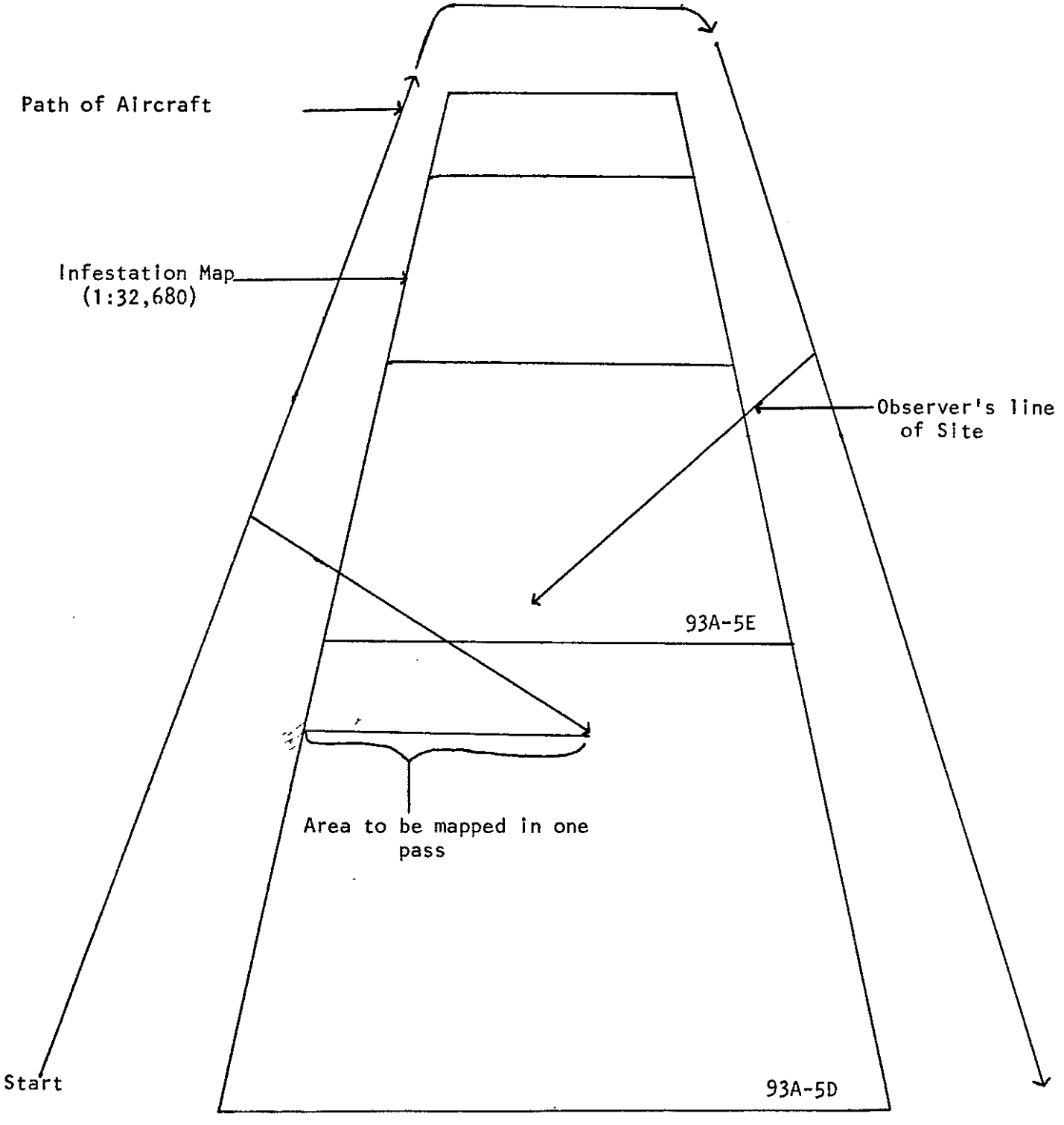


Figure 3 Arrangement of Flight Lines for Fixed Wing Aircraft on maps which are sparsely infested



Finally, as many consecutive maps in a row as is possible should be flown from South to North or North to South to save turning and alignment time. This mapping system will accommodate a systematic coverage of each 1:31,680 map.

4.2 Layout of Flight Lines for Helicopters

For helicopters used in mountainous conditions a recommended procedure is to fly up one side of each creek in a drainage basin and make a return pass on the other side as shown in figure 4. Mappers should sit on the left-hand side of the helicopter.

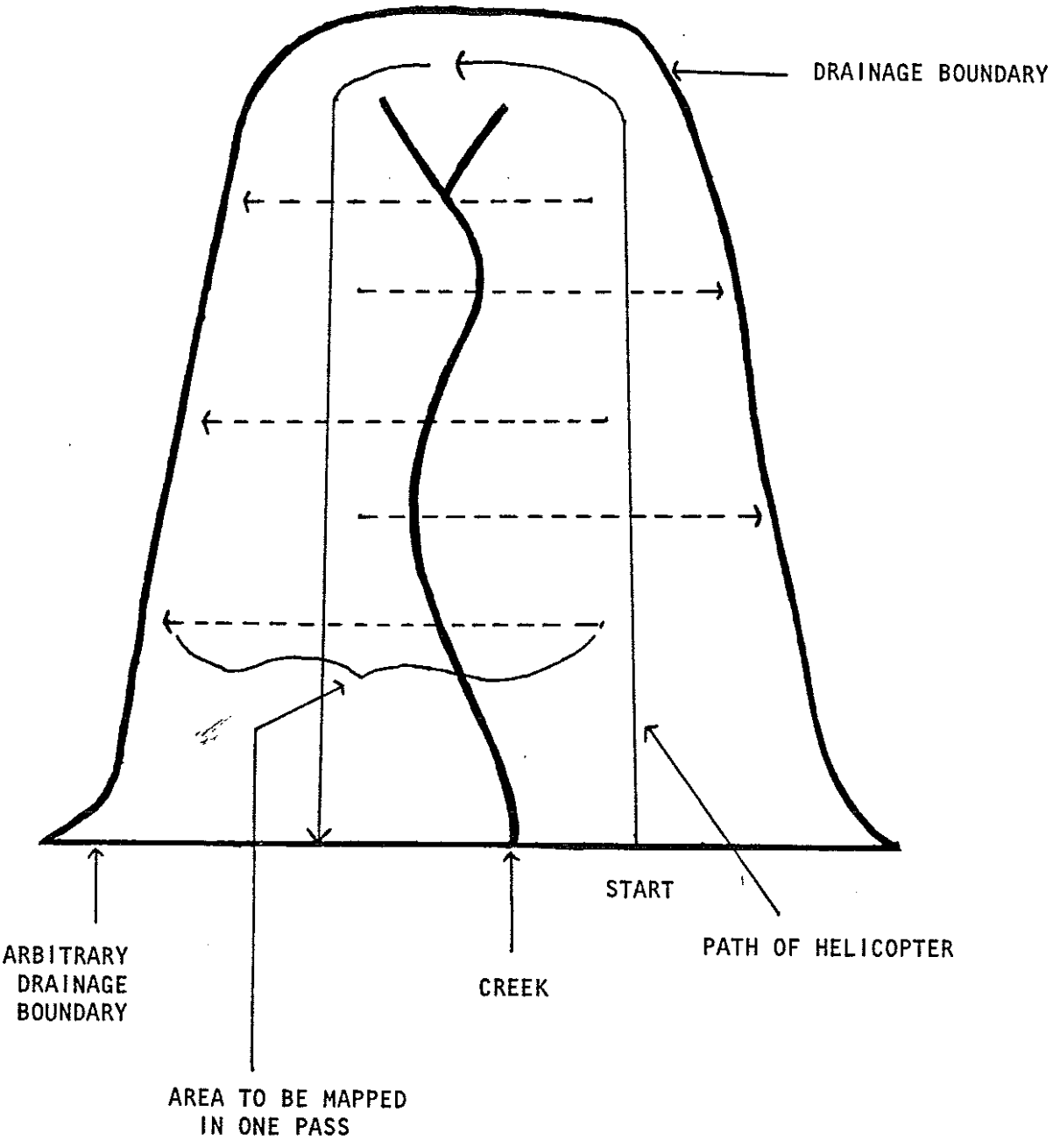
4.3 Mapping

As infested areas are detected, they should be plotted on a map using standard symbols as shown in Table 1. A polygon should be drawn around the infested area and the appropriate attack symbol should be printed inside the polygon. In this table the percentage of attack is based on the total number of stems in a stand and not just on susceptible tree species.

When mapping an attacked area, the minimum standard of delineation that can be made is X,L,M or H, and what species is being attacked. It is usually not possible for make a further breakdown to determine what percentage of each species has been attacked.

Only visible damage can be plotted. Therefore aerial sketch mapping should be done when the damage is most apparent, usually mid-July to October for bark beetles in the Interior.

Figure 4 Helicopter Flight Paths



Finally, grey or old attacks should be plotted in initial surveys so that a complete estimate of timber losses can be made. This can be deleted in subsequent annual surveys.

4.4 Preparing a Composite Map

At the end of each flight the District and Regional sketch mappers should compare their respective maps and construct a composite map in a neutral colour. Green felt pen is recommended to avoid obscuring forest cover type lines or labels. This composite map should be a representational compromise between what the Regional and District personnel have mapped. The composite should be constructed immediately after each flight while visual information retention is still good.

After a composite map has been constructed, a hand drawn copy should be made. This copy is for the District Office and the original map is for the Regional Office. A copy should be hand drawn because a photocopy will not reproduce colour. Maps should be made available immediately to Canadian Forest Service Forest Insect and Disease Rangers to augment their own surveys and reports.

4.5 Assessing Sketch Maps

To assess the accuracy and discover possible bias in the sketch mapping, a check using ground probing, colour photos, or 70 mm slides

can be useful (Harris, et al. 1982, Harris and Dawson 1979). Sketch mappers should be able to estimate the correct symbol category as defined in Table 1 on page 4. If consistent bias is discovered then volume and area estimates can be adjusted.

5. Data Analyses

This section is intended to assist Regional Protection and Inventory personnel who will be involved in area and volume calculations. It will discuss how to analyze data to estimate area and calculate tree volumes infested. Detailed examples are given after a general discussion.

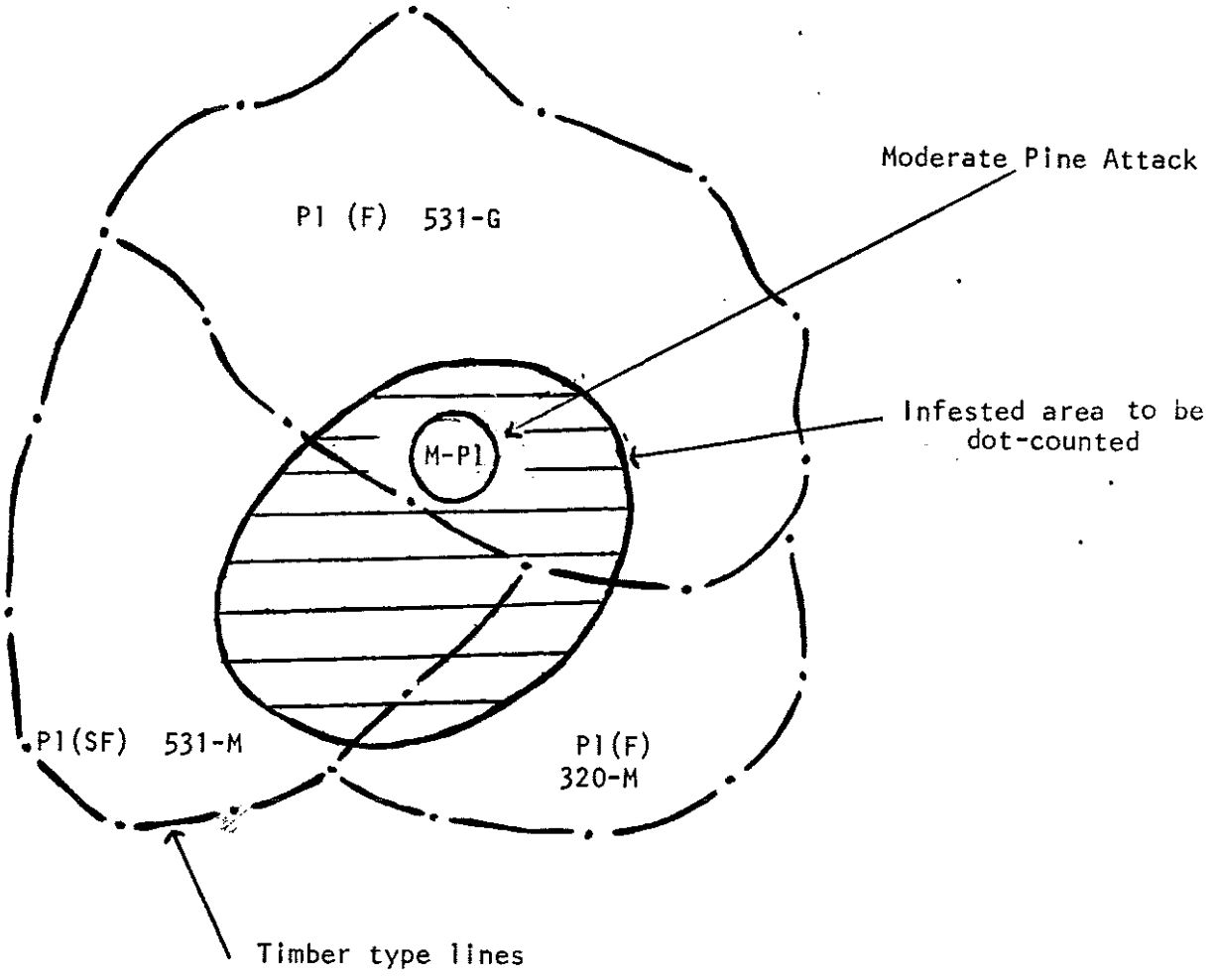
5.1 Area and Volume Estimates

To estimate area attacked, dot count each infested area on the 1:32,680 composite maps and transfer the results to the recommended data sheet as shown in Figure 5. To obtain accurate results, only the attacked portions of timber types should be dot counted as shown in Figure 6. Make sure that the correct scale of dot grids is used. A grid of 64 dots per inch grid is used for 1:32,860 maps.

1 Geographic Reference	2 Mapsheet Number	3 Forest Type	4 Inter-sity of Attack	5 Ha	6 Stand Vol./ha of all tree species	7 Total Volume (m^3)	8 Vol./ha for Attacked tree species	9 Attacked Species Reduced Ratio	Vol. Reduced and Lost of Attacked Tree Species		12 Total Volume Remaining
									10 Vol. Reduced/ha	11 Total m^3 lost	
----------From Sketch Maps----------					Local & Zonal average volume	5x6=7	Local & Zonal average volume	See Section 5.1	8x9=10	5x10=11	7-11=12
			See Table 2		per hectare line tables		per hectare line tables				
					See Section 5.1		See Section 5.1				

Figure 5 Suggested Data Sheet for Area and Volume Estimates

Figure 6 Example of a Sketch Map showing a moderate attack in a Pine Type



Infested areas are stratified according to forest cover type and intensity of attack, and recorded in columns 1 to 5 on the data sheets. Columns 6 and 8 are compiled by consulting the C_1 listings to obtain the average line number [5] for each attacked forest type. Next consult the local and zonal average volume per hectare line tables to obtain volumes per hectare. All other columns are self-explanatory, except column 9. Data in column 9, Attacked Species Reduced Ratio is calculated for each infested area as follows:

$$\frac{\text{Total Volume of all Species}}{\text{Volume of Attacked Species}} \times \text{Midpoint fraction for Intensity Range (Table 3)} = \text{Attack Species Reduced}$$

Note that the maximum value of the ratio calculated for column 9 cannot be greater than 1.0. This is because not more than 100% of an attacked species can be reduced. For more detail see Example 1.

Table 3 Midpoint Fractions for each Attack Symbol

Symbol	Midpoint Fraction to Use
X	—
L	0.03
M	0.18
H	0.63

5 Through sampling procedures Inventory Branch has developed average lines for timber types to give on indication of the expected volume per hectare. (Ministry of Forests, Inventory Branch, 1980)

The Attacked Species Reduced Ratio has been used for the following reasons:

i) To calculate losses based only on volume of an attacked species.

ii) To limit losses in stands where the attacked area was sketched incorrectly (See Section 5.2).

iii) To estimate stand volumes attacked rather than by counting the number of stems attacked and multiplying by an assumed volume-constant per tree to obtain total volume (Harris, et al. 1979).

5.2 Sample Calculations

Two examples of problems that are encountered in determining volume are given in this section.

Example 1

A Douglas-fir stand designated as F 721-P was sketch mapped as a moderate pine attack. This type of problem occurred frequently in the Stum Public Sustained Yield Unit (P.S.Y.U.)[6] in the Williams Lake Timber Supply Area (T.S.A.)[7] and was because of misplaced mapping. In this example the pine volume component of the stand was 2 m^3/ha and total volume 102 m^3/ha. The pine volume is 2% of the total volume of the stand. The problem was how to interpret these results. Four volume deductions were possible.

6&7 In the 1981 Cariboo Aerial Survey, the Region was broken down according to Timber Supply Areas and Public Sustained Yield Units.

i) Because the attack frequency was moderate, deduct 6-30% of the total stand volume (102 m^3/ha).

ii) Because the attack frequency was moderate, deduct 6 - 30% of the volume of the attacked species (2 m^3/ha).

iii) Use the method recommended.

iv) Move the attacked area to an adjacent pine stand, then use the method recommended.

Let us examine these cases separately:

i) If 6-30% of the total stand volume were deducted, one would include attacked and non-attacked species together. This was not satisfactory as pine was identified as the attacked species. This method would overestimate the actual volume loss.

ii) If 6-30% of the pine volume were deducted, then one would underestimate the volume attacked. For the above example this method would involve deducting 18% of the pine volume. This gives an overall deduction of .36% of the total volume. This result was unsatisfactory because there was a moderate attack in the stand rather than a light attack.

iii) If the recommended method was used then the results would be:

$$\frac{102\ m^3/ha}{2\ m^3/ha} \quad X\ 0.18 = 9.18$$

The result, 9.18 would be equivalent to a 918% deduction (9.18 x 100). However only a maximum of 100% of the attacked species can be deducted as per the attacked species reduced equation. Therefore all the pine volume 2 m^3/ha was deducted as a loss. This procedure appeared more realistic than steps i) or ii), because it did not count non-attacked species and it was closer to the estimated infestation level.

iv) A final possibility would be to move the attacked area to an adjacent pine stand and then use the recommended method. If time permits, this procedure would indicate volumes attacked more accurately than either of the above three cases.

Example 2

In the Quesnel Lake P.S.Y.U. in the Quesnel T.S.A. a pine stand with a minor spruce component, designated as Pl(S) 84l-G, was sketch mapped as a light attack. In this example the pine component of the stand was 403 m^3/ha and the total volume was 466 m^3/ha. The pine volume was 86% of the total volume of the stand.

Using the recommended method the results were:

$$\frac{466\ m^3/ha}{403\ m^3/ha} \times 0.03 = 0.034$$

Therefore the ratio 0.034 was used in column 9 on the data sheet. This means that approximately 3.4% (0.034 x 100) of the pine volume was lost.

5.3 Compilation of Results

The final steps of the aerial survey project are to write a report which complies area and volume loss estimates and to produce a legible map. This report should compare current and previous years losses and summarize the cost undertaken to complete the survey. This report should then be sent to District, Regional, and Branch personnel.

Acknowledgements

This report would not have been possible without the assistance of J. Hunter and D. Doidge in the 1981 Cariboo Mapping Project. I would like to acknowledge their assistance and the assistance of J. Muir, P. Hall, P. Humphreys, and R. DeBoo in editing this manual. I would also like to thank S.K. Grimaldi for permission to use portions of his 1981 manual.

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