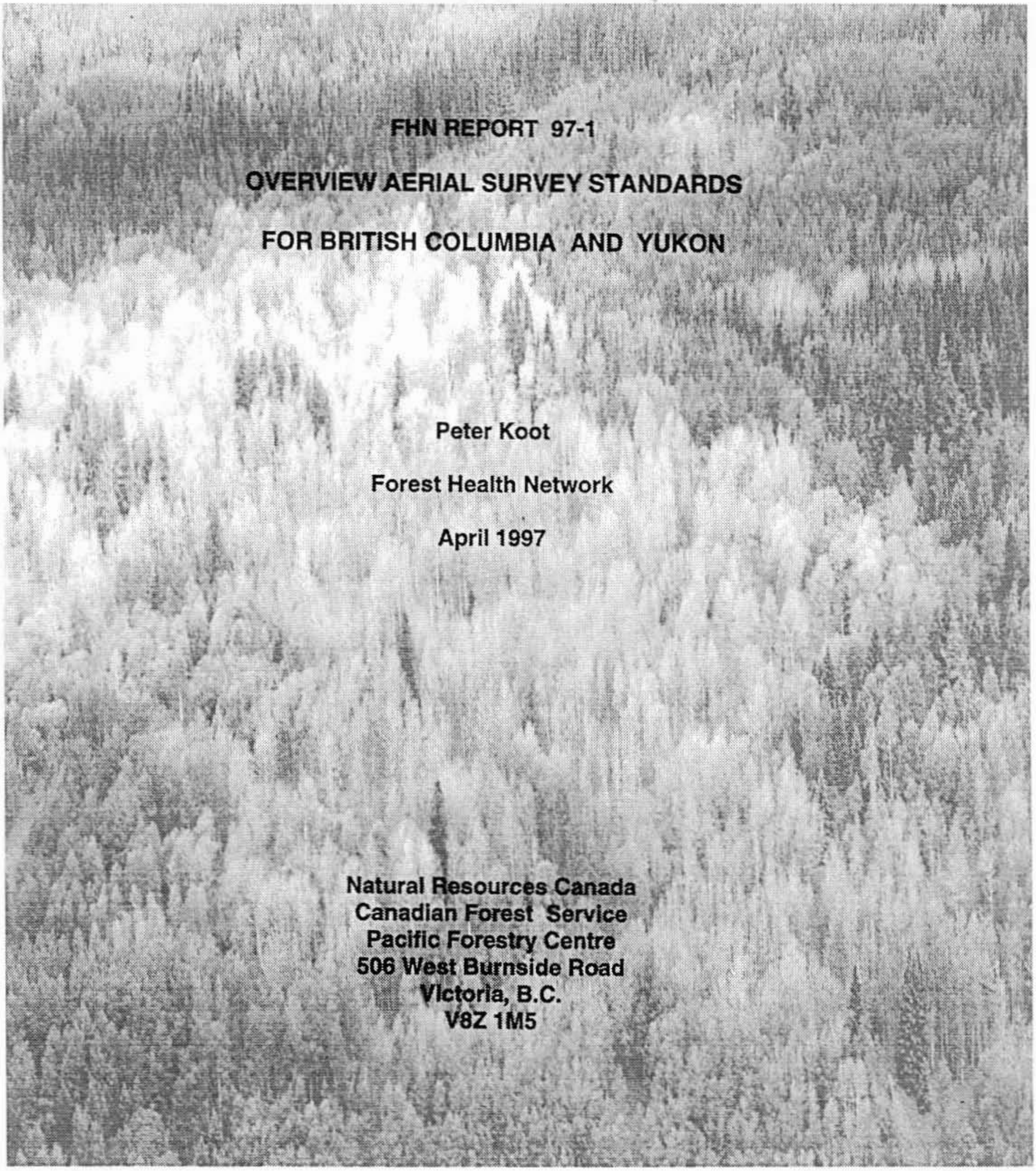

FHN REPORT 97-1

OVERVIEW AERIAL SURVEY STANDARDS FOR BRITISH COLUMBIA AND YUKON

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April 1997

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INTRODUCTION

Fixed-wing overview aerial surveys have been an invaluable tool for detecting and monitoring forest disturbances (i.e. pest and abiotic damage) for many years. Since the 1950's, aerial survey information, coupled with ground truthing and stand cruise data, has been the basis for annual calculations of losses due to pests at the local stand level and up to and including the national reporting level. With changing technology and varying levels of expertise and experience among those responsible for carrying out the surveys, it became necessary to develop guidelines that describe the methods and quality checks necessary to ensure a standardization of annual overview aerial surveys for major forest disturbances. In so doing, pest survey data, quality and comparability can be enhanced.

These guidelines form the basis for discussions and cooperation with the BC Ministry of Forests and should lead to the development of national standards for the Forest Health Network and their collaborators to meet national requirements for Criteria and Indicator reporting. This standard is in partial fulfillment of the Canadian Forest Service (CFS) commitment to develop criteria and indicators for sustainable forest management that reflect sound ecological processes, and also supports the intent conveyed by the British Columbia Forest Practices Code[1]. The Code states that before a development plan or a prescription is prepared, a survey must be done to determine the incidence of damaging agents in high hazard forest ecosystems.

Aerial survey flights are designed for national and provincial overviews, and as such may lack the accuracy required for local stand level detail. They are, however, sufficient and timely for provincial summaries, national requirements for the Forest Health Network such as Criteria and Indicators, historical or research purposes, for adding valuable data to the historical database which allows for hazard and risk ratings for cyclical pests and will also help indicate where more detailed surveys are required. Coverage includes all forms of land ownership, including crown land, provincial and national parks, municipal, forest industry and other private lands. However, forested areas are prioritized for aerial sketch-mapping according to pest damage trends, historical records, previous ground evaluations and requests by resource managers. This type of aerial survey is a cost effective means for obtaining reliable pest activity information over large areas and an economical way to get uniform estimates of changes in pest populations over successive years.

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[1] Forest Practices Code Standards, Section 4.1

PURPOSES FOR ESTABLISHING STANDARDS

- to provide information that is consistent, quantifiable and comparable with the requirements for both Criteria and Indicator reporting and the British Columbia Forest Practices Code
- to provide an accurate historical record of pest and other major disturbances
- to accurately assess current forest health
- to record and highlight changes in forest health over time
- to increase overall efficiency of surveys, thereby decreasing costs
- to provide an accurate data base on which to make decisions
- as an aid to training personnel in the objectives and performance of an aerial survey
- to assist aerial surveyors in all aspects of producing quality maps for analysis and regional and national compilations.

AERIAL PEST DETECTION SURVEYS

PLANNING

Aerial overview surveys are generally conducted from early July through August to coincide with the optimum damage symptom expression of major forest pests and damage in British Columbia and the Yukon. By this time sufficient knowledge about current pest conditions has been gained from early season surveys and anecdotal reports, so that the most efficient coverage of known and historically likely outbreaks can be planned. Occasionally, special flights are conducted to address specific pests which express themselves either earlier or later than the mid-summer period.

Coordinated planning is essential to a successful aerial survey. Generally, in consultation with CFS, initial aircraft selection and charter arrangements are done by the British Columbia Forest Service at a regional level, while the day to day aerial surveys are coordinated at a district level. Aircraft reservation should be made well in advance of the expected flight as planes could be in short supply during fire season and alternate arrangements may need to be made. Mapping personnel should also be given as much advance notice as possible to accommodate flight scheduling. Aircraft charter companies should be informed that surveys are weather dependent and final decisions on suitable flying conditions cannot be made until the day of flight.

FLIGHT PREPARATION

Maps

Map scale will be determined not only by availability, but also by product requirements. For both national and provincial overviews, pest information is usually recorded on colored provincial or national topographic series maps of 1:100 000 or 1:125 000 scale or on 1:250 000 when those scales are not available. While larger scale maps allow for greater accuracy and detail, the use of scales such as 1:40 000 or 1:50 000 are more appropriate for local stand level detail.

At least two copies of each map are needed; one as a working map and the other as a clean summary which is to be digitized. As an aid to detection, the working copy may include the previous year's infestations plotted by GIS. This enables the observer and pilot to plan the flight efficiently and accurately locate areas where pest damage is to be mapped. It also allows any more expansions and changes over time to be checked and better identified. Flight lines with directional arrows are recorded on the map as the flight progresses. The date of the survey and the names of observers should also be noted on the map. Since space in an aircraft is at a premium, excess paper on the map edges is often trimmed away and the maps folded.

Equipment

Each observer should be equipped with a supply of pens and sharp pencils, binoculars, camera, extra film, amber-tinted sunglasses, lunch and motion sickness medication if needed. If the aircraft is not equipped with radio headsets, foam ear plugs or some other form of hearing protection should be used. Aircraft must be equipped with a radio programmed for BC Forest Service District and Air Operations/Fire Centre check-ins.

Aircraft

Aircraft selection may be largely determined by local availability, but should be of high-wing configuration for ease of lateral and downward viewing, have seating capacity for at least four and be capable of sustained flight of 80 to 90 knots. In remote coastal applications and some northern locations, a float or amphibious version is often more desirable due to better fuel availability and landing opportunities. In the central and southern interior of the province, wheeled aircraft with fixed or retractable landing gear are preferred. Performance characteristics of the aircraft will be determined by type of terrain and area of coverage. Over flat and rolling landscape or small drainages, a Cessna 180 or equivalent may be sufficient, while in mountainous terrain, an aircraft with stronger performance such as a Cessna 210 or twin-engine Cessna 337 is more appropriate for climbing out of steep valleys. Though aircraft availability and type may be a limiting factor, safety should never be compromised. To avoid fatigue and loss of concentration, daily flights should be limited to 5 hours duration. Also ensure you are well rested before flight and avoid changes in diet prior to flying. For overview surveys helicopters are not cost effective and are usually limited to the occasional pest identification or assessment in otherwise inaccessible areas or as a follow-up after the initial fixed-wing flight.

Weather

Weather is one of the most critical factors governing the success of an aerial survey and an essential part of preflight planning. Regardless of the prevailing weather, a daily weather forecast describing flying conditions should be obtained to ensure there is good visibility and a minimum ceiling of about 3000 feet. Local weather information can be obtained by calling the Forest District office in the area scheduled for mapping. Clear and sunny days are preferred to maximize detection of defoliation and bark beetle-killed trees for mapping and photography, but solid high overcast giving the forest a monochromatic look, is also acceptable. Broken cloud conditions where one is constantly shifting between sun and shade are extremely difficult to map under, as the eyes are forced to adjust every time the light changes. Such conditions are very fatiguing and important infestations can be missed in the blind spots. Since shadow from low sun angle can obscure features early or late in the day, especially in areas of significant topographic relief, the optimum flight period is between mid-morning and mid-afternoon when the sun angle is highest. Typically, some flight adjustments may be required when dealing with unstable air in the afternoon.

Safety

Prior to each flight, onboard personnel and the ground communications centre should know the intended flight plan and duration. Known as "positive flight following" or "flight watch", location updates are radioed every 30 minutes to either the BC Forest Service Fire Centre or the appropriate district office, depending on the local protocols. Emergency equipment such as first-aid kit, emergency locator beacon and survival gear must be in place and emergency procedures gone over by the pilot prior to flight. Radio headsets are highly recommended if available, for both hearing protection and flight communication. At the very least, in the event the aircraft is not equipped with radio headsets, noise abatement equipment such as foam ear plugs should be used. Amber-coloured sunglasses are often used for both eye protection and to enhance color differentiation on the ground. Be in frequent communication with the pilot regarding direction, altitude changes, air speed adjustments, fuel considerations, meteorological conditions and ferry time estimates. Do not hesitate to ask questions or discuss with the pilot anything which causes you concern. While the observer who chartered the aircraft has jurisdiction over the basic flight procedure, the pilot is ultimately responsible for the aircraft and the safety of the passengers, and may overrule any aspect of the survey plan with respect to aircraft operation and safety. While the normal flying height is usually between 1500 and 3000 feet above the terrain, a minimum flying height of 500 feet above ground level must be observed as a safety precaution, such as when crossing ridges between drainages. Depending on the type of aircraft used, minimum airspeed should range between 70 and 90 knots.

- Public Service of Canada employees are covered by The Flying Accidents Compensation Regulations for injury or death as result of a non-scheduled flight undertaken by an employee in the course of duty.

AERIAL SURVEY PROCEDURES

LIMITATIONS

The primary limitation of the overview aerial survey is one of perception, particularly as it pertains to bark beetles. Some forest managers may expect to be able to make stand level decisions on the basis of the overview when this is clearly beyond its scope. Generally, only estimates of current damage are given, while older tree mortality is usually not included in the total acreage figure. However, mortality estimates are made, if applicable, following the collapse of defoliator infestations. If the intent of the overview survey program has been consistently met, estimates can also be made of cumulative mortality caused by bark beetles in specific stands by overlaying successive years of damage. Additional ground survey assessments are needed to calculate the total extent of pest incidence and damage. In the absence of more detailed information, aerial-sketch mapping results should not be extrapolated beyond reasonable bounds and expectations.

MAPPING

Ideally, two observers are used, one on either side of the plane, to expedite coverage and improve accuracy. The forward observer is usually the more experienced individual for the particular area and has the overall responsibility for flight direction, altitude and speed. With attention to elevation, map contours and natural features, the location, relative size, severity and damage, and probable cause are delineated on topographic maps. As infested areas are detected, they are plotted on the map either as a polygon, or as a dot representing infestations of less than one hectare.

Plan a flight line that covers the survey area. Topography will usually have an influence on the route. Over level terrain, flight lines are usually flown on a parallel grid with some overlap so that no area is missed. In mountainous terrain, contour flying is most efficient with one or more passes through a watershed depending on its size and lighting. In some instances a zigzag flight through a valley may be sufficient when only one pass is made. This action gives the opportunity to map pest damage behind and below the aircraft as well as laterally. Flight lines should always be marked on the map with arrows showing direction. Some oblique photography or video is recommended for a visual record, a training guide, and occasionally to refine sketch maps and assessment of damage. After each flight, both mappers compare their respective maps and produce a composite which later will facilitate GIS entry at the office.

The detection and location of damage should be accurate to the scale of the map used. However, when using smaller scale maps such as 1:250 000, the size of infestations is frequently exaggerated, especially when small pockets comprised of 5 to 50 trees each are mapped. This was found to be true in comparisons of selected outbreaks shown on aerial photographs versus sketch mapping. Harris and Dawson (1979) found the total area sketch mapped to be 34% larger than measured on photographs. Similar results were obtained by Gimbarzevsky et al. (1992) in comparison data from ground plots, aerial sketch mapping and various types of remote sensing. As a rule, the largest topographical map scale available should be used, normally up to 1:100 000. Occasionally, larger scale maps up to 1:50 000 are used, but the large number of maps required for overview coverage makes organization and sorting in the cramped environment of a small plane difficult and time consuming.

CLASSIFICATION OF DAMAGE

While classification of damage is a subjective judgment by the observer, past surveys have shown that experienced personnel can estimate damage intensities fairly accurately. Help in maintaining accuracy and consistency can be done by referring to photo standards (see photos), periodic flights with others and thorough quality check flights.

Observable damage symptoms can vary among the different bark beetles and between bark beetles and defoliators. Even some defoliators can be differentiated by their damage patterns. It is important that the observer recognize these differences. Some of the types of damage visible from the air include:

- defoliation (budworms, loopers, tussock moths, tent caterpillars, larch casebearers, etc)
- fading or discoloration of foliage (needle miners, aphids, climatic)
- single or group tree killing (bark beetles, porcupine, root rot, flooding, lightning)
- flagging of foliage (animal, fire, herbicides)
- blowdown

BARK BEETLES

Pine killed by mountain pine beetle initially appear chlorotic, then gradually turn yellow and fade to red within one year of attack. By the last stage of color change in mid-summer the trees are mostly without brood, as is also the case with Douglas-fir beetle. Trees killed by spruce beetle have variable colour and red or brown trees can still contain live beetles. As new attacks are not detected by aerial surveys, ground assessments are made to determine current infestation status. For aerial survey purposes, a red tree is one that was attacked and killed the previous year. These are the trees that are mapped. Gray trees are those that have been dead for two or more years and should have been mapped during a prior survey. Small infestations of up to 50 trees may be located on the map as a dot, with the number of trees and the abbreviation for the appropriate tree species beside it. All dots (point sources) are classified as severe. For GIS input the following scale is applied to area estimates:

2-30 trees = 0.25 ha; 31-50 trees = 0.50 ha.

For larger areas, a polygon is drawn around the infested trees and marked with the appropriate damage classification as follows (only red trees are recorded—or note if otherwise):

Light: 1-10% of trees recently killed

Moderate: 11-29% of trees recently killed

Severe: 30%+ of trees recently killed

Gray: (Old): tree mortality 2 or more years old

DEFOLIATORS

Defoliated trees, stands or hillsides assume a reddish tinge as a result of active feeding on the foliage. Only the current year's feeding damage is mapped. In areas where severe defoliation has occurred for several years, trees with little or no remaining foliage may appear gray. In light infestations close observation is necessary because defoliated trees do not readily stand out. Defoliation intensities also tend to fade into each other and subjective delineations must often be hastily made between areas of differing intensity. When possible, ground checks should be done to verify identification of the defoliator, particularly in new infestations. Following are the severity classes normally used to help classify an infestation (see also photo standards in Appendix).

Light - discolored foliage barely visible from the air, some branch tip and upper crown defoliation.

Moderate - pronounced discoloration, noticeably thin foliage, top-third of many trees severely defoliated, some completely stripped.

Severe - bare branch tips and completely defoliated tops, most trees sustaining more than 50% total defoliation.

Classification of *tree mortality* caused by defoliators is the same as that for bark beetles.

OTHER PEST AND ABIOTIC DAMAGE

While bark beetle and defoliator infestation assessments are the main targets of the aerial survey flights, other types of damage are noted if the observer considers this damage significant. Other forest disturbances mapped during regular aerial surveys include blowdown, winter damage, animal damage, flooding, foliage diseases, root rots and pollution damage. Observable damage symptoms can vary considerably between each, or be very similar. Where blowdown and flooding are usually easy to recognize due to their physical characteristics or association, others such as winter damage and foliage diseases are more difficult to identify as they can mimic other types of damage such as defoliation (and vice-versa). Root rot disturbances are also difficult to map due to the scattered nature and various stages of decline of infected trees.

Damage agents sometimes observed during aerial surveys that can be confused with damage caused by insects include:

- porcupine feeding
- bear damage
- herbicide application
- weather related (winter drying, hail, drought, sunscald, lightning)
- large cone crop
- needle diseases
- root rots
- fire damage
- flooding
- pollution; ground level ozone

AERIAL SURVEY TIMING

The overview aerial survey is designed to incorporate mapping of visible damage from as many forest pests as possible in one flight. However, the period when damage (primarily insect) is most visible varies with the pest species and its geographical distribution. In most cases there is sufficient overlap of defoliator damage and bark beetle-kill to properly schedule both types of damage in the same survey. The normal aerial survey period in British

Columbia and Yukon is between early July and late August, which provides maximum detection of common pests with a minimum of duplicate flying (Table 1). Winter moth, tent caterpillars, spruce aphid and lodgepole pine needle disease are examples of some common pests that do not fit the general bio-window and may require separate surveys prior to July 1.

Table 1. The bio-window for aerial survey mapping of bark beetle-killed tree and defoliator damage in British Columbia and Yukon.

Tree Species	Pest	Peak Period
Bark Beetles		
Pine		
lodgepole, western white whitebark, ponderosa	mountain pine beetle	early July—early Sept.
ponderosa	western pine beetle	early June—mid-Aug.
lodgepole	engraver beetles (Ips spp.)	July—September
Spruce		
Engelmann, white	spruce beetle	mid-June—early Sept.
Douglas-fir	Douglas-fir beetle	mid-June—late Aug.
True firs		
sub-alpine fir	western balsam bark beetle	anytime
grand fir	fir engraver	early July—late Aug.
Defoliators		
Douglas-fir	western spruce budworm	late June—mid-Aug.
	Douglas-fir tussock moth	mid-July—late Aug.
	false hemlock looper	mid-July—late Aug.
Hemlock		
western	western blackheaded budworm	mid-July—early Sept.
	western hemlock looper	mid-July—early Sept.
	green-striped forest looper	mid-July—early Sept.
	saddleback looper	mid-July—early Sept.
	phantom hemlock looper	early July—late Aug.
	gray spruce looper	late Aug.—early Oct.

Tree Species	Pest	Peak Period
True firs		
sub-alpine	2-year-cycle spruce budworm	mid-July—mid-Aug.
Pine		
lodgepole	pine needle sheathminer	late June—mid-Aug.
	conifer sawflies	mid-July—late August
	pine butterfly	July through August
Spruce		
Sitka	spruce aphid	March through June
Larch		
western	larch casebearer	mid-May—mid-June
	larch sawfly	late July—early Sept.
	larch budmoth	early July—mid-Aug.
Deciduous	tent caterpillars	early June—early July
	satin moth	early June—mid-July
	birch leafminers	early June—mid-July
Other Damage		
Pine		
lodgepole	pine needle cast	May through June
	winter drying	April through June
True firs		
sub-alpine	balsam woolly adelgid	Aug. through Sept.
amabilis fir	balsam woolly adelgid	Aug. through Sept.
grand fir	balsam woolly adelgid	Aug. through Sept.

MAP PROCESSING

COMPOSITE MAP

Daily mapping results should be compared among observers and a composite (master map) drawn after each flight while visual image retention is still good. The product should be a quality sketch map suitable for digitizing or photocopying. Each map should have a standard color-coded legend (see appendix) representing each pest mapped. Additional data includes dates of flight, names of observers and type of aircraft used. Upon completion of the composite map, current infestations and areas of damage are entered into a GIS, from which the completed data is ultimately distributed. It should be noted that traditionally pest data from maps has been entered into the GIS by the Canadian Forest Service, but digital format is preferred from outside agencies. Because GIS generated maps appear clean and professional, it is easy to make assumptions regarding their veracity, but it must be emphasized that the results are only as good as the data entered.

GIS ACTIVITIES

Pest data from maps is recorded by digitizing the polygons and assigning attributes of pest severity, year, forest region and map reference. From these data, searches or compilations of any combination of desired attributes can be made. During digitizing, the current and previous year's infestations can be viewed on-screen, providing an opportunity to make changes before entry into the database. A final edit of the digital map against the sketch map is required. A legend should be produced to accompany the map according to the standards outlined in the appendix. Observers are generally responsible for input of their own data, so errors and omissions can be minimized. However, increasingly the input of map data will be by people other than those participating in the actual mapping and will leave little basis for decision making if discrepancies occur. GIS reproductions at various map scales are distributed to cooperating agencies such as the BC Forest Service, forest industry and Parks. Using report generators, area and polygon tallies can be derived for selected areas, map sheets, administrative regions or the entire province or territory.

DATA PREPARATION

Map data from sources other than CFS should be provided in digital format whenever possible. ARC/INFO (UNIX) EXPORT format, i.e. ".e00" files are preferred, however special arrangements can be made to accommodate other digital formats. Data incompatibilities can create time delays and this should be taken into account whenever data processing is required. Our GIS section should be consulted prior to making any data transfer or sharing agreements. Digital information must contain the minimum attributes:

- year
- pest
- severity
- NTS map reference

METADATA

In addition, all mapping data must be accompanied with its own metadata (associated information), which describes in detail:

- map projection (Lambert, UTM, Polyclinic, etc)
- projection parameters (Numerical data describing the units, origin, false easting and northing, central meridian, etc)
- accuracy limitations (scale the data was created at, speed at which data was gathered, level of accuracy desired, i.e. overview or operational)
- description of each item in the database and the values for each
- method of data collection (detailed aerial survey, overview quick sketchmapping, ground survey, transfer of data from air photos)
- scale data was originally collected at
- purpose of data collection - what the data is intended for (collected as secondary data while conducting other surveys, detailed operational procedures, overview survey, rough locational information only)

- contact names and location for future reference
- permission or restrictions on redistribution of data

DATA TRANSFER

Media

1. Via "ftp" - the Forest Health Network uses the Natural Resources Canada anonymous site 'ftp.pfc.forestry.ca', or with special arrangements through the NRC computing department an account can be created on our GIS workstation.
2. 3 1/4" diskette
3. 1/4" tape data cartridge

Format

1. UNIX is preferred
2. DOS can be handled

Many other data transfer mechanisms exist, however they are either not available to us or not compatible with our hardware or software. In the event these methods are not available to the user, consultation with the GIS section at Pacific Forestry Centre may prove helpful. With additional special arrangements, hardcopy maps can be received and digitized at a scale of 1:100 000 or 1:250 000 depending on time and availability of maps. The key to successful GIS data submissions and processing is consultation before commencing a mapping project.

ACCURACY

Aerial surveying is not an exact science, but an observer should do everything to ensure the best calls are made. No matter what type of aircraft, the flying height, the weather, the survey map base or the bio-window, the survey is always going to be less than perfect. Credibility comes from following established criteria:

- not missing extensive damage
- getting the polygon or dot in the right geographic location
- drawing polygons to accurately reflect infested areas on the ground
- correctly calling the tree (host) species
- knowing and calling the pest damage correctly
- accurately estimating defoliation or damage intensity and numbers of trees

Aerial sketch-mapping can be enhanced with the use of aerial photographs, especially in areas of extensive pest damage on even terrain with few geographical features. Up-to-date aerial photos can be useful in showing logging, burns and other details that observers can delineate from infested timber.

Studies have shown that defoliation estimates are frequently exaggerated during sketch mapping, while counts of bark beetle-killed trees are low when compared to aerial photographs, ground plots and some remote sensing techniques (J.W.E. Harris et al. 1979, 1982, and Gimbarzevsky et al. 1992). For a given area, assessment of aerial survey accuracy and presence of bias are best determined using a multistage sampling procedure, comparing sketch mapping, aerial photography and ground plot data.

CHECK FLIGHTS

Periodic check flights of overview surveys should be done by experienced observers to maintain accuracy and precision of pest assessments within acceptable parameters such as the qualitative and quantitative criteria listed above. The recommended process is as follows:

1. A flight audit should be made no more than two weeks after the initial survey and remain within the bio-window of the pests mapped.
2. Identify the pests to be assessed from the map legend.
3. Use same map scale and any previous data.
4. Randomly select sample polygons or dots representing 5 to 10% of the total area mapped. This can be done by plotting transects through infestations and mapping only intersected polygons. Normally, this should not amount to more than the equivalent of a weeks flying for all of B.C. and the Yukon.
5. Analyze and compare both maps against established criteria such as pest and host identification, damage intensity levels, etc.
6. It is suggested that the level of accuracy be proportional to the degree of mapping difficulty, i.e., scattered occasional defoliation or bark beetle kill versus extensive defoliation or large scale beetle outbreak mapping. However, acceptable limits of accuracy are expected to be within 30% plus or minus the check flight assessment. When those limits are exceeded the observer should be re-assessed to determine the source of discrepancy.

CONCLUSIONS

While improvements and efficiencies will continue to be sought, annual aerial surveys are expected to remain a basic method for contributing to the national and provincial annual summary of forest health conditions. It is hoped that this standards manual will aid in providing consistency and accuracy to aerial sketch mapping.

For further information or comment please contact:

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COLOR PHOTOS OF PEST DAMAGE

Bark Beetles

Figure 1 a) Enlargement of 1:100 000 NTS map showing polygons of mountain pine beetle-killed lodgepole pine and the original 70 mm photo, Flathead Valley, Nelson Forest Region.

Figure 1 b) Enlargement of original 70 mm photo with examples of LIGHT, MODERATE and SEVERE mortality of lodgepole pine caused by mountain pine beetle.

Figure 2 a) Enlargement of 1:100 000 NTS map showing polygons of mountain pine beetle-killed lodgepole pine and the original 70 mm photo, Elk Creek, Nelson Forest Region.

Figure 2 b) Enlargement of original 70 mm photo with examples of LIGHT, MODERATE and SEVERE mortality of lodgepole pine caused by mountain pine beetle.

Figure 3 Examples of LIGHT, MODERATE AND SEVERE classification of mountain pine beetle infestation (from FIDS *General Instructions Manual*).

Defoliators

Figure 4a) Enlargement of 1:100 000 NTS map showing polygons of Douglas-fir tussock moth defoliation of Douglas-fir and the original 70 mm photo, Lanes Creek, Kamloops Forest Region.

Figure 4b) Enlargement of original 70 mm photo with examples of MODERATE, SEVERE and GREY categories of defoliation of Douglas-fir by Douglas-fir tussock moth, Lanes Creek, Kamloops Forest Region.

Figure 5a) Enlargement of 1:100 000 NTS map showing polygons of western spruce budworm defoliation of Douglas-fir and the original 70 mm photo, Boston Bar, Vancouver Forest Region.

Figure 5b) Enlargement of original 70 mm photo with examples of LIGHT, MODERATE and SEVERE categories of defoliation of Douglas-fir by western spruce budworm, Boston Bar, Vancouver Forest Region.

Figure 6 Examples of LIGHT, MODERATE and SEVERE defoliation of Douglas-fir by the western spruce budworm (from FIDS *General Instructions Manual*).

AERIAL SURVEY MAPS

Figure 7 Example of a working (rough) copy of the aerial survey map.

Figure 8 Example of a composite map, prior to digitizing.

Figure 1 a) Enlargement of 1:100 000 NTS map showing polygons of mountain pine beetle-killed lodgepole pine and the original 70 mm photo, Flathead Valley, Nelson Forest Region.

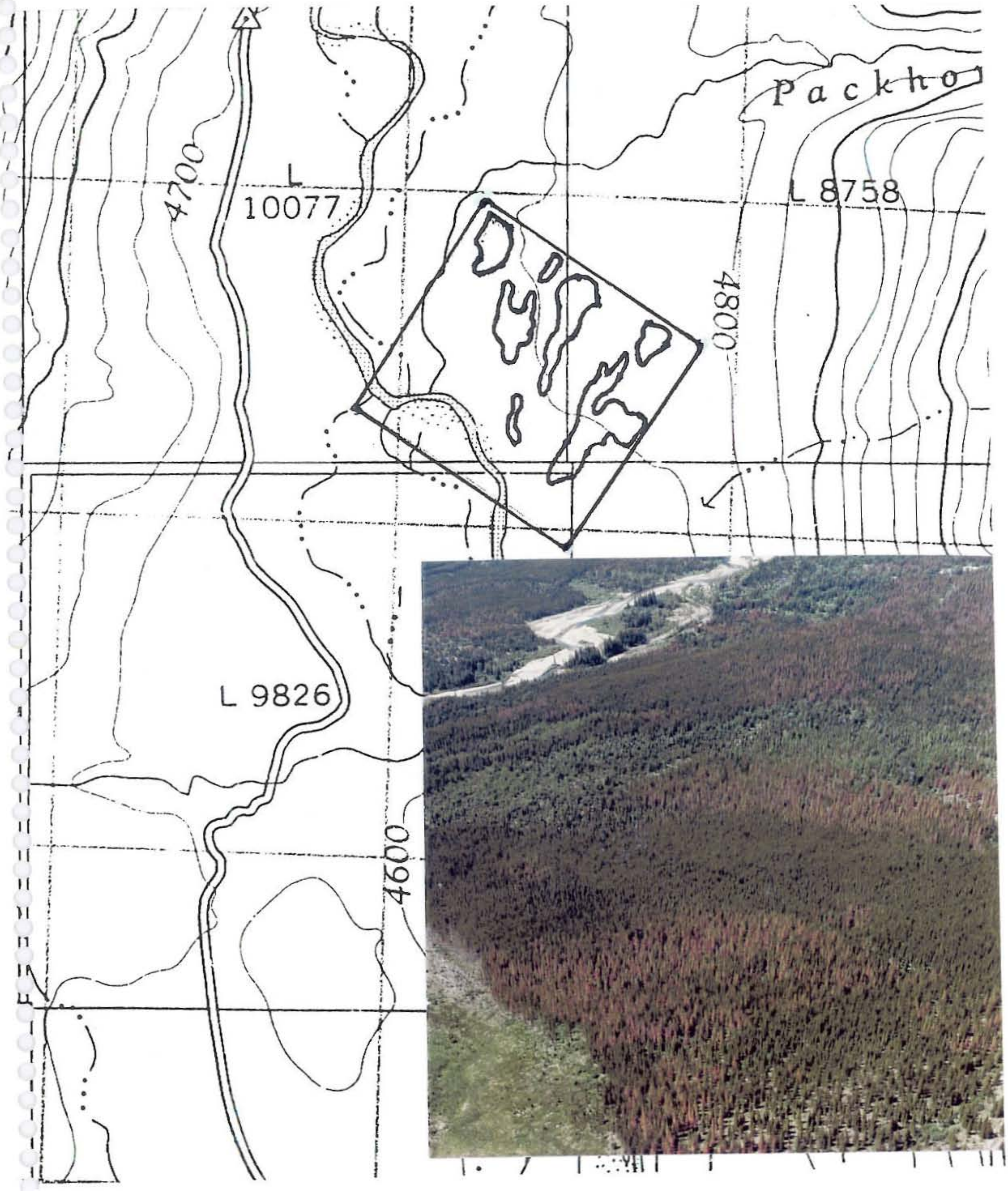
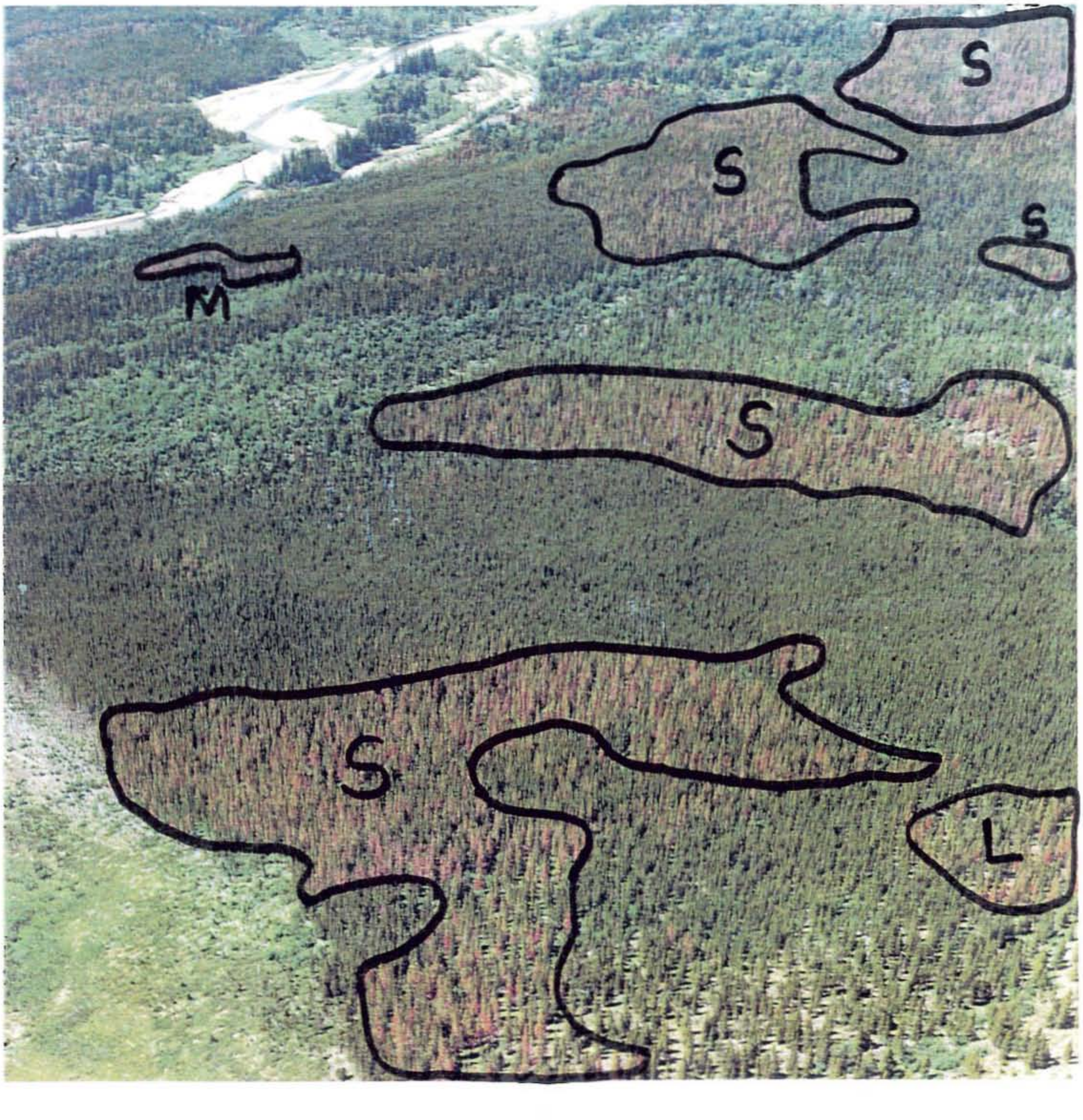


Figure 1. b) Enlargement of original photo with polygons describing LIGHT, MODERATE and SEVERE mortality of lodgepole pine caused by mountain pine beetle



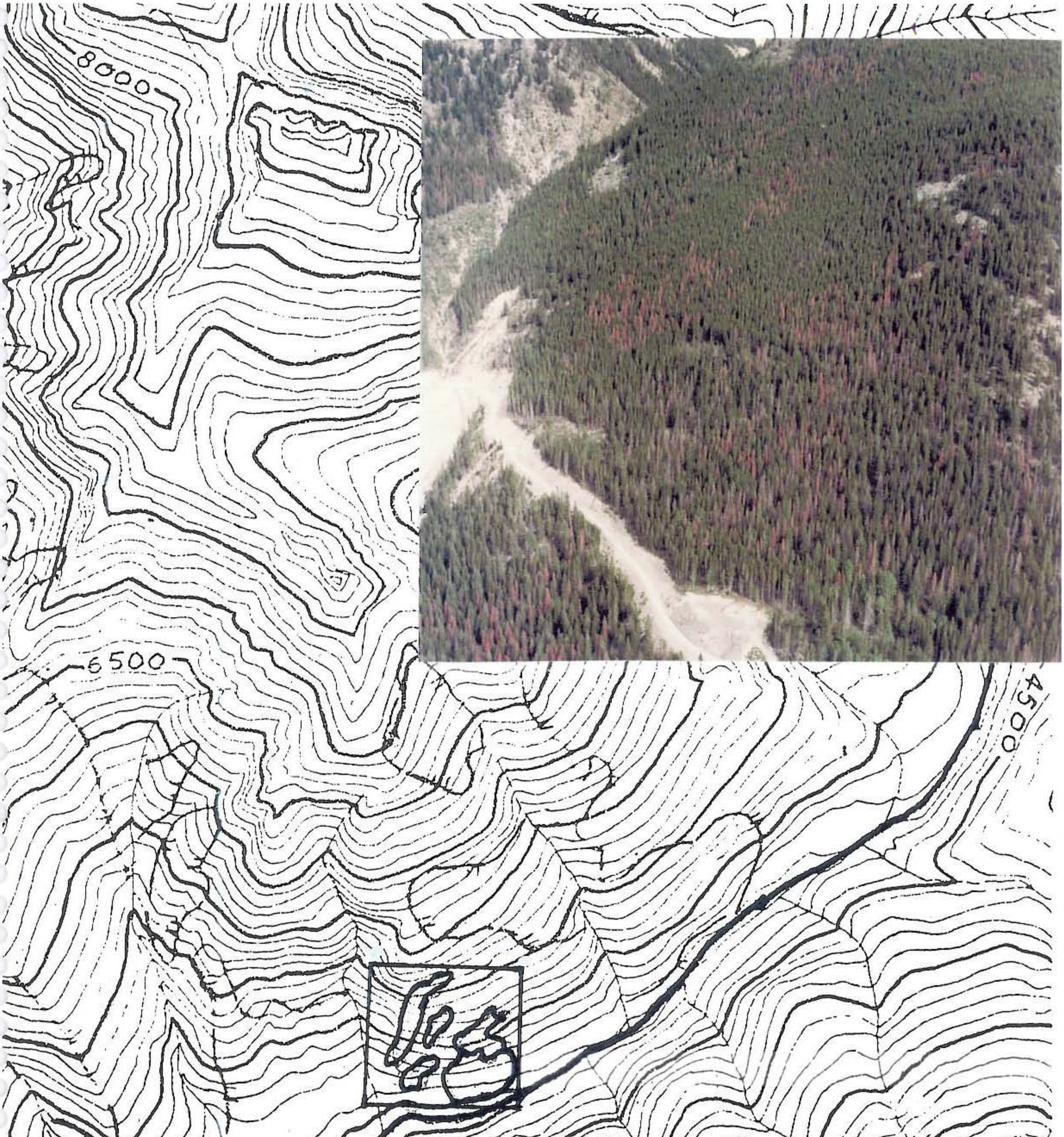
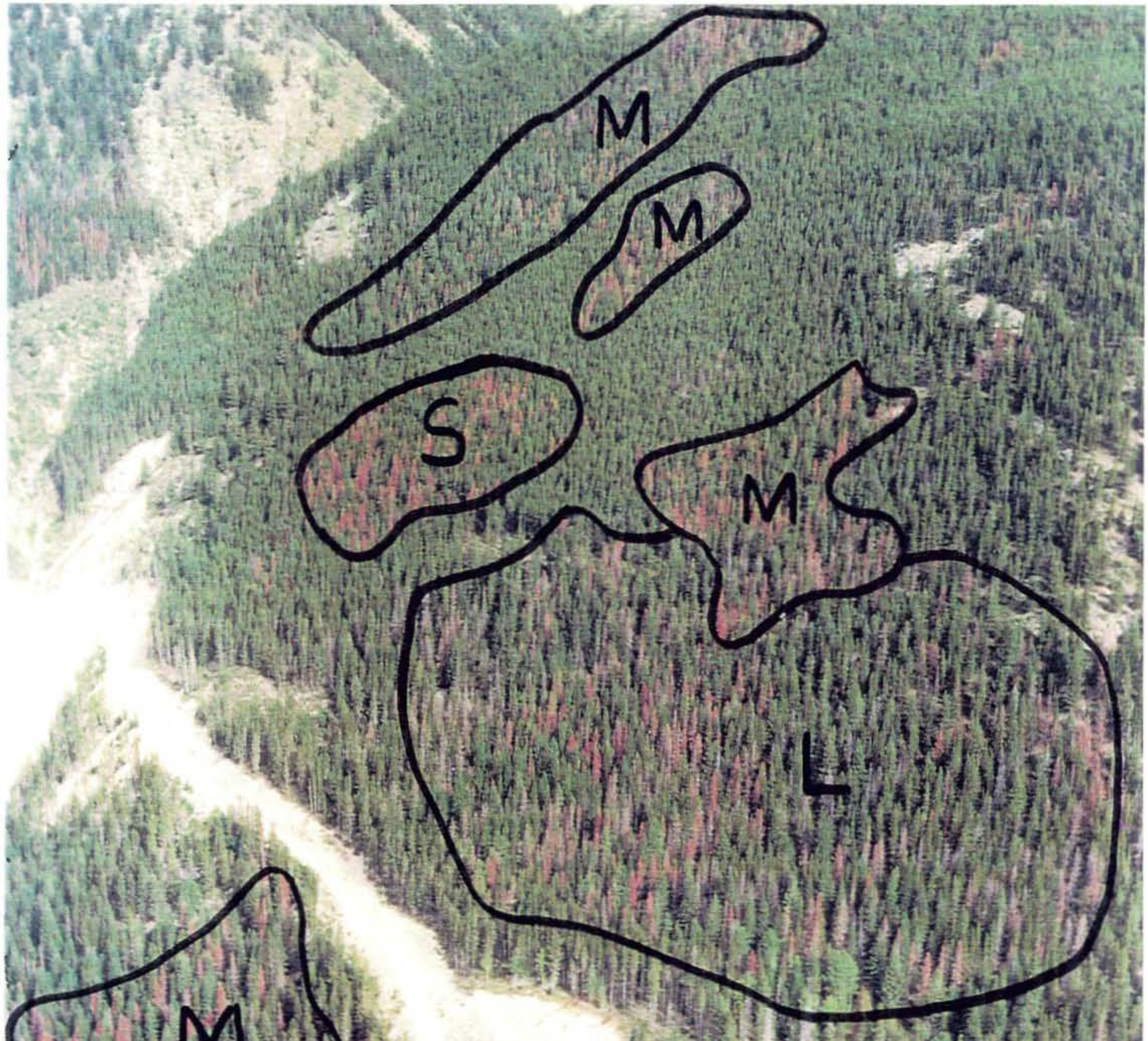


Figure 2 a) Enlargement of 1:100 000 NTS map showing polygons of mountain pine beetle-killed lodgepole pine and the original 70 mm photo, Elk Creek, Nelson Forest Region.

Figure 2 b) Enlargement of original 70 mm photo with examples of LIGHT, MODERATE and SEVERE mortality of lodgepole pine caused by mountain pine beetle.



Light -
Moderate
(prob. 5-10%)

Moderate

Severe

Figure 3 Examples of LIGHT, MODERATE AND SEVERE classification of mountain pine beetle infestation (from FIDS *General Instructions Manual*).

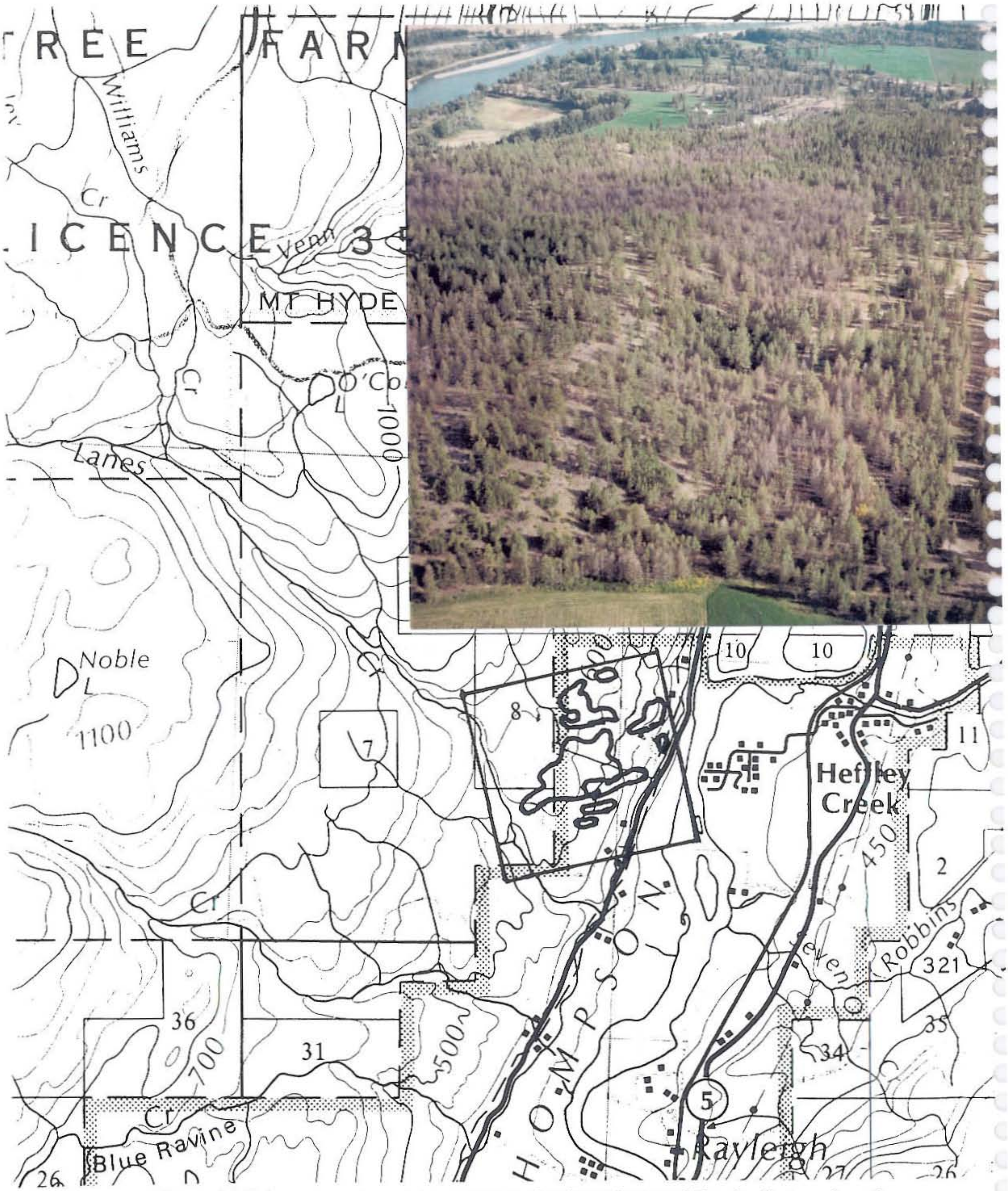


Figure 4a) Enlargement of 1:100 000 NTS map showing polygons of Douglas-fir tussock moth defoliation of Douglas-fir and the original 70 mm photo, Lanes Creek, Kamloops Forest Region.

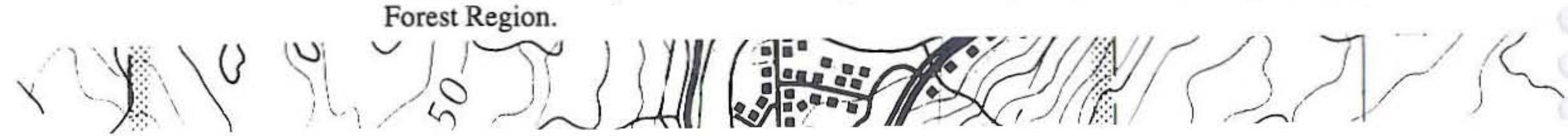
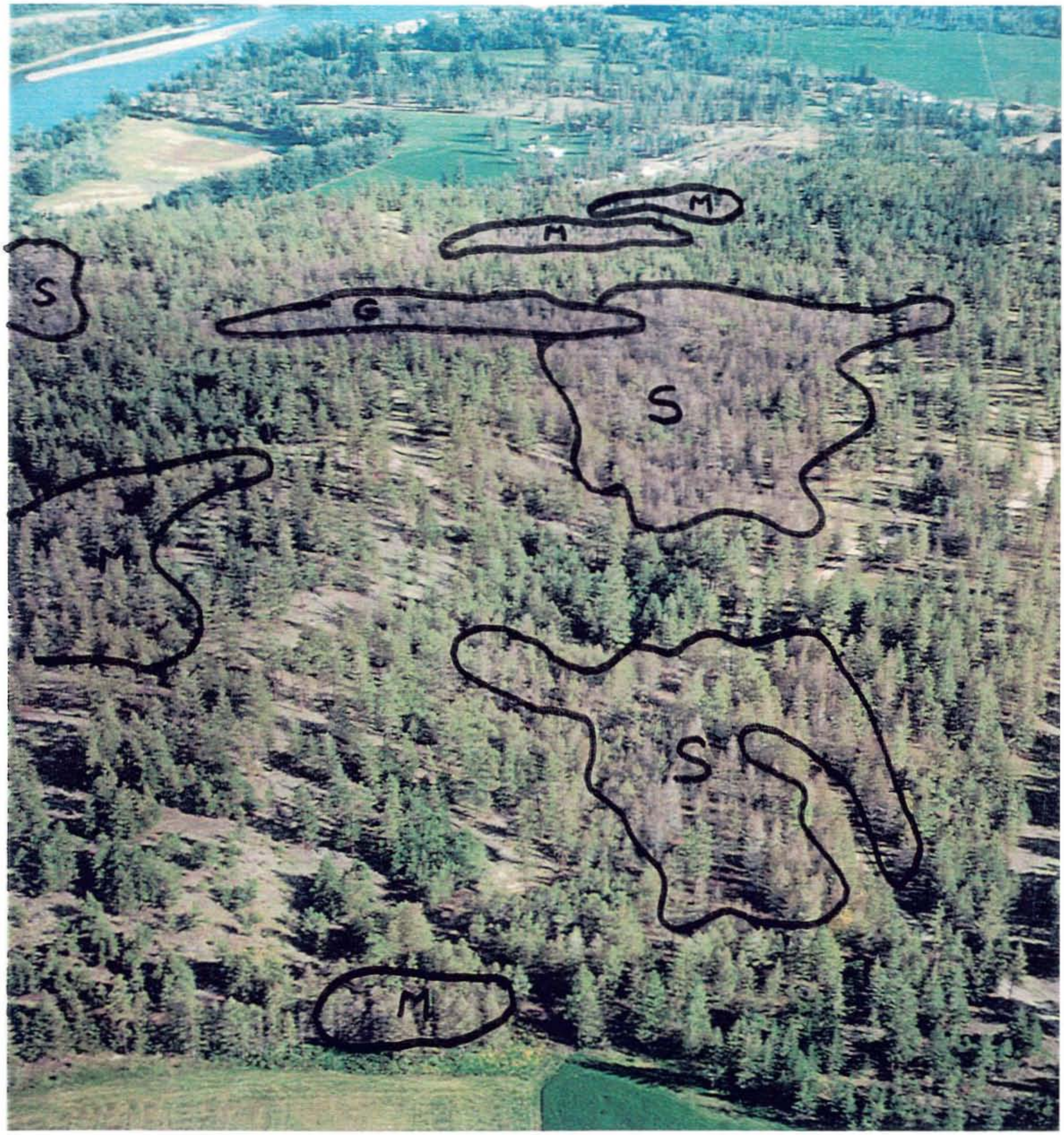


Figure 4b) Enlargement of original 70 mm photo with examples of MODERATE, SEVERE and GREY categories of defoliation of Douglas-fir by Douglas-fir tussock moth, Lanes Creek, Kamloops Forest Region.



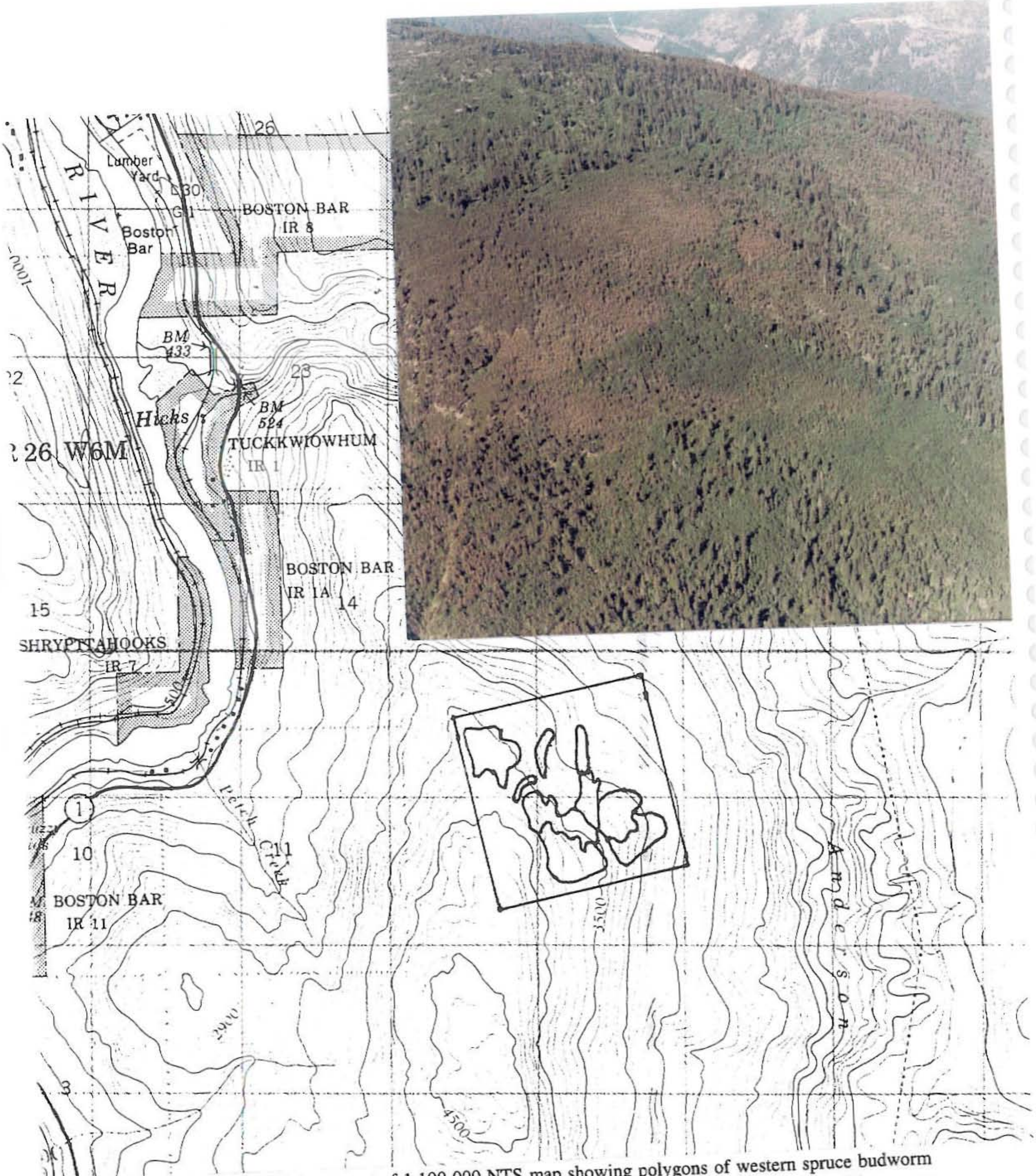
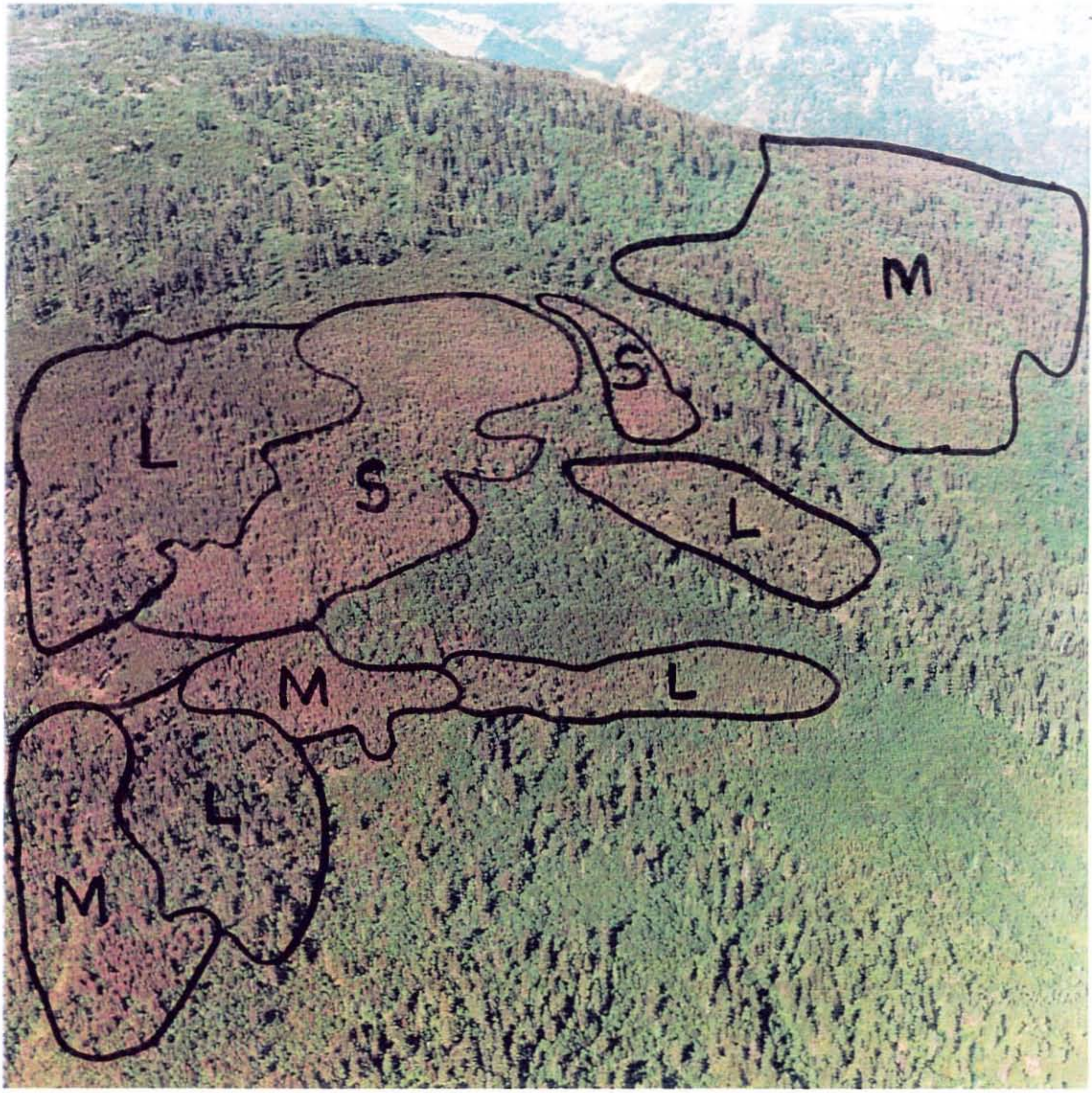


Figure 5a) Enlargement of 1:100 000 NTS map showing polygons of western spruce budworm defoliation of Douglas-fir and the original 70 mm photo, Boston Bar, Vancouver Forest Region.

Figure 5b) Enlargement of original 70 mm photo with examples of LIGHT, MODERATE and SEVERE categories of defoliation of Douglas-fir by western spruce budworm, Boston Bar, Vancouver Forest Region.



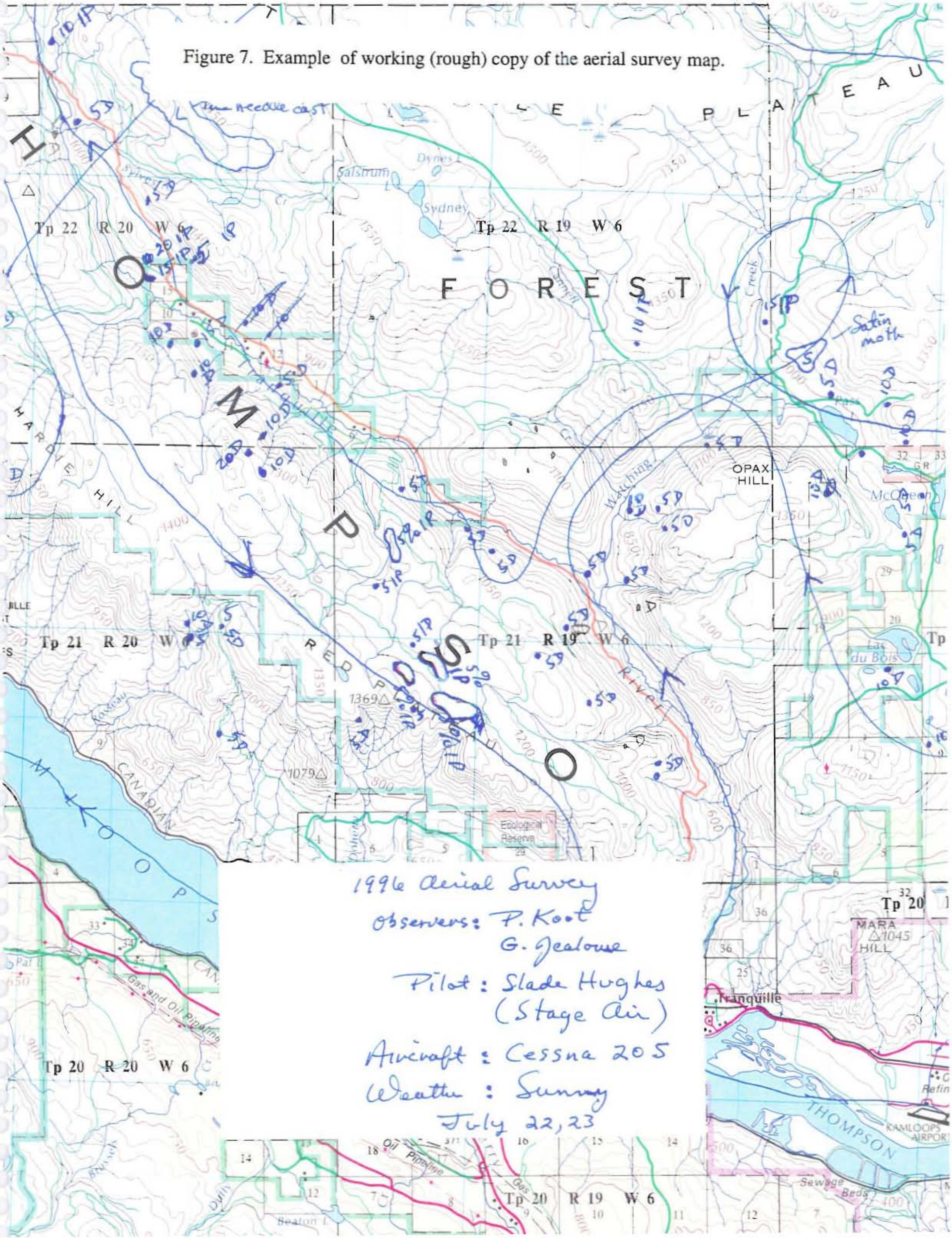
Light

Moderate

Severe

Figure 6 Examples of LIGHT , MODERATE and SEVERE defoliation of Douglas-fir by the western spruce budworm (from FIDS *General Instructions Manual*).

Figure 7. Example of working (rough) copy of the aerial survey map.



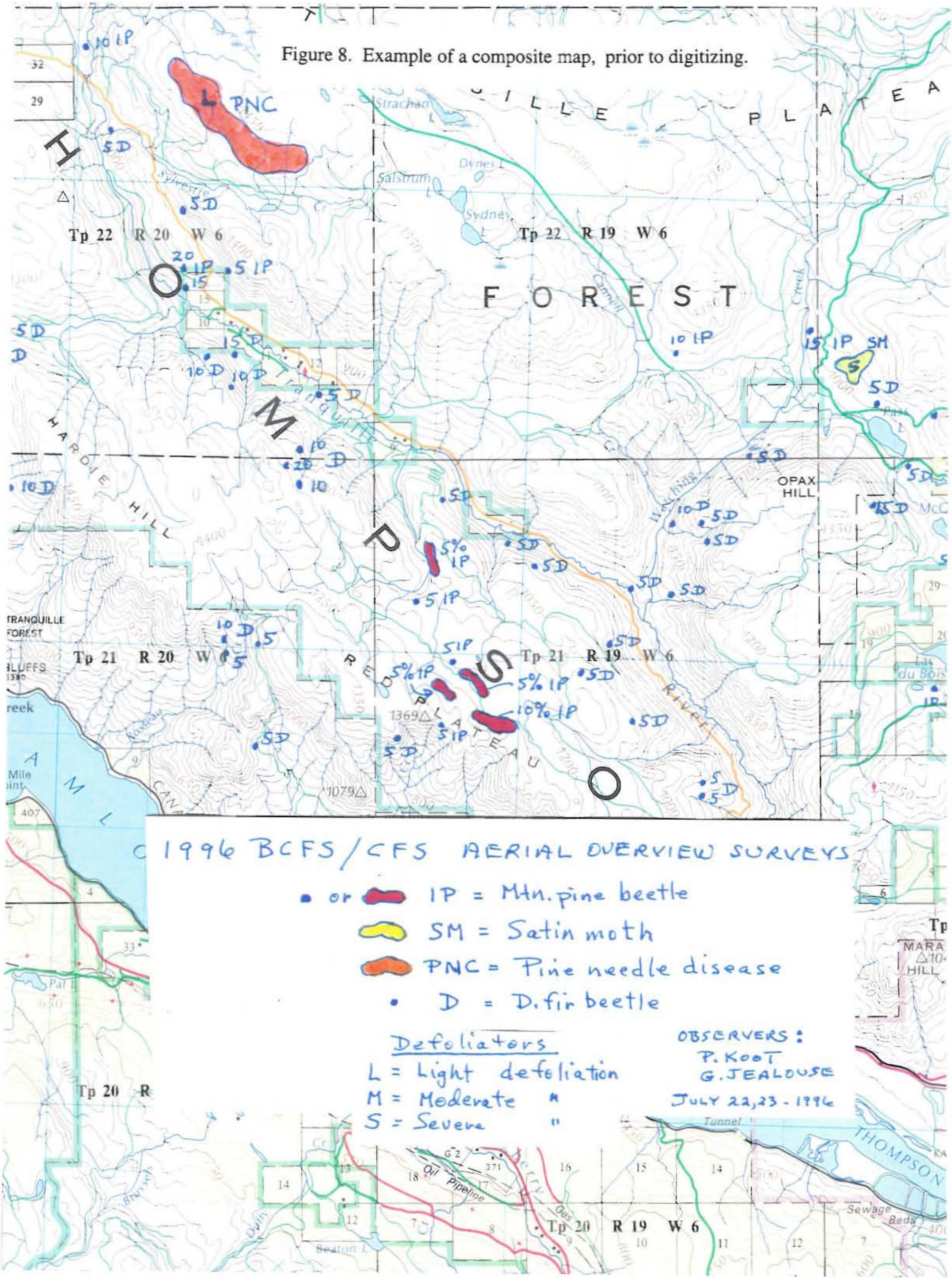


Figure 8. Example of a composite map, prior to digitizing.