REMOTE SENSING FOR RENEWABLE RESOURCE MONITORING IN THE MARITIME PROVINCES

ANGUS C. HAMILTON

August 1978

TECHNICAL REPORT
NO. 62

PREFACE

In order to make our extensive series of technical reports more readily available, we have scanned the old master copies and produced electronic versions in Portable Document Format. The quality of the images varies depending on the quality of the originals. The images have not been converted to searchable text.

REMOTE SENSING FOR RENEWABLE RESOURCE MONITORING

IN THE MARITIME PROVINCES

By: Angus C. Hamilton
Chairman, Dept. of Surveying Engineering
University of New Brunswick

For: Land Registration and Information Service
Council of Maritime Premiers

August 1978

Reprinted October 1986

PREFACE AND ACKNOWLEDGEMENTS

This study is one of a series of background studies undertaken for the Council of Maritime Premiers at the request of the Land Registration and Information Service.

The author gratefully acknowledges the whole-hearted cooperation and assistance of all those, listed in Appendix E, who provided information and with whom helpful discussions were held. Many of these discussions were rather general in nature, however several individuals took the time to compile source material, or to review parts of the manuscript; for this, special thanks are extended to Mr. Ed Bailey, Mr. Ed MacAulay, Dr. Gordon Baskerville, Mr. Cal Bricker, Dr. Eugene Derenyi, Dr. A.F. Gregory, Dr. P.A. Lapp, Mr. Burtt Smith, Mr. C. Bradley Fay, Mr. Jack Bidlake, Mr. W.R. Trenholm, and Mr. Victor Zsilinszky. In addition, the assistance of Mr. Neil MacNaughton in editing and proof-reading the manuscript is gratefully acknowledged.

A.C. Hamilton

TABLE OF CONTENTS

REMOTE SENSING IN THE MARITIMES

LIST OF TABLES

LIST OF FIGURES

Glossary of Abbreviations

A.C.R.S.	Alberta Center for Remote Sensing
C.C.R.S.	Canada Centre for Remote Sensing, Dept. of Energy, Mines and Resources, Ottawa
C.G.I.S.	Canadian Geographic Information System, Lands Directorate, Dept. of the Environment, Ottawa
D.O.A. (C.)	Dept. of Agriculture (Federal)
D.O.A. (N.B.)	Dept. of Agriculture (New Brunswick)
D.O.A. (N.S.)	Dept. of Agriculture (Nova Scotia)
D.L.F.	Dept. of Lands and Forests (Nova Scotia)
D.N.R.	Dept. of Natural Resources (New Brunswick)
F.M.I.	Forest Management Institute, Dept. of the Environment, Ottawa
For. Res.	Forest Resources Dept. University of New Brunswick
L.R.I.S.	Land Registration and Information Service, Council of Maritime Premiers
M.R.M.S.	Maritime Resource Management Service, Council of Maritime Premiers
N.S.L.S.I.	Nova Scotia Land Survey Institute, Lawrencetown, N.S. (Dept. of Education)
O.C.R.S.	Ontario Centre for Remote Sensing
S.E.	Surveying Engineering Dept. University of New Brunswick
WOSFOP	Wood Supply and Forest Productivity (Software package)

INTRODUCTION AND SUMMARY

Remote sensing is a tool for gathering data. As such it is necessary to know what data is needed before developing a remote sensing program.

From a brief look at the challenges in forestry and in agriculture, it is apparent that there is a need for a renewable resources information system in the Maritimes.

It follows that if an information system is needed an on-going monitoring program will be essential. Thus a monitoring system is outlined.

The major part of this study is the definition of two projects - one in forestry and one in agriculture - to develop a monitoring program for a renewable resource information system.

In Chapter 1, an overview of Remote Sensing at the regional level is presented. From this it is concluded that the establishment of a centre or centres solely for remote sensing is not warranted in the Maritimes at this time. Instead it is suggested that it will be better to "build on strength" i.e. to strengthen those units in the operating departments and in academic institutions where there is already some capability. Unnecessary duplication can be minimized by a modest amount of cooperation.

In Chapter 2, on the assumption that a forest information system and hence a monitoring program is needed, a three year project to develop a forest monitoring program is proposed. The manpower requirement for this project is estimated at 17 person-years with equipment and operating costs equalling the costs for personnel.

In Chapter 3, on the assumption that an agriculture information system and hence a monitoring program is needed, a project to develop a crop monitoring program is defined. The manpower requirement for this is estimated as 10 person-years for development and 12 person-years per province for compiling a complete farm field inventory.

It is assumed that the Canada Centre for Remote Sensing, the Forest Management Institute, the Forest Fire Research Institute and Agriculture Canada will each collaborate on the project by making their expertise and equipment available from time to time as part of their research effort. It must be stressed however that if some regional agency, such as LRIS, operating directly under the Council of Maritime Premiers does not provide the coordination and the major funding, it may take a decade or more for an effective renewable resource monitoring program to evolve.

In Chapter 4 a list of facilities in the Maritimes available for tactical applications is tabulated. The term "tactical application" is introduced in order to include a wide range of sensor and interpretation methods under one heading. Thus it covers light aircraft, towers, balloons, survey cameras, Hasselblad cameras, as well as various mounts and hand-held configurations. No major project is proposed for tactical applications however the chapter is included in order to emphasize the point that a "quick response" capability is an essential part of remote sensing.

In Chapter 5 the evidence pointing to the need for a Renewable Resources Information System is summarized and the first step towards such a system is outlined.

1. OVERVIEW AND ORGANIZATIONAL STRUCTURE

1.1 What is Remote Sensing?

For many decades air photography was the only significant method other than the eye for "sensing" the features of the earth. In the last two decades however many non-photographic methods have been developed for sensing at a distance. Hence the term "remote sensing" has evolved to cover all of these methods, including photography. There are two significant ways in which remote sensing is more comprehensive than photography:

(i) remote sensing is not limited to the visible portion of the electro-magnetic spectrum; and

(ii) the method of recording the sensed data is not limited to light sensitive film; there are many instruments in which the sensed data is converted to an electrical signal, which in turn is converted to digital format and stored in some form of computer memory.

To describe all the forms of data whether recorded photographically or digitally the term "imagery" has evolved. "Remote" sensing can also be defined as all methods of sensing except proximity and immersion sensing. Even though it is a relatively new field of activity it has grown very rapidly. In 1975, the American Society of Photogrammetry published the Manual of Remote Sensing; it is in two volumes with a total of 2144 pages. For obvious reasons, no attempt will be made to summarize, condense or paraphrase the manual in this brief report. Nor would it be reasonable to expect that the reader should have read the Manual. However in view of the fact that there is no better definition of the terminology than can be found in the first chapter of the Manual, it is suggested that the reader review pages 1 to 26. (One copy of these pages is being submitted along with this report to LRIS; the reason more copies are not being provided is that many of the illustrations in the Manual are in color and hence not readily reproduceable.)

1.2 Remote Sensing Imagery and its Utilization in the Maritimes

1.2.1 Inventory

An approximate inventory of remote sensing imagery in the Maritimes is listed in Table 1. This is not intended to be by any means a complete inventory. To compile such an inventory would be a major project in itself. It is included here simply to establish the order of magnitude of the volume of imagery and to indicate the variety and the approximate proportions.

It is immediately clear that until recently black and white vertical air photos predominated. It is equally clear that color air photos are gaining acceptance and that the amount of color infrared is not neglibible. Although only a small amount of oblique photography is listed, this does not mean that only a small amount is taken. Oblique photography from hand-held cameras is usually taken for an immediate use and is not generally filed in any regional library.

Similarly, only a small amount of satellite imagery is listed. There are two reasons for this: one is that only a small amount of use has been made of satellite imagery to date; and the other is that one satellite image covers a very large area.

1.2.2 Use of Air Photography

Air photography generally has a primary use and a secondary use. The primary use is usually for some type of mapping; the specifications (flying height, camera type, film type, season, etc.) being drawn up to facilitate the production of the planned mapping.

There are countless secondary uses for air photos. Prior to the advent of the photomap series photos were used extensively in the field as a base on which to delineate data; foresters, geologists, pedologists (soil scientists), agrologists, biologists and many others all have used and still do use air photos in connection with their field work. Occasionally they have photography flown specifically for their project but generally they use copies of the best photography that is already available. Many individuals use air photos for recreational purposes such as hunting or fishing or simply to have a "bird's eye view" of their property. An important secondary use is as a historical record. In many cases, there is simply no other way to find out what changes have occurred in 30 or 40 years; this can apply equally to ecological or to economic (property related) questions.

Table 1(a). Aerial Photography: New Brunswick
(All Black and White)

Period	Flown by	Approx. Scale	Format	Approx. No. of Photos	Coverage and Purpose
1925-38	R.C.A.F.	1:15 840 (1" = 1 320')	7" x 9"	10 000	Selected areas for revision of N.T.S. map series.
1944-45	R.C.A.F.	1:15 840	7" x 9"	41 000	Entire province, multi-purpose.
1948-62	Dept. of Lands & Mines (Now DNR)	Oblique	6" x 6"	5 000	Various
1951-55	Contractors	1:15 840	9" x 9"	25 000	Entire province, for forest inventory.
1962-67	Contractors	1:15 840	9" x 9"	22 000	Entire province, for forest inventory.
1967-68	Contractors	Various	9" x 9"	3 000	By and for the federal government.
1968-69	Contractors	1:15 840	9" x 9"	3 000	Ste. Anne-Nackawic, International Paper and Miramichi Timber Resources, turned their negatives over to DNR.
1967-77	Contractors	From 1:3 000 to 1:40 000	9" x 9"	66 000	For line mapping at 1:1 200, 1:2 400, 1:4 800 and for photomapping at 20 000 1:10 000
1974-76	Contractors	1:20 000	9" x 9"	14 000	Entire province for forest cover mapping.
				189 000±	

There are no significant holdings of satellite imagery in N.B.

Table 1(b). Aerial Photography: Nova Scotia

Period	Scale	Format		Approx. No. of Photos
1961	1:15 840	B & W	9" x 9"	2 092
1962	1:15 840	B & W	9" x 9"	1 520
1964-65	1:15 840	B & W	9" x 9"	6 199
1966	1:15 840	B & W	9" x 9"	4 373
1967	1:15 840	B & W	9" x 9"	2 006
1969	1:6 000	B & W	9" x 9"	739
	1:16 800	Color	9" x 9"	3 120
1970	1:18 600	B & W	9" x 9"	309
	1:6 000	B & W	9" x 9"	112
	1:16 800	Color	9" x 9"	1 360
1971	1:39 600	B & W	9" x 9"	116
	1:19 920	B & W	9" x 9"	920
	1:6 000	B & W	9" x 9"	1 558
	1:12 000	B & W	9" x 9"	447
	1:18 000	B & W	9" x 9"	238
	1:16 800	Color	9" x 9"	3 971
	1:15 840	Color	9" x 9"	675
1972	1:6 000	B & W	9" x 9"	507
	1:19 800	B & W	9" x 9"	456
	1:12 000	B & W	9" x 9"	63
	1:2 400	B & W	9" x 9"	256
	1:16 800	Color	9" x 9"	130
1973	1:15 840	Color	9" x 9"	1 608
	1:6 000	B & W	9" x 9"	1 003
	1:10 000	B & W	9" x 9"	2 071
	1:33 000	B & W	9" x 9"	1 964

Table 1(b). Aerial Photography: Nova Scotia (Cont.)

Period	Scale	Format		Approx. No. of Photos
1974	1:10 000	B & W	9" x 9"	8 452
	1:10 000	Color	9" x 9"	2 399
	1:33 000	B & W	9" x 9"	1 548
1975	1:10 000	B & W	9" x 9"	8 587
	1:33 000	B & W	9" x 9"	3 394
	1:10 000	Color	9" x 9"	6 565
	1:62 000	I.R.	9" x 9"	356
1976	1:18 000	B & W	9" x 9"	68
	1:10 000	B & W	9" x 9"	451
	1:10 000	Color	9" x 9"	4 871
	1:62 000	I.R.	9" x 9"	750
1977	1:10 000	Color	9" x 9"	4 346
				79 600

Table 1(c). Aerial Photography: Prince Edward Island

Period	Scale	Format	Approx. No. of Photos	
1935	1:24 000	B & W 9" x 9"	948	
1958	1:15 840	B & W 9" x 9"	2 378	NAPL Ottawa
1964	1:36 000	B & W 9" x 9"	836	
1968	1:12 000	B & W 9" x 9"	2 777	
1974	1:10 000	Color 9" x 9"	4 585	
			11 522	

All by contract .

As noted above, this section is included only to give a general picture of the use of air photos and it must be stressed that this picture is far from complete.

1.2.3 Use of Landsat Imagery

The only other type of imagery for which coverage of the entire region is available is Landsat imagery. Photomaps of each province and of the whole of the Maritimes have been compiled and have received wide distribution. These are at scales in the range of 1:500 000, the scale being such that the area to be shown is suitable for mounting and hanging on an office wall. This type of Landsat product is sometimes called the "Gee Whiz" variety. This means that when a person sees it, he or she says "Gee Whiz, a picture of the whole province and I can even see..., etc.". If by chance, the imagery were to be taken at a critical time, such as the high point of a flood, then it also is extremely valuable. The problem is that one satellite passes overhead only once every 18 days (when there are two, they are programmed 9 days apart) and there is only a 50-50 chance that cloud will not obscure the target area.

A description of the Landsat sensing system and of the production of a photomap from this imagery is given in Appendix A.

In the Maritime provinces, in addition to the photomaps described above, there has been some experimental work to explore the usefulness of the Landsat imagery. The most significant that I have found is the project on potato acreage by Dr. R.A. Ryerson and W.M. Strome of the Canada Centre for Remote Sensing and Dr. P.N. Mosher of the N.B. Dept. of Agriculture; in their report entitled 'N.B. Potato Acreage from Landsat' they conclude that the acreage of potatoes can be determined to within 85% provided that cloud-free imagery is available in mid-summer. The proposal for an experimental project in the use of Landsat imagery for detecting changes in the forest cover is included as Appendix D; at the time of writing a progress report was not yet available. Undoubtedly other tests have been conducted, but in the Maritime provinces, no one is yet using Landsat data on a day-to-day basis.

1.2.4 Other Imagery

Imagery from GEOS (Geostationary) weather satellite is being used on a daily basis by the N.B. Dept. of Environment to predict run-off following major storms and to monitor the snow melt for flood prediction in the spring. If we exclude remote sensing for geophysical purposes - mainly geomagnetic surveys - the only other type of imagery that has been flown is some thermal scanning of residential areas. This was done to help identify buildings which were losing heat at an excessive rate and hence needed better insulation. As this type of use is very much one-shot project-oriented, it will not be discussed further.

1.3 Provincial Centres for Remote Sensing

The Canada Centre for Remote Sensing (CCRS) has, since its formation, been advocating the establishment of provincial or regional centres. Although it is never stated explicitly, it is implied that the Centres should focus their efforts on developing applications for Landsat imagery rather than on air photography. Within CCRS itself much of the effort has been directed to developing instrumentation for receiving and processing Landsat data with the expectation that provincial or regional centres would find and develop applications.

Two such centres have been in operation for some time: the Alberta Centre for Remote Sensing (ACRS) in Edmonton and the Ontario Centre for Remote Sensing (OCRS) in Toronto. As their objectives and methods of operation differ widely, it is relevant to discuss each briefly.

The Alberta Centre is an "information" centre, that is, an extensive file of imagery is maintained and the basic equipment for using it is available along with guidance in its use at no charge. Slide/tape presentations are available and will be shown to groups anywhere in the Province on request. The Centre does not sell imagery directly nor will it do either experimental or production jobs. However, in addition to managing the Centre, the Director acts as a co-ordinator for all requests for new photography within the province and as a liaison officer for the province with CCRS. In other words, the Centre provides guidance on all aspects of remote sensing. A description of the Centre and its resources and facilities is included in Appendix B.

On the other hand, the Ontario Centre functions as a research group on applications. It has a staff of more than 30 (See Appendix C) and equipment with a replacement value of approximately three quarters of a million dollars. It is conducting a physiographic survey of the James Bay lowlands, it is providing data to the Forest Fire Control Services, it is using Landsat imagery and low altitude photographs to evaluate forest regeneration and it is involved in many other projects. It operates, in part, on a cost-recovery basis, i.e. the funds for its major projects of interest to other provincial departments must be justified by the department concerned before becoming available to the Centre. The Centre gets involved mainly in projects using satellite imagery or in innovative applications of airborne imagery.

In Manitoba, Quebec and British Columbia, centres have been identified but so far as I can find out the level of activity in each has been significantly less than that in Alberta or Ontario. In the Maritime Provinces there have been a variety of suggestions and some proposals but neither a provincial nor a regional centre has evolved.

1.4 What Organizational Structure is Appropriate for the Development of Remote Sensing in the Maritime Provinces?

Before attempting to answer this question it will be relevant to recall that the rationale for provincial centres is primarily the exploitation of Landsat imagery and secondly as a focus for liaison with CCRS on all types of remote sensing activity; it will also be useful to review the more successful applications of Landsat imagery.

Exploitation of Landsat imagery: Landsat imagery is ideal for making a province-wide photomap as described in 1.2.3 above. Also as noted in 1.3 above, it is being used effectively for the physiographic mapping of Northern Ontario at a scale of 1:250 000. Other applications at this scale include ecological mapping of Labrador, up-dating the National Topographical Series (NTS) and extending the Canada Land Inventory series. Attempts to use Landsat imagery at the 1:50 000 scale have not been particularly rewarding and for larger scales it is out of the question. As virtually all of the mapping being done in the

Maritimes is at the scale of 1:20 000 or larger, it follows that there is not a great potential for its use in mapping. This is not to rule it out entirely. Sizeable (several hectares) burns and cuts can be detected with adequate accuracy for updating forest cover maps. Similarly, as discussed in 1.2 above crop acreages can be measured provided suitable imagery is available. There is no reason however that those units (Forestry or Agriculture) interested in these applications cannot use it without a regional centre if it is technically and economically feasible. Thus for the purpose of exploiting Landsat data there is no significant evidence to indicate a centre would be worth the investment.

Liaison: The total activity in any of the Maritime provinces is modest and as there already is a provincial committee with a chairman who serves as liaison member, it is doubtful if the existence of a person in a centre would greatly improve this situation.

General Education: Having a slide/tape presentation to take to schools and to other groups on request undoubtedly would improve public awareness of remote sensing. However, as an equally good case for general public education on many topics could be made it is doubtful if a centre can be justified for this purpose. Education, including adult (or continuing) education, is the responsibility of the educational institutions and if continuing education in remote sensing is desireable then the appropriate institutions should be helped to acquire equipment and expertise so that they can include remote sensing as part of their regular programme.

Centre of expertise and equipment:

A. Provincial -- In each province the bulk of the utilization of remote sensing, including air photography, is in two departments - Forestry and Agriculture; there is a lesser interest in Environment and a very modest interest in one or two others. In each of the two major user departments in each province there already is one or more persons specializing in remote sensing; unless a centre had a truly outstanding specialist, it is more likely that the one at the centre would be seeking guidance from the departmental specialist rather than vice versa.

B. Regional -- At the regional level there is a better chance of the centre being able to retain a specialist of the calibre who could be of assistance to the departmental specialists, however geography (i.e. travel time) works against the regional centre concept. Considering that CCRS has a team of specialists and that the travel time to Ottawa by air is in most cases less than the travel time to another Maritime centre, it is probable that a "specialist" in a regional centre would find himself and his centre passed over in favour of CCRS.

In summary, there does not appear to be good grounds either for provincial centres or for a regional centre for remote sensing in the Maritimes.

This is not to say, however, that the "status quo" is satisfactory and that no initiatives should be taken. As an alternative to the centre concept, it is suggested that specific information requirements be defined and that project teams be established on a regional basis to develop the best method(s) to meet these requirements using remote sensing - and other tools.

From this brief overview of the state of the art in Canada generally and of the particular situation in the Maritime Provinces as of 1978, it is concluded that

> *rather than establish provincial centres, or a regional centre, for remote sensing, specified information system needs should be identified and projects to meet these needs should be defined.*

Two such projects are defined in Chapters 2 & 3.

2. MARITIME FOREST MONITORING PROJECT

2.1 The Need for a Forest Information Monitoring System

In Chapter 1 of this report it was concluded that rather than establish one general purpose centre for remote sensing in the Maritimes it would be more beneficial to support a project team or teams to tackle specific tasks. The task suggested for consideration first is that of developing the data collection methodology for a long-term program to monitor the Maritime forests. It is further suggested that a system to monitor the conifer forest should be emphasized first; this is because shortages in conifer wood supply are imminent.

In New Brunswick and in Nova Scotia a large part of the land area is forested. In both provinces the forest is the basis for one of the largest industries in the province. Until a few years ago, the conventional wisdom said that there was plenty of wood and that if there were problems it was a matter of harvesting and marketing rather than of growing wood. During the time that this belief prevailed the pulpmill capacity of the region was almost doubled. Subsequent projections indicated that there was a very high probability of a shortfall in supply of softwoods (spruce and fir) before the end of the century. This probability has been recognized only recently. It is due in part to the increase in pulp mill capacity and in part to the damage caused by the spruce budworm.

Until recently the cyclic harvesting of the conifer forest by the budworm was not understood. By nature's way there was a heavy "harvesting" of the forest every 50 to 60 years by the budworm. Each budworm harvest was followed by a generation of growth. Man's method of harvesting calls for approximately equal harvests each year; man's total would not exceed the total growth <u>if</u> the growth were distributed uniformly over all age stands. Due to the budworm's impact on the history of the forest the growth is not distributed uniformly, hence shortfalls in requirements can be foreseen. At present, as there is no foreseeable way of eliminating the budworm, it is necessary to strike a balance between budworm control measures, harvesting, and intervention such as thinning, fertilization and reforestation. To strike this balance a fine-tuned management program is essential. To quote from the Report of the Task-Force for Evaluation of Budworm Control Alternatives:

> "The study indicates a problem in maintaining forest productivity if harvesting is maintained at the current level and management is continued at its current passive level. The problem is far enough in the future to be successfully dealt with, but it requires action now. If New Brunswick wishes to maintain the present level of industry based on the fir-spruce forest, then it must both protect and actively manage that forest. Since the forest must be actively managed, either to maintain or improve our present position, every effort should be made to do so in a way that reduces its susceptibility to outbreak and vulnerability to budworm caused mortality. It is clear that minor changes in species composition achieved either by planting or differential harvesting will have little influence on the nature of the protection problem. Substantial continuous long term management effort will be necessary to appreciably ease the problem."

Although it is not explicitly stated it is certainly implicit in the above-quoted paragraph that much better information is essential for successful "active" management. In fact the principal investigator (Dr. Gordon Baskverville) of the Task-Force followed up the report with the development of a computer program (WOSFOP: Wood Supply and Forest Productivity) as a first step in getting tools for the active management of the forest. Similarly in Nova Scotia the need for a computer program to estimate sustainable yields was recognized and a program has been developed for the Department of Lands and Forests by the N.S. Research Foundation. For each of these programs it has been necessary to make assumptions about the growth patterns of various types of stands - in other words to postulate a dynamic model of the forest.

A dynamic model of the forest is one which, taking account of growth and other factors, gives an estimate of what any forest stand will contain at any time in the future. This implies that forest dynamics are well understood. From experience foresters have compiled "development curves" which, given the age and the mix of a stand, can be used to predict the volume of wood at any time throughout the life of the stand. Unfortunately due to human intervention many of the stands now existing represent new types of stands; for these the development curves are not well understood.

Traditional forest management concerned itself almost entirely with the current inventory. Individual foresters, of course, are well aware of forest dynamics. For example under certain conditions they know that after cutting the regeneration often starts with alders and hardwoods and that fir and spruce comes in more sporadically; they also know that gradually the conifers will overtake the hardwoods and finally spruce will overtake the fir.

A regional forester gets to know his region and more or less intuitively knows the state of the forest dynamics in his region. It is however beyond the capability of any person or even of any group to work out countless "What if...?" scenarios for a region by manual means. This is because the Maritime forest is made up of innumerable stands of a few hectares in area - on a typical 1:20 000 map covering some 11 000 hectares there may be 350 identifiable stands ranging in size from five hectares to 200 or 300 hectares.

The dynamic modelling problem is compounded by many factors. The most significant of these is the "historical disturbance" of various harvesting activities, however the ravages of the budworm and of other pests and of forest fires all superimposed on a wide range of fertility conditions add to the complexity of the problem. In modelling there is never as much information as one would like however without a certain minimum of information any scenario developed from the model is only a poor "guesstimate".

There have been many studies on the forests in the Maritimes but as mentioned above the latest and the most definitive of these has concluded that much more intensive management of the forests is essential. For more intensive management more detailed information is needed. Specifically, it is necessary to know not only which stands are mature enough to be harvested but to know their location and the state and location of all the stands in the region and their position on the development curve as well as the mix and the vigor of the species. Forest inventory mapping provides a portion of this information at one epoch however its primary purpose has been to identify wood for current harvesting. Forests do not stand still; some sections are cut, there are burns and there is growth. With growth there is a change in the distribution of species and of the value of the end product; some species grow more vigorously than others, some have a longer life span; and not only are the dimensions of each stand changing, but the mix is continuously changing. From experience, foresters have compiled development curves which show that a forest of a given age and mix should progress through a certain pattern. However, the forest that is now growing in New Brunswick started under different circumstances than the older forests, that is, in many cases it started from either selective cutting or clear cutting as opposed to forests which evolved from a natural forest condition. Further, the protection program against spruce budworm has maintained large areas of forest to a development stage never seen before. Consequently, many types of forest are now growing which have never occurred before. Thus, development curves based on a natural forest do not necessarily apply to a forest which has started under quite different conditions.

For a long-term comprehensive monitoring program, on an annual basis all areas in which there has been significant intervention - harvesting, severe pest damage or fire - need to be remapped. As growth is a slow process those areas in which growth is the only change need be re-mapped infrequently - at say eight to ten year intervals. For this latter category, the example of Statistics Canada is relevant. The decennial census is used not only for a "head count" every ten years but for analyses of changes since the previous census and for the development of countless "time series" over many decades.

Previously, inventory maps were used by foresters to make decisions - by the "eyeball" method - on where cuts should be made; however as mentioned above modelling techniques have been developed by which when sufficient information about the forest is fed into a model, it is possible to determine what cut levels can be sustained indefinitely. This modelling technique, to be fully effective, calls for an information system that provides up-to-date input information and tells the operations manager which specific stands belong in the "cut" category.

If remote sensing is to contribute to the input to the model, it must provide either a reasonably economical method for updating the information on the present forest cover maps, or it must provide information that is needed but is now not available on the forest cover maps. Specifically, for the latter requirement, it must refine the species mix and the age distribution of any given stand and it must provide a measure of the vigor of the stand. In addition to data on the forest itself, there is a need for information about the site; that is, if thinning or reforestation is being considered, it is necessary to have information on the soil, on the drainage and on the local climate.

Each of these needs will be defined more specifically:

i) The need for species identification and age distribution - Softwoods (mainly spruce and fir) are the best source of pulp fibre. The two species generally occur in the same stand but in varying proportions i.e. spruce may be dominant or fir may be dominant (if they are about equal the spruce will eventually dominate), however, as the life of spruce is approximately twice that of fir distinctly different management approaches are required for different mixes.

By conventional photointerpretation techniques, it is relatively straightforward to distinguish between softwood stands and hardwood stands and to rank the propertion of hardwoods and softwoods in a mixed stand. It is even possible to estimate whether the spruce or the fir is dominant. However, it is not possible to quantify the ratio of the two species.

ii) The need for defoliation measurement - Defoliation and refoliation information is needed over large areas in order to monitor recovery from budworm damage as well as the extent of the damage. This is currently collected by observers in aircraft making "eyeball" estimates at 30 second intervals along a flight path.

iii) The need for site potential classification - Reforestration is costly - of the order of 200 to 250 dollars per acre initially with a return period of about 50 years. Before making this type of investment, it is essential to be certain that the site characteristics are suitable for the species being planted. The site characteristics include type of soil, drainage, local climate and other ecological factors. The Canada Land Inventory maps provide some of this data but as they were at reconnaisance scale, it is not surprising that they are generally inadequate for this purpose. Thus another important challenge in remote sensing applications is the development of an effective site potential evaluation method that requires only a modest amount of ground control and monitoring.

The needs outlined above have been defined mainly on the basis of current concerns with the conifer forest. However hardwoods constitute an important part of the forest economy and any system which is developed should also have provision for the development of a hardwood information system. Thus in Section 2.2 below although a conifer forest monitoring program is defined it is implicit that the procedures would apply equally well to a hardwood forest if WOSFOP or the N.S. program contained development curves for hardwood stands.

2.2 A Hypothetical Maritime Forest Information System

In order to have some framework - some perspective - to give direction to the monitoring program, and hence to the monitoring project, I have tried to visualize the sort of forest information system that appears to be needed and that could be made available within a few years. This is illustrated in a schematic form in Figure 1 and a few brief comments follow on each of the components depicted.

Sensors - There are now and there will continue to be for the foreseeable future basically three methods of sensing; ground observing, air-borne sensing and satellite sensing. Everyone is familiar with the air photograph taken from an airplane; it is, to date, the sensor that has contributed the bulk of the data that we now have in our maps, charts, files and data sheets. However for every form of remote sensing a certain amount of work on the ground must be done to confirm what has been interpreted from the imagery; in some cases it must be done to collect information that is not detectable by any type of remote sensing. The multi-spectral scanning data from Landsat has great potential as a monitoring device for the forest information system, but it has not as yet made a great contribution in this area becuase we do not now have data bases and the associated procedures to utilize it effectively. As we trace through Figure I we will see how the Landsat input will be utilized when the system comes to maturity.

Interpretations and Analysis - To date most of the interpretation and compilation of the data from sensors has been done by

A FORESTRY INFORMATION SYSTEM

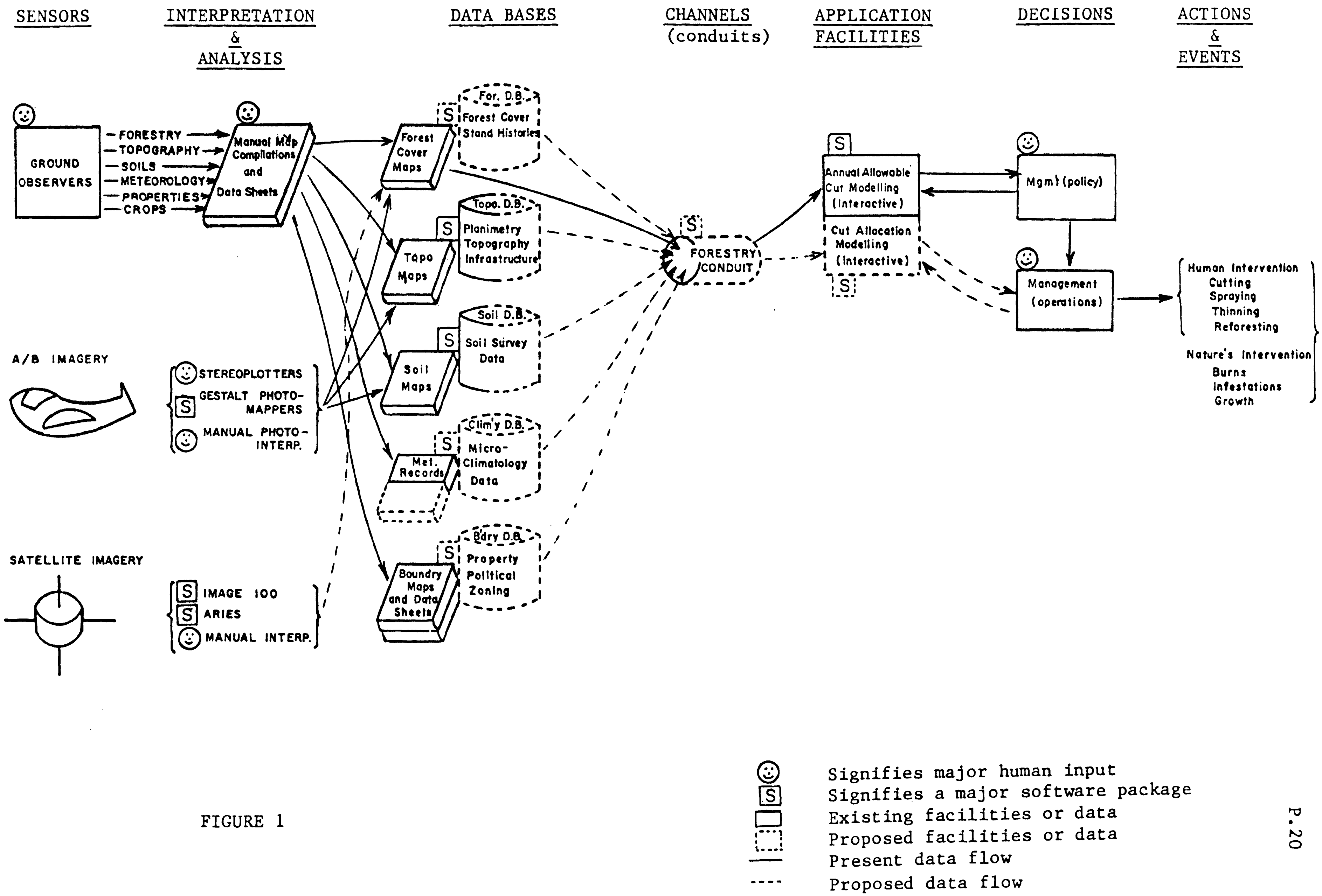


FIGURE 1

a skilled photo-interpreter using a stereo-viewer. For many purposes there is no foreseeable replacement to the skilled interpreter; only the human eye can effectively cope with subtle variations in shape and texture. There are, however, some tasks which are yielding to automated processes. The measurement of elevation by the Gestalt Photo-Mapper is one example; the analysis of multi-spectral imagery by the Image 100 (developed by the Canada Centre for Remote Sensing) or by Aries (developed by the Forest Management Institute) is another. In general, however a judicious combination of automated techniques and human interpreters is desireable.

Data Bases - Just over a year ago I made an extensive search of literature and consulted several authorities to get a definitive definition for the term "data base". There was no consensus. As used in this report it has three components: there are the hard-copy files - maps and tabulations of data; there is the software and of course associated with it the hardware for processing and storing the data; finally there is the data itself which is presumed to be in digital form on disc or magnetic tape. Using this definition it is obvious that the map holdings of various federal agencies constitute quite large hard-copy data bases.

A brief discussion of each of the data bases follows:

The Forestry data base - As discussed previously, in New Brunswick there has recently been completed Forest Cover Mapping for the entire province at the scale of 1:20 000; in Nova Scotia the same information has been compiled though not in one series at one time. This data base has been compiled using proven equipment and established techniques for photo-interpretation with test plots and training sites on the ground. Subsequently selected stand data has been key-punched and used as input to a modelling program (See Applications Facilities below). However so far as can be ascertained a digital forestry data base at stand level has not yet been developed.

The Topographic data base - Everyone is familiar with the NTS (National Topographic Series) maps produced by the Topographic Division of Surveys and Mapping Branch; there is coverage at 1:50 000 for all of southern Canada and coverage at a scale of 1:250 000 for the whole of the country. Some ten years ago work was started on an Automated

Cartography System culminating in a software package to replace the scribing process; this is called XCM. Some two years ago an interactive system to process the output digitized directly from the stereo-plotters was acquired; when it becomes operational the only human in the system will be the stereo-plotter operator. When this new methodology becomes operational, a digital topographic data base will be built up.

The Soil data base - As mentioned in the introduction soil capability was one of the components of the Canada Land Inventory compiled during the 1960's. However this was at reconnaissance scale; subsequently more detailed soil surveys are being conducted across the country. The Land Resource Research Institute of the federal Department of Agriculture has developed the software for and is beginning to build up a digital soil data base called CANSIS: this is described in a paper entitled "Canadian Soil Information System" by Messrs Dumanski, Kloosterman and Brandon of the Institute. To date some 70 maps have been compiled using this system and a production rate of approximately 100 map sheets per year is anticipated.

The Climatology data base - Although the amount of climatology data needed for forestry and agriculture analyses is rather modest, it is nevertheless essential. It is included as a separate entity because the expertise and the techniques to collect and analyse the data are distinctly different from those of any of the other data bases in this group. To be consistent with the concept that a data base should be managed by those who are responsible for the input this is being shown as a separate data base.

The Boundaries data base - In a society in which all of the agricultural production and much of the forest production is from land held privately, boundaries and hence ownership data are essential to the decision-making process. In the Maritime Provinces the Land Registration and Information Service -- an agency of the Council of Maritime Premiers -- has been proceeding steadily with the production of property maps delineating the boundaries of all properties in the provinces. To date no attempt has been made to put this data in digital form, however it is not seen to be a difficult task. As a matter of convenience it is suggested that political boundaries and zoning boundaries also be included with property boundaries in this data base.

Data Channels (Data Conduits) - The idea of a data channel or data conduit is being introduced here in place of the data bank concept that has been prevalent in syntheses of this type. This is visualized as a much more realistic approach to the merging of data than the development of a large repository — comparable to Fort Knox — in which all data of every sort, type and description would be buried. By thinking of data "flowing" from place to place we will begin to break out of the log-jam that we are in with respect to merging, synthesising and effectively utilizing data.

Applications Facilities - Under this general heading there are two types of facilities: the first type is the modelling program in which data selected from one or more data bases can be used for modelling and for developing scenarios and alternatives in preparation for management decisions. The application facility that is most relevant to this discussion is the Annual Allowable Cut modelling facility -- there is one of these in New Brunswick that goes by the acronym WOSFOP (Wood Supply and Forest Production) and there is one in Nova Scotia which does not have an acronym (there is also one in Quebec called MODAS). The input to the Annual Allowable Cut modelling program currently is key-punched from manually compiled data on stand areas and wood volume estimates for each stand. These modelling programs are being used extensively in arriving at major decisions with respect to the forests. This program is also useful for woodland managers in deciding which of the many stands in a region should be cut in any given year consistent with the decision taken on the basis of the Annual Allowable Cut model.

The Decision-Maker - The decision-maker is the key element in the system. If he is not included or if he is not interested, then the system is doomed to fail. In particular, if decision-makers are not interested and do not use the capability of the system at an early stage of development, there will be a loss of momentum. Conversely if decision-makers try to replace their largely intuitive methods by reliance on modelling prematurely, there will be misunderstanding and failures. Thus it bears repeating that the attitude of the decision-makers is vital to the success of the system.

From this discussion, some general guidelines can be listed:

i) The decision-maker is the key element in the system; without him here is no need for a system.

ii) Data Bases should be owned, managed and maintained by the discipline group that has the responsibility for collecting the data that is in the data base. Similarly, Applications Facilities should be maintained by the decision-makers that are using the output of the Facility. There should not be any Super-Service pre-empting the handling of all information.

iii) Some form of consortium of all Data Base owners and Facilities Users is necessary to provide technical support for the development and maintenance of the data conduits.

iv) Assuming that satellite imagery continues to be available at nominal cost there is good reason to expect that the forestry data base could be kept up-to-date at a modest cost.

It must be stressed that the concept outlined above is not meant to be definitive; it is presented only to provide a framework within which to define a monitoring program.

Without a clear concept of an integrated forest information system the need for an on-going monitoring program is limited; by the same token, without the development of an effective monitoring program the feasibility of a viable forest information system is questionable. This is a "chicken and egg" situation. In the following sections, on the assumption that some type of integrated forest information system is desirable, the data sources for such a system will be discussed and a project to develop an on-going monitoring program will be outlined.

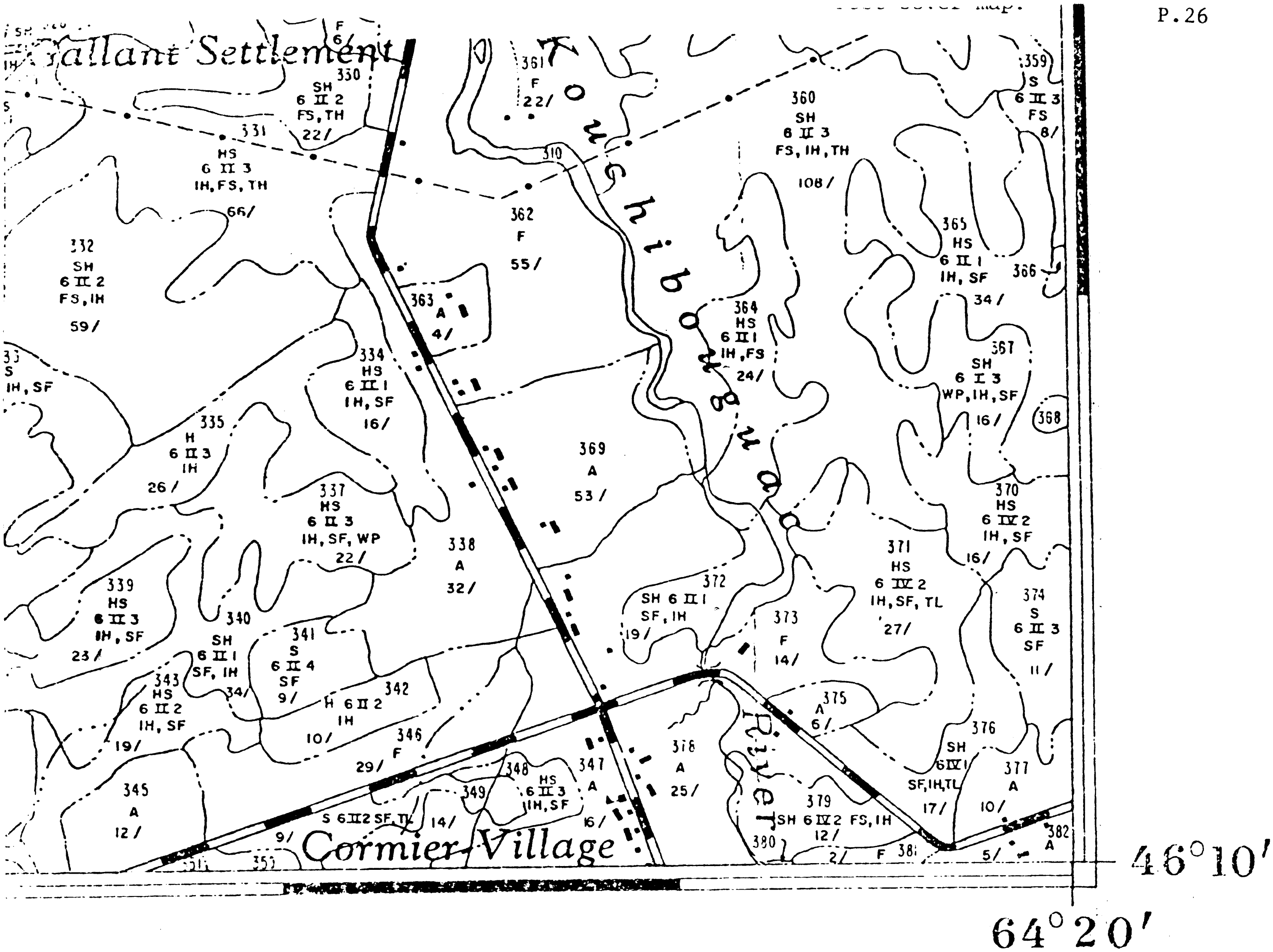
2.3 Data Sources for a Maritime Forest Information System

In New Brunswick for many years, the Department of Natural Resources did mapping and management planning for the smaller holdings but not for the large tracts leased or owned by pulp and paper companies. The companies maintained their own inventory maps suitable for development of their management plans. A few years ago, as a step towards implementing the recommendations of the Tweeddale report the province contracted for forest inventory mapping of the entire province at a scale of 1:20 000. The photography was flown in 1974-5-6 and compilation of the maps was completed by the spring of 1978; this work was done by the firm of Darveau, Grenier and Lussier of Quebec City and by Woodlot Services Ltd., Fredericton. Along with each map sheet, there is a computer listing showing the cover type, height class, major group, volume category, species association and area for each stand within the map sheet in one table and the ownership classification, condition and area in another table. (See Figure 2 for an example of a New Brunswick forest inventory map.)

The first forest cover inventory in Nova Scotia was compiled in the years 1953-56 on a 1:15 840 topographic base which was derived from the 1:50 000 NTS mapping. A second series was compiled in the years 1965-71. Both series covered the entire province. A third and more detailed series was initiated in 1972 covering only Crown lands and it is approximately 25% complete. This series will be transferred to the 1:10 000 orthophoto base as the maps become available. (Figure 3 is an example of a Nove Scotia forest inventory map.)

In addition to the forest cover maps discussed above the output of the LRIS photomapping program is rapidly becoming available. These are being published at the scale of 1:10 000 for the entire province. There are two versions of the photomaps: on one the contours are overlaid on the photo base and on the other, the property boundaries are shown. The latter version is, of course, only available for those regions in which the property mapping has been completed. The publication status of these series is summarized in Figure 4.

In conjunction with the property mapping program, a digital data base containing ownership, encumbrances and related data is being



METRIC

Cover Type: S,SH,HS,H
Height Class: 1:0-4m,2:5-8m,3:9-12m
4:13-16m,5:17m+,6:uneven
Maturity Group:
I 70† m^3/ha; 26cm †DBH class
II 35† m^3/ha; 16-24cm DBH class
III 0-70 m^3/ha; 26cm † DBH class
IV 0-70 m^3/ha; 10-14cm, † DBH class, or no merchantable volume
Volume Class (m^3/ha) 1:C-35, 2:36-70, 3:71-105, 4:106-140, 5:140 †

SPECIES ASSOCIATION

CLASSIFICATION SYMBOLS

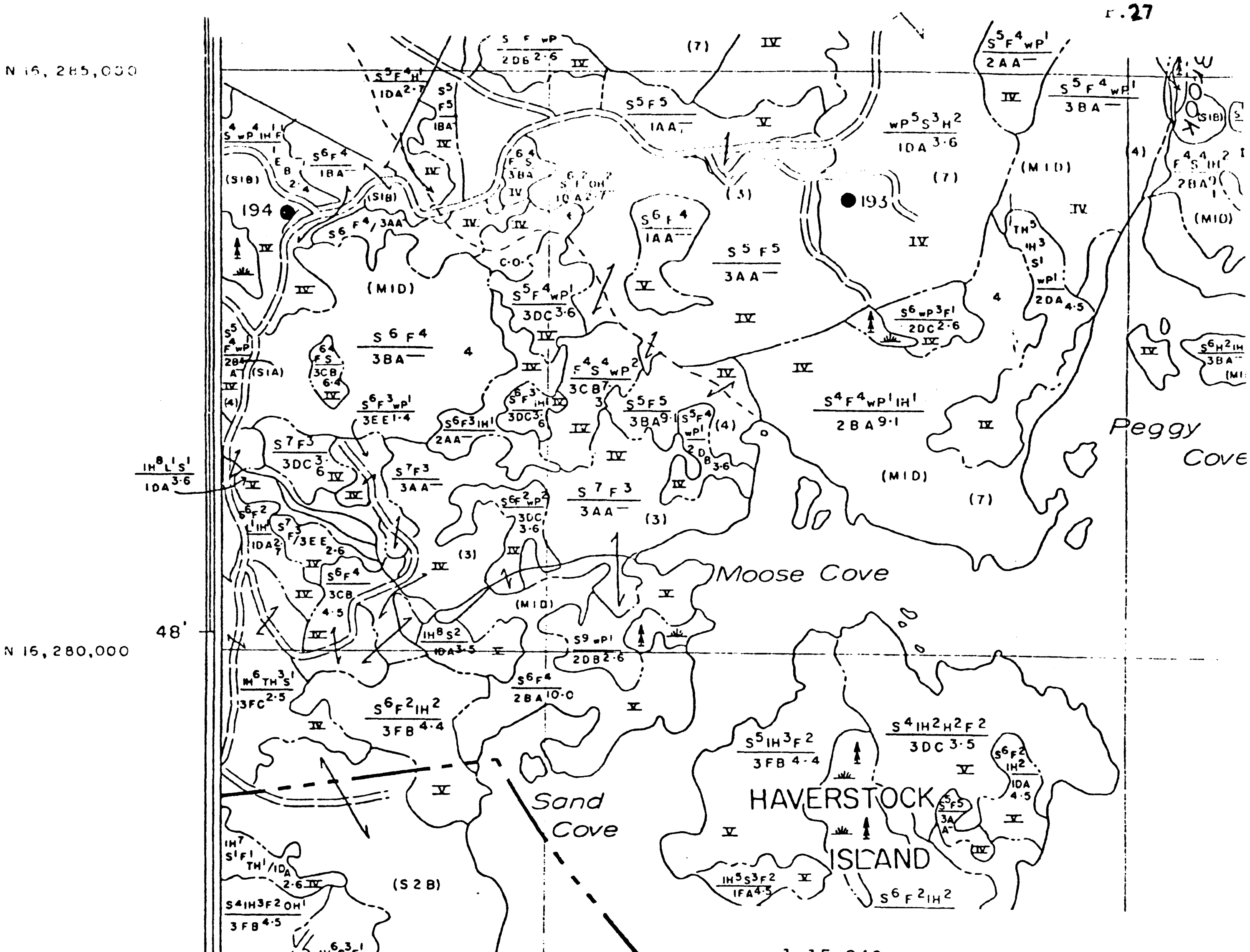
A Agricultural Land
O Occupied
SW Wasteland
W Water
NPF Non-productive Forest
R Rock outcrop
C Recent clear cuts
B Recent burns
F Old fields
OWNERSHIP
C CROWN
F FREEHOLD

Map Sheet 215/IX

SAMPLE CLASSIFICATION

337 HS 6 II 3 IH, S.F., WP 22/:

indicates that stand number 337 is a hardwood-softwood stand, of uneven height, has most of its volume in the 16-24 cm DBH class, 71-105m^3/ha total volume and has a composition of intolerant hardwoods, spruce-fir and white pine in order of decreasing volume. The stand contains 22 hectares.



1:15 840 11D-13 West

FOREST REFERENCE

SPECIES - SOFTWOODS:

- S . Red & Black Spruce
- bS . Black Spruce
- wS . White Spruce
- H . Hemlock
- rP . Red Pine
- jP . Jack Pine
- ScP . Scotch Pine
- C . Cedar
- L . Larch
- OS . Other Softwoods

HARDWOODS:

- IH : Intolerant - White Birch, Red Maple
- TH : Tolerant - Yellow Birch, Sugar Maple
- A . Aspen
- O . Oak
- OH . Other Hardwoods

CROWN CLOSURE

- 1 . 0 - 40% (Inadequate)
- 2 . 41 - 60% (Adequate)
- 3 . 61 - 100% (Overstocked)

HEIGHT CLASS

- A . . . 0' - 15'
- B . . . 16' - 30'
- C . . . 31' - 40'
- D . . . 41' - 50'
- E . . . Over 50'
- F . . . All Heights

VOLUME - CU. FT./ACRE

- A . . . Under 600
- B . . . 600 - 1200
- C . . . 1200 - 1800
- D . . . 1800 - 2400
- E . . . Over 2400

SIZE CLASS - IN %

4" - 6" D.B.H. Noted First
7" - 9" D.B.H. Noted Second
Over 10" D.B.H. By Subtraction

FOREST CAPABILITY - CU. FT./ACRE/YEAR

- I . . . Over 110
- II . . . 91 - 110
- III . . . 71 - 90
- IV . . . 51 - 70
- V . . . 31 - 50
- VI . . . 0 - 30

EXAMPLE

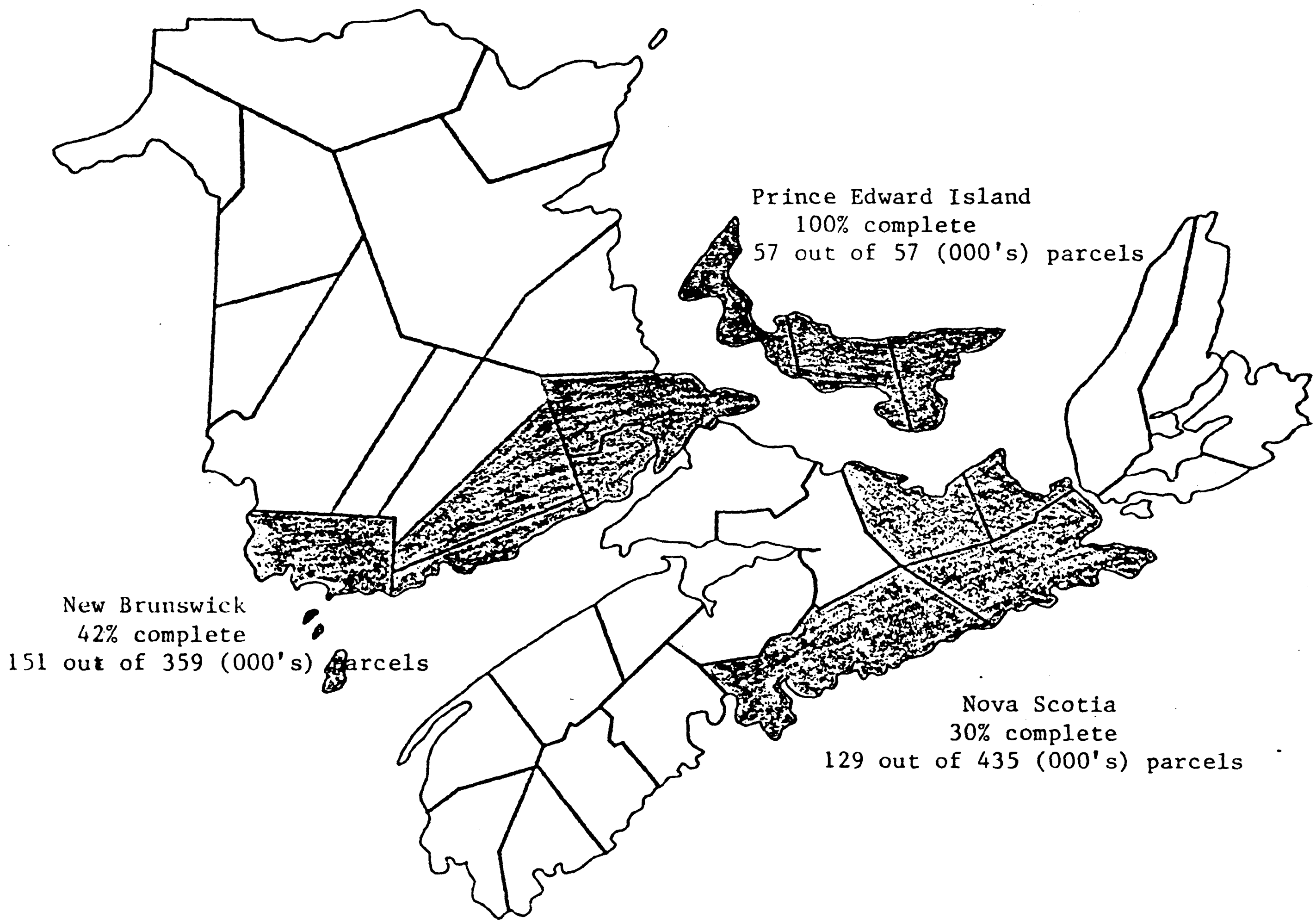
$$\frac{S^6 F^2 OS^2}{2DC^{2.6}\ \ II}\ (S3B)$$

- S^6 . . 60% Spruce
- F^2 . . 20% Fir
- OS^2 . . 20% Other Softwoods
- 2 . . . Crown Closure 41 - 60%
- D . . . Height 41' - 50'
- C^{26} . . . Volume 1200 - 1800 Cu. Ft./Acre
  20% Volume In 4" - 6" D.B.H. Class
  60% Volume In 7" - 9" D.B.H. Class
  20% Volume In 10" & Over D.B.H. Class
- II . . . Forest Capability
  91 - 100 Cu. Ft./Acre/Year
- (S3B) . . . Understory
  S = Over 50% Softwood
  3 = Crown Closure 60 - 100%
  B = Height 16' - 30'

FIGURE 4

STATUS OF LRIS PROPERTY MAPPING

Scheduled for Completion March, 1979



Maritime total 337 out of 851 (000's) parcels = 40% complete compiled. For those regions in which much of the forested land is held privately in small and medium sized holdings this will be a useful complement to the integrated forest data base.

As noted above the soils maps prepared as part of the program of reconnaissance mapping for the Canada Land Inventory are available at the scale of 1:250 000 and much of the data is in digital form in the data base of the Canada Geographical Information System.

In discussing the existing sources of information the knowledge accumulated by experienced foresters is invaluable. Although it may not be readily convertible into data base input any integrated forest information system must provide for this input in a meaningful way.

In summary, the following are available at present or will be in the near future:

- i(a). Inventory of the forest in New Brunswick at a scale of 1:20 000 (from 1974, 75 and 76 photos).
- i(b). Forest cover maps of Nova Scotia at 1:15 840.
- ii. Enhanced photomaps at 1:10 000 (with some at 1:20 000).
- iii. Overlays for the photomaps showing property boundaries and the key to a computer file on ownership.
- iv(a). Canada Land Inventory maps at a scale of 1:250 000 and the same information in digitized form in the C.G.I.S. data base.
- iv(b). Assorted soil mapping projects at larger scales for certain regions.
- v. Regional climatological data.
- vi. A corps of experienced foresters who have an intuitive understanding of the forest.

In looking over the above summary of data sources, it is apparent that in some sub-sets such as property boundaries an up-dating program is essential for reasons other than the needs of the forest data base. However, considering them as together constituting an integrated forest information system, it is readily apparent that without an on-going program to monitor changes in the forest there cannot be a meaningful forest information system. A project to develop an on-going Maritime forest monitoring program is outlined in the next section.

2.4 Proposed Project to Develop an On-Going Monitoring Program

2.4.1 The Objective of the Project

The objective of the Maritime forest monitoring project is to develop the methodology for providing the input on an on-going basis to the provincial forest data bases. The type of sensors and data collection procedures should be specified along with the method of analysis and of processing the collected data in a form suitable for the data base or for other purposes as may be specified by the forestry community.

It is recognized of course that the methodology for data collection will be modified as tools and new methods of processing data become available. It should, however, reflect the best "state of the art" application as of the final year of the project.

2.4.2 The Rationale for Proposing that Several Teams Collaborate on the Project

In Chapter 1, it was concluded that there was not a good case for setting up either provincial centres or a regional centre for remote sensing in the Maritimes. At the same time, it was suggested that project teams be identified and supported in their collaboration on problems of concern to the Maritimes. The development of a Maritime forest monitoring program is suggested as the first problem for this team approach. A list of centres at which there is some expertise in remote sensing applicable to forestry along with a list of relevant projects and equipment follows:

Government --

N.S. Dept. of Lands and Forests:

Expertise -	Mr. Ed Bailey, Mr. Ed MacAuley, Mr. Fred Wellings
Projects or experience	- The use of colour photography for forest mapping.
	- Experimental project to compare various types of imagery for mapping forest insect damage and for measuring other forest parameters scheduled for 1978 (See Appendix D)
Equipment	- 2 B & L Zoom Stereoscopes

N.B. Dept. of Natural Resources:

Expertise	- Mr. Burtt Smith, Mr. Norman Young Mr. Thomas Spinney, Mr. Donald Carlin
Project and experience	- Forest inventory of province using black & white aerial photography. - Ground sampling of forest conditions for comparison with, and expansion of the photo interpreted data. - Monitoring possible uses of Landsat imagery in forestry applications.
Equipment	- B & L Zoom Transfer Scope

Educational Institutions --

N.S. Land Survey Institute:

Expertise	- Mr. Vernon Singhroy, Mr. John Wightman
Projects and experience	- A wide variety of remote sensing projects in Manitoba. These projects have involved ground and light aircraft photography, standard mapping photography, special remote sensing photography and analysis of Landsat images. Analysis experience has been gained on such equipment as advanced digital systems, colour additive viewers, density slicing systems, and advanced stereoscopic systems.
Equipment	- Numerous stereo plotters, colour additive viewer, density slicing unit, zoom transfer scope.

U.N.B. Forest Resources Dept.:

Expertise	- Prof. Wm. Hilborn, Prof. Steve Oliver
Projects and experience	- Forest and land interpretation from various types of imagery, particularly aerial photography. User oriented research, development and training.
Equipment	- Various types of stereoscopes including Old Delft scanners and Bausch & Lomb SIS-95. Stereo plotter.

U.N.B. Surveying Engineering Dept.:

Expertise	- Dr. Eugene Derenyi, Dr. Salem Masry

Projects and experience	- Analysis of various types of imagery including Skylab photography
Equipment	- Analytical plotter, digitizing and plotting units, various stereo plotters

The private sector --

Woodlot Services Ltd., Fredericton

Expertise	- Mr. Harold Paige
Project(s)	- Forest cover mapping in N.B.
Equipment	- Mirror stereoscope

The rationale for this approach is based on the following:

i. People. There is no single agency in the Maritime Provinces at which all the types of expertise needed is available. Obviously not all of those who can make a contribution to the project will be free to do so. On the other hand, most of them would welcome the opportunity to participate in a project as team members. Even by combining the efforts of all those who have expertise to contribute to the project, it is likely that assistance from elsewhere will be necessary.

ii. Knowledge transfer. The hidden agenda item in the project is knowledge transfer. When potential users are actively involved in a development, knowledge transfer is facilitated. By having a "piece of the action" and by periodic project meetings, the knowledge transfer process will, for the most part, happen without any significant conscious effort.

iii. Maximizing the use of previous work. It must be remembered that this is not a new problem. Air photos have been in use for many years (see Table 1). Most of the new sensors have been tried at least once or at least have been subject to some form of evaluation. This process continues - the most current example being the tests scheduled for the Cape Breton Highlands this summer (see Appendix D).

iv. Equipment. As indicated above, there is a limited amount of equipment for analyzing imagery in the Maritimes and it is widely scattered. As the cost of equipment could easily exceed half a million dollars (in Appendix C, the cost of the equipment at the O.C.R.S. is listed as approximately three quarters of a million dollars), the need to pool equipment at the development stage should be self-evident.

v. Digital methodology. The development of software is costly. With even a modest amount of coordination, the same basic programs can serve both New Brunswick and Nova Scotia. This approach was adopted by the telephone companies; they formed the Atlantic Province Telecommunication Council and through it, they set up a group to develop the software and related procedures for a Customer and Records Billing System.

2.4.3 Tasks, teams and time frame

As indicated in Figure 5, this is proposed as a three year project. The first year is designated for what might be called basic research, that is to studying the reflectance characteristics of the conifer forest under all significantly different conditions. In other words, it is assumed that the reflectance would be measured at fairly frequent intervals during the summer and also at the beginning and the end of the dormant season. It is implicit, of course, that the entire range of the spectrum would be scanned in the search for useful spectral signature information. It's anticipated that the bulk of this work would be done using towers, tethered balloons, or other fixed platforms from which a prolonged series of measurements could be made on a scheduled basis. However, in view of the fact that not all mixes of forest are likely to be visible from either towers or balloons, it is expected that certain measurements would be made from light aircraft.

During the second year, the major task would be the analysis of the results of the basic research done during the first year and of designing and conducting tests using aircraft capable of flying at higher altitudes. For these tests, it is assumed that a variety of film-filter combinations would be used to obtain data photographically and also that some scanning equipment would be used. Simultaneously, using the conclusions from the study of spectral characteristics, a thorough evaluation of all Landsat imagery would be made.

The program during the third year would, of course, be very much dependent on the analysis of the results obtained during the previous two years. It is, however, visualized that by this time some clear decisions would have been reached on the type of sensors to be used for the on-going monitoring program and that if these are commercially available, they would be acquired, even if on a temporary basis, and

START – 1	1 – 2	2 – 3
Study the spectral characteristics of all types and ages of the forest at all seasons Ground towers, tethered balloons, and/or light aircraft.	Continue study of spectral characteristics using larger aircraft. Analyse spectral characteristics; select those most promising for the monitoring program. Using the conclusions from the study of spectral characteristics make a thorough evaluation of all relevant Landsat imagery.	Test existing sensors and if necessary draw up specifications for new sensor(s). Draw up specifications for the on-going monitoring program.

START 1 2 3

YEARS

Figure 5. Schedule for development of the Maritime forest monitoring project

some test results taken. If it appears that a sensor will have to be designed specifically for the purpose, then the design and fabrication process would be initiated.

In the testing of airborne photographic sensors, it is assumed that the manual method of photointerpretation would be used in conjunction with both the density slicing/color additive viewer analysis methods and in addition to the digital analysis of the data.

One of the many possible ways of breaking the project into tasks to be tackled by various teams is outlined below.

Tasks

Systematic reflectance and emissivity measurements throughout the growing season from dormant to dormant state. By observations from towers, tethered balloons, and possibly light aircraft. The emphasis to be on learning about the spectral characteristics of the forest rather than on finding an operational procedure.

Teams

One team to concentrate on forest damaged by budworm (or other pests) i.e. to concentrate on vigor.

One team to concentrate on the reflectance variations of various species throughout the year i.e. to concentrate on species differentiation.

Designation of a field of concentration is only to aid in the choice of test sites. Having chosen the test sites both teams to be involved in both aspects of the study.

Evaluation of alternatives for combining automated and manual interpretation methods to get a digital output from photography.	One team to approach the problem from the conventional production viewpoint i.e. to use proven methodology as economically as possible. One team to approach the problem from an inter-active point of view i.e. with the aim of reducing the manual component as much as possible.
Data Base team to develop a method for collecting and using time-series data on the forest.	One team made up of representatives from various agencies.
Evaluation of all the reflectance data and the drafting of specifications for operational sensors.	One team made up of representatives from all the participating agencies.
Evaluation of the project and formulation of recommendations for an on-going monitoring program.	One team with representatives from all the participating agencies.

The objectives and the priorities would be set by an Advisory Committe; members of this Committee would be sufficiently senior that they could speak on behalf of their agency and hence make commitments as to what resources would be available to their team. In other words, the Committee would direct the project leaving the day-to-day operations to the project co-ordinator. Ideally the project co-ordinator would be able to devote all of his time to the project; if so he would probably double as team leader for the part being done by his agency. Alternatively the co-ordinator could be one of the members of the Advisory Committee who undertook the task of co-ordinator along with his on-going duties; in this case, someone else in his agency should serve as the leader for their team.

2.4.4 Resources Needed: Staff, Equipment, Operating Funds

It is implicit in the above discussion that the full co-operation of CCRS will be available; this will be in various forms notably:

i. Loan of equipment to teams on a temporary basis.

ii. Use of equipment at CCRS.

iii. Flights to get imagery with various sensors.

iv. Advice from specialists at CCRS.

It is implicit too that insofar as is possible existing expertise and equipment in the Maritimes will be used. This does not mean that additional resources will not be necessary. None of the specialists have free time on their hands. To make time available for this project, they must be relieved of other duties. As discussed in some detail above, the rationale for this approach is that they have a wealth of experience to bring to the project and they are, generally, in a position to initiate changes in methodology i.e. to ensure that there will be no delay in technology transfer. This does not by any means exclude the possibility of researchers being recruited for various periods to assist the team leaders and even to act as team leaders.

Staff - consistent with the general format outlined above staff requirements will be defined in person-years without, at this stage, imposing constraints as to category or location.

Research scientists (or equivalent)	- 5 person-years
Technologists	- 7 person-years
Seasonal assistants	- 5 person-years

Equipment - Colour additive viewer, zoom stereoscope, four film light table, Hasselblad camera.

Funding - In addition to the salaries for personnel, there would be operating costs estimated at half the cost for salaries.

A recommendation as to the source of funds will not be made, however, two models will be outlined:

Model 1 - In this model, the project is fully and directly funded and hence can be completed in a specified time (3 years is suggested).

Model 2 - In this model, funding is from sources such as NRC operating grants for research, and Canada Works programs as well as indirectly by the various agencies mentioned. With this approach, the tempo would be much slower and no specific completion date could be set.

With respect to Model 1, it should be noted that the cost/year of the project (spread over 3 years) would be approximately the same as the yearly cost of a centre similar to the one in Alberta. Needless to say, the total cost would be less than the cost of operating the Ontario centre for one year. If some regional agency, such as LRIS operating directly under the Council of Maritime Premiers, does not provide the coordination and major funding, it could easily take a decade to complete the developments outlined.

2.4.5 What Type of System Can Be Anticipated?

Briefly, one can anticipate that an on-going monitoring program will utilize a mix of conventional and new techniques. Because a Landsat satellite does overfly the region every 9 days, it is likely to be the best source of imagery for delineating certain major changes such as burns or large cuts. At the other extreme, it will never be possible to completely eliminate the need for "ground truth" methods for examining small plots in detail and it is probable that there will be a need for light aircraft and very simple hand held or readily mountable cameras to bring back certain information that is needed in a short time frame.

It is probable however that the main source of the information for monitoring the Maritime forest will continue to be obtained by airborne sensors. It is in the type of sensors, the altitude at which they are to be flown and the times of year at which they are to be flown that there should be a significant contribution from the project. Although some improvements in the methods of interpreting the data collected by the airborne sensors can be anticipated,it seems certain that there will continue to be a role for the human photo-interpreter; this is because characteristics such as texture and shape can still be determined much better by the human eye than by any automated method yet developed. On the other hand, density slicing techniques and digital analysis techniques do permit certain characteristics to be detected that are not readily discernible by the human interpreter.

In summary, it can be anticipated that the recommendations for an on-going program will lead to a judicious balancing of proven techniques with new techniques rather than to any one big break-through.

3. AGRICULTURE MONITORING PROJECT

3.1 The Need for an Agriculture Information System for Use in the Maritimes.

It is obvious that there are many similarities in the agriculture patterns in New Brunswick and Nova Scotia and it is equally obvious that there are many respects in which agriculture in both of these provinces differ from that of Prince Edward Island. Fortunately a comprehensive study of the agriculture resources in New Brunswick has recently been released (Report of the Agriculture Resources Study, Nov. 1977) and although the specific conclusions and recommendations are intended to apply specifically in New Brunswick it is reasonable to assume that most of the more general observations and conclusions will be applicable to Nova Scotia and some will be applicable to Prince Edward Island.

A selection of extracts from the Report of the Agriculture Resources Study 1977 follows:

P. 90 Food Production Capability

> In 1971 there were 0.8 acres of improved farmland per capita in New Brunswick. This is substantially below the figure of 1.5 acres considered sufficient to maintain one person for one year on a traditional North American diet.
>
> To obtain a level of self-sufficiency in those food products that can be grown within the Province, there must be an expansion of 263,000 acres by the year 1985, on the basis of present technology and levels of production. If present levels of food exports from the Province are also to be maintained, then an expansion of 326,000 acres will be required.
>
> Such an expansion in improved farmland, although large, can be undertaken. In New Brunswick, there are approximately 3.75 million acres of Class 2 and 3 agricultural land, of which 1.34 million acres, at the most, are in use. Moreover, this expansion may be justifiable considering the present low production per capita and the loss of farmland in other regions of Canada.

Projections of population growth and the consumption of farmland in Canada by the process of urbanization, brings to light the fact that by the year 2001, Quebec and British Columbia will be heavy net importers of agricultural products. Only the Prairies and the Maritime region will have the land base to feed their population and continue exporting foodstuffs. In the year 2001, New Brunswick will have the available land base and potentially should have the ability to supply the Quebec and some of the Ontario markets with agricultural commodities, based on the assumption of present levels of productivity. The challenge to the people of New Brunswick is to look ahead and realize that food will be what oil is today, a scarce resource. Farmland should be preserved so that as demand increases in the future, the land base will be available to meet this demand.

P.93 Pressure on Farmland

Statistical data concerning the sub-division of farmland are not available.

P.98 The distance that farmers have to travel from their main farm to other parcels of land, either owned or rented, is another indication of the degree of land fragmentation.

P.98 The Challenge of Countryside Planning

The challenge of rural planning is one of resource utilization. New Brunswick has a finite amount of resources such as land of good agricultural capability;

p.99 Basic Characteristics of the Planning Process

Land use planning is not simply the production of paper plans which show neatly defined allocations of land for various purposes. Allocations of land are the result but planning must be a dynamic process. The ability to produce satisfactory results on the land will depend on the inclusion of vital characteristics in this process, the most important of which are the objectives of society, the delineation of public and government responsibility and the provision of an adequate data base.

p.99 The public is prepared to go through a comprehensive planning exercise as long as it is done at the local level with reliable information and competent human resources.

p.100 Informational Requirments and the Data Base

Decisions regarding the allocation of land require information to determine the implications of various alternatives and their effectiveness in terms of meeting objectives.

The most effective allocation of land requires information on land qualities and capabilities. In addition, a broad range of socio-economic information is required to determine the impact of decisions on people as well as on the environment because land use decisions often have implications of an irreversible or long-term nature. It is important that trends be considered so that decisions can be assessed in terms of their impact on options for the future.

p.100 Data Needs

Substantial amounts of data are required regarding critical areas for both policy formulation and land plan implementation. Some of these data are presently unavailable, some are collected but not interpreted, some are collected and used extensively and others are available but not put to best use.

Three main types of data are necessary to enable proper decision-making in the field of resource management. They are land ownership, land assessment and taxation, and soil capability. The Council of Maritime Premiers has decided to establish, through the Land Registration Information Service, a system which will, over the next ten years, bring together and rationalize the land ownership and assessment information for each of the Maritime Provinces. As far as soil capability is concerned, New Brunswick has, in the past three years, established the Agricultural Land Planning Section of the Department of Agriculture and Rural Development for this purpose. However, having set up the necessary agencies, it is important to examine how these can be used to the best advantage.

Most projections of the future cropland availability assume that individual decision makers will continue to respond to market and non-market forces in much the same manner as they have in the past. However, a large proportion of all cropland and forest land in New Brunswick is held in private ownership. Therefore, the expectations and motives of these private owners will ultimately determine how much land, which land and under what conditions land will be used for crop production.

A comprehensive program is needed to provide the policy making framework for future agricultural production. This will be achieved if the Land Planning Section works closely with LRIS to relate these three main land data bases.

It is most important to devise better ways for making this information more readily accessible. One procedure to alleviate many of the difficulties with land capability would be to use computer technology along with map overlay techniques. This would provide a data base that is both comprehensive and understandable.

p.101 The Specific Need for Reliable Soil Data

The availability and reliability of soils information in New Brunswick varies greatly from one area of the Province to another. Some areas have recently been covered at a semi-detailed scale and the information is presented in a form easily lendable to multiple usage; in other areas, no systematic soil survey has ever been conducted and the only information available is through the C.L.I. maps. The accuracy of these maps depends upon soil survey information and where this information is non-existent the maps are unreliable. New Brunswick is one of two provinces where there is little reliable information concerning the capability and suitability of the soils.

A systematic effort must be made, as soon as possible, to provide New Brunswick with a more uniform and reliable soil data base. In establishing a priority to achieve this goal two alternatives must be considered:

1. The requirement for agricultural development generally is for detailed soil surveys that allow planning at the farm level for the purposes of soil improvement and crop selection. While agricultural specialists can make use of semi-detailed surveys in a general manner, they are of little use for advising on the problems of individual farms. This fact partly explains why such surveys have not been extensively used in the past by staff of the Department of Agriculture and Rural Development.

2. The requirement for land use and resource planning in rural areas is, generally, for a semi-detailed type of soil survey. In areas of intense and mixed

development it is useful for the planner to have detailed surveys in order to be more specific. This, to some extent, explains why surveys carried out for land use planning purposes in the vicinity of major urban centres have been of the detailed type.

Since it is neither possible nor desirable to proceed with both of these alternatives, the type of soil survey conducted should have the potential of satisfying both needs. In order to accomplish this, future surveys should cover the cleared areas of the Province at detailed scale and forest land adjacent to roads and populated areas should be covered at semi-detailed scale. This approach would satisfy most of the needs of the major users of soil surveys and it would enable the Province to obtain good coverage of its soil resources within a reasonable period of time.

The Objective of an information System

To best serve future provincial needs, an information system should be developed in order to facilitate decision-making at all levels of society. This would include anticipating data requirements for the future, isolating critical decision points and organizational problems and setting out alternative recommendations for the ultimate decision-making authority.

To ensure that such an objective is achieved, on a continuing basis, it is necessary that two things be done:

1. Improve the information base itself. This would include classification criteria and systems for the collection, storage and retrieval of data best suited to various user groups.

2. Develop and refine the information system. This would include building on past experience, identifying critical relationships and adopting changes that seem likely to improve the methodological base.

p.104 Conclusions

3. In many regions of the Province there is a serious lack of reliable data.

p.109 Provincial Soil Survey Requirements

The Study recommends that the Land Planning Unit of the Department of Agriculture and Food, as a priority, undertake semi-detailed soil surveys to complement existing information and that only cleared areas be covered at a detailed scale. For purposes of this report this type of survey is referred to as a multi-purpose soil survey.

p.111 Ch. 11 Land Improvement

Introduction

The development of the New Brunswick agricultural industry is heavily dependent on the quantity and quality of agricultural land that will be available for future production. As of 1976, the Province had 443,000 acres of improved agricultural land in production, approximately equal to 1971 levels, indicating that the decline in active agricultural acreage which has been occurring for decades may be levelling out. It should be understood, however, that the immobility of land leads to the unfortunate circumstance in which some areas of the Province may be blessed with an adequate land resource while others are desperately short. Furthermore, a substantial portion of this land is not fully productive and is in need of improvement and some is simply not suited for modern production methods. It is estimated, for example, that upwards of 90,000 acres of cropland, in 1976, was in need of improvements to facilitate drainage.

These two factors, along with an ownership pattern which holds some land in a relatively unproductive state for long periods of time, necessitate caution when comparing land availability to land requirements at the Provincial level. Nevertheless, the Study has estimated the quantity of good quality agricultural land which would be required if all of the commodity objectives outlined in this report are met. By 1985, assuming both output and yield objectives are met, the farm industry would require approximately 365,000 acres of good quality land in peak production. This acreage does not reflect long term needs, since increased self-sufficiency in feed grains as well as increased acreages in other commodities is anticipated. It must be stressed, however, that in view of the locational, quality and ownership problems as referred to above, significant increases in farm output cannot be accomplished without the following comprehensive land development program.

p.113 Field Size

Many fields used for agricultural production are too small to cultivate with modern machinary. Large investments in machinary are feasible only if the fields to be worked are of sufficient size to minimize such factors as turn around time. The solution to this problem lies largely in field consolidation as many of these fields lie adjacent to each other, separated by such obstacles as old fence lines and treed areas.

Shortage of Land in Heavily Farmed Areas

Some farming areas of the Province display intensive agricultural production as evidenced by the proportion of cleared and improved land under production relative to total farm land. In these areas, a need for expansion of the land base is evident. In some areas farmers have had to rent lands over a mile from the homestead to accommodate their expanded production requirements. In many of these areas, however, there is a considerable acreage of potentially highly productive land under forest that, if cleared, could alleviate these supply bottlenecks.

Idle Abandoned Land

The Study has estimated that there are approximately 17,000 acres of cleared abandoned farmland in the Province, in blocks of ten acres or more, which would be economically returned to agricultural production. In addition, much of the improved farmland leaving agriculture each year, holds good potential to be farmed again. It is estimated that while 50 percent of these lands would require drainage, the remainder would require only liming to raise the pH level in the soil to an acceptable level.

p.117 5. Land Clearing

A land clearing program is recommended to allevaite the short supply of good farmland in areas of intensive production. The program would include a grant designed to cover 50 percent of the costs of heavy clearing equipment and recommended lime application in the first year less the net salvage value of the wood on the land, if the stand were valuable enough to warrant harvesting. The total average clearing cost per acre to the farmer is estimated at $495 which is based on average costs of $485 per acre for machinery rental and $70 per acre for liming less an average of $60 per acre net return for a harvested wood stand. In any case, the total net cost, to the farmer, of bringing uncleared land into production should not be less than the agricultural value of comparable cleared land in the community whether actually available for purchase or not.

6. Soil Erosion Prevention Through Terracing and Contouring

To arrest the acute soil erosion in the Upper St. John River Valley, it is recommended that a planning team, employed by the New Brunswick Department of Agriculture and Food, identify those farms with the severest erosion and that the owners be strongly encouraged to introduce the necessary terracing or contouring measures. The aim would be to provide a complete conservation plan for each farm rather than to "shoreup" only those fields most affected by erosion. To this end financial assistance is recommended as follows:

(a) a grant covering 50 percent of terrace construction costs (terracing costs are estimated to average $150 per acre);
(b) a payment of $25 per acre to farmers who leave land unplanted for this purpose during the period June 15 to September 15.

All professional and technical services required for either contouring or terracing would be provided through the provincial Department of Agriculture and Food.

Approximately 35,000 acres of productive land in the Province's potato belt are in need of some conservation system or practice.

p.118 10. Land Identification

Land identification programs represent an approach to preserving agricultural land that is finding acceptance in a number of areas, including Prince Edward Island and certain states in the United States. Such programs can be (a) voluntary, in which case a farmer agrees to have his land classified as agricultural land in return for compensation (i.e. exemption from land taxes); or, (b) they can be compulsory, in which case, in return for subsidized land improvements such as those recommended in this Chapter, a farmer must have his land classified as agricultural.

Land identification programs have a distinct advantage over the zoning of agricultural land through the planning process. The latter can be time consuming, even if accepted and acted upon. The former offers an effective measure that produces quick results and that can operate concurrently with the development of a long range land use plan.

In light of the urgency to arrest the decline of good agricultural land in New Brunswick and in order to ensure that government investment in improving agricultural land is protected, the Study recommends the implementation of a land identification program under which the following categories of land would be "identified" as agricultural land:

1. All land for which the government has made a grant for land improvement purposes under the proposed land improvement program in this chapter.

2. All actively farmed land which farmers care to have voluntarily identified.

As compensation for the farmer, all identified land would be exempt from the provincial land tax and would remain so as long as the land were maintained in agricultural production by either the owner or a leasee.

Under the program, an agreement should be made for a minimum of ten years and could be cancelled or altered only with the consent of the current owner and the Department of Agriculture and Food. When the agreement is cancelled, back taxes on land should be paid at market value plus interest, dating back to the time of the signing of the agreement.

p.247 Benefits

The total impact of the program, of course, is much more than production and employment increases. The social and economic advantages which will accrue to the rural economy as a result of increased activity in the agriculture sector are obvious benefits which the Study has not attempted to document explicity. Likewise, the benefits arising from increased activities by the regional councils, district planning, co-operatives, farmers' markets and the introduction of resource appreciation into the school curriculum have not been expressed in monetary terms.

By 1983, if proposed programs are implemented and targets reached, the additional value of production would be $60 million annually, in 1976 terms, above the 1975 level, the latest year for which data was available. This would result in an initial contribution of $31 million to the gross domestic product and a total contribution of $94 million per year above 1975 levels. These production increases would raise the index of Physical Volume of Agricultural Production from 84.7 in 1975 to approximately 114 by 1983.

> Under the efficient management systems expected to be employed in most future production increases, it is estimated that 0.167 man-years of employment would be associated with each thousand dollars of output (in 1974 dollars) made up of 0.137 man-years at the non-farm level of 0.030 at the farm level. Thus, approximately 8,500 to 9,000 man-years of employment would be created of which 20 percent would be at the farm level. Not all of this increased employment would result in new jobs, however, due to underemployment currently existing in the industry, especially at the farm level.
>
> \- Agricultural Resource Study 1977

The needs for information are many, to cite only a few:

i) An expansion of 263 000 acres is recommended. There are more than 17 000 000 acres to choose from. Direct clearing costs are estimated at $495 (1976 dollars)/acre. In addition there may be infrastructure costs (new roads, bridges, buildings) and social costs (new educational and cultural facilities).

Question: Without data bases on soil, climate, topography, infrastructure, ownership, how can the best 263 000 acres be selected from the 17 000 000?

ii) The implementation of a land identification program is recommended.

Question: How can it be fairly administered without an annual or biennial monitoring program to ensure that the identified land is in fact being used as agricultural land?

iii) Proposals are made for programs to:

(a) improve productivity by drainage;

(b) improve productivity by liming;

(c) prolong the productive period of fields by terracing and contouring;

(d) reactivate idle abandoned cleared land; and

(e) consolidate small fields into larger ones.

Question 1: How can the most suitable land for each of these programs be selected without an extensive field inventory?

Question 2: How can the results of these programs be monitored without an on-going monitoring program linked to a field inventory?

3.2 The Agriculture Segment of a Hypothetical Renewable Resource Information System

In Figure 6 the agriculture segment of a renewable resource information system is shown schematically. There are five main parts to this system. There are the sensors and interpretations, there is the family of data bases, there is the data conduit, there are the applications programs and there are the decision-makers. Of these the most important by far is the latter; unless the decision-makers have important decisions to make and unless they are prepared to base their decisions on facts there is no 'raison-d'être' for the system. As the function of each group was described in section 2.2, only those elements of the agriculture sub-system that differ from the forestry sub-system will be discussed here.

Data Bases - In the agriculture sub-system, there would be an agriculture data base along with the data bases for soil, climatology, topography, and boundaries that were discussed in section 2.2 as part of the forestry sub-system.

As discussed in section 2.3 every significant (larger than 5 hectares) forest stand is delineated on a forest cover map at medium scale (1:20 000 in N.B.). Farm fields can be considered the equivalent of forest stands yet there is no map series on which farm fields are delineated. There are not even any maps on which farms are delineated!

For those parts of the Maritimes in which property mapping is completed it would be relatively easy to delineate and number all farm fields. This would make it possible to keep an on-going record of crops and other significant items relating to each field; in effect it would make it possible to have a farm field map series and a farm crop data base.

The Data Conduit - The concept of a data conduit has been introduced to make it unmistakebly clear that the data bases remain the property of and under the jurisdiction of the agency that collects and manages the data in the data base. The data conduit is simply nothing more and nothing less than the mechanism whereby data from various data bases can be brought together for a specific application. It need not exist as one physical entity; it is obvious however that in merging data

AN AGRICULTURE INFORMATION SYSTEM

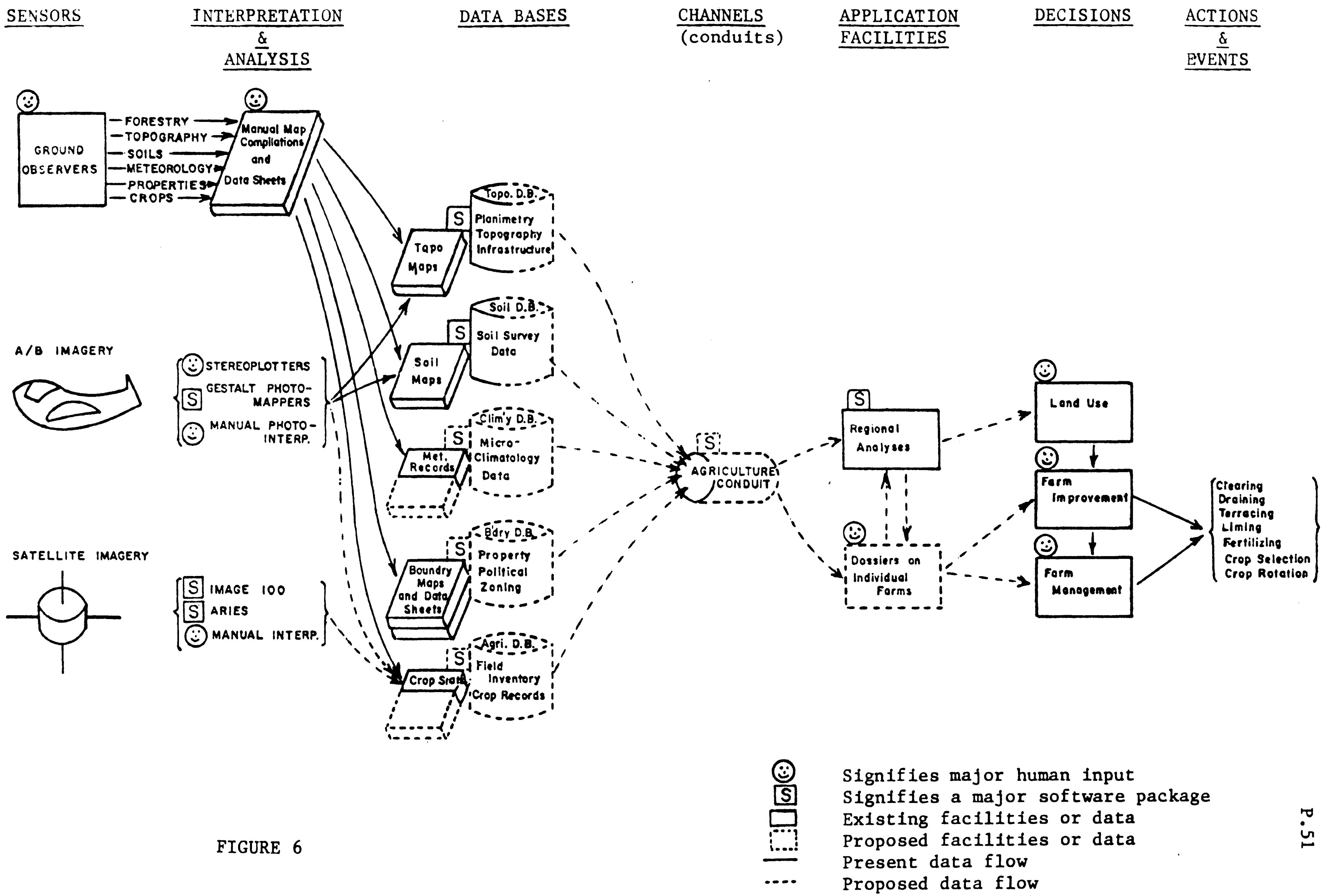


FIGURE 6

from four, five or more data bases for two, three or more different applications, there will be many common problems and a few programs unique to each user group. The concept of the data conduit is introduced simply to ensure that the common problems are tackled collectively.

Application Facilities - There are two main types of applications anticipated for the agriculture segment of the renewable resource information system. One type of application is for regional analyses requiring large amounts of data and rather sophisticated procedures. It should be noted that at present in Canada the CGIS system is perhaps the most powerful for this type of application.

The other application is for decision-making with respect to individual farms. The relevant data for each farm is retrieved, merged appropriately and presented in the format most useful to the farmer and to those who make decisions about individual farms.

Each season as soon as crops were sufficiently advanced that their spectral signatures were identifiable from the Landsat imagery, a crop forecast could be made. Even if fog or haze obscured some parts of the region, a forecast could be made using statistical techniques just as the prediction of election results can be made using only a portion of the votes counted. Every nine days there would be more data and an improved forecast could be made. As indicated in Figure 6, the forecast would be passed to those responsible for developing marketing strategies.

3.3 A Low-cost Monitoring Program Defined

In section 3.2 a proposed farm field map series and a farm crop data base is outlined. In this section a monitoring program to up-date the crop records is described briefly.

In Figure 6 the essential elements of a possible program to monitor crops and to up-date the farm field data base on a regular basis is shown schematically. It is anticipated that Landsat imagery (See Section 1.2.4 and Appendix A) will be the main source of data. As countless experiments have shown, this is not as straight forward as it may seem. Because the smallest element observed by Landsat (a pixel) is approximately one acre it follows that for small fields (10 to 20

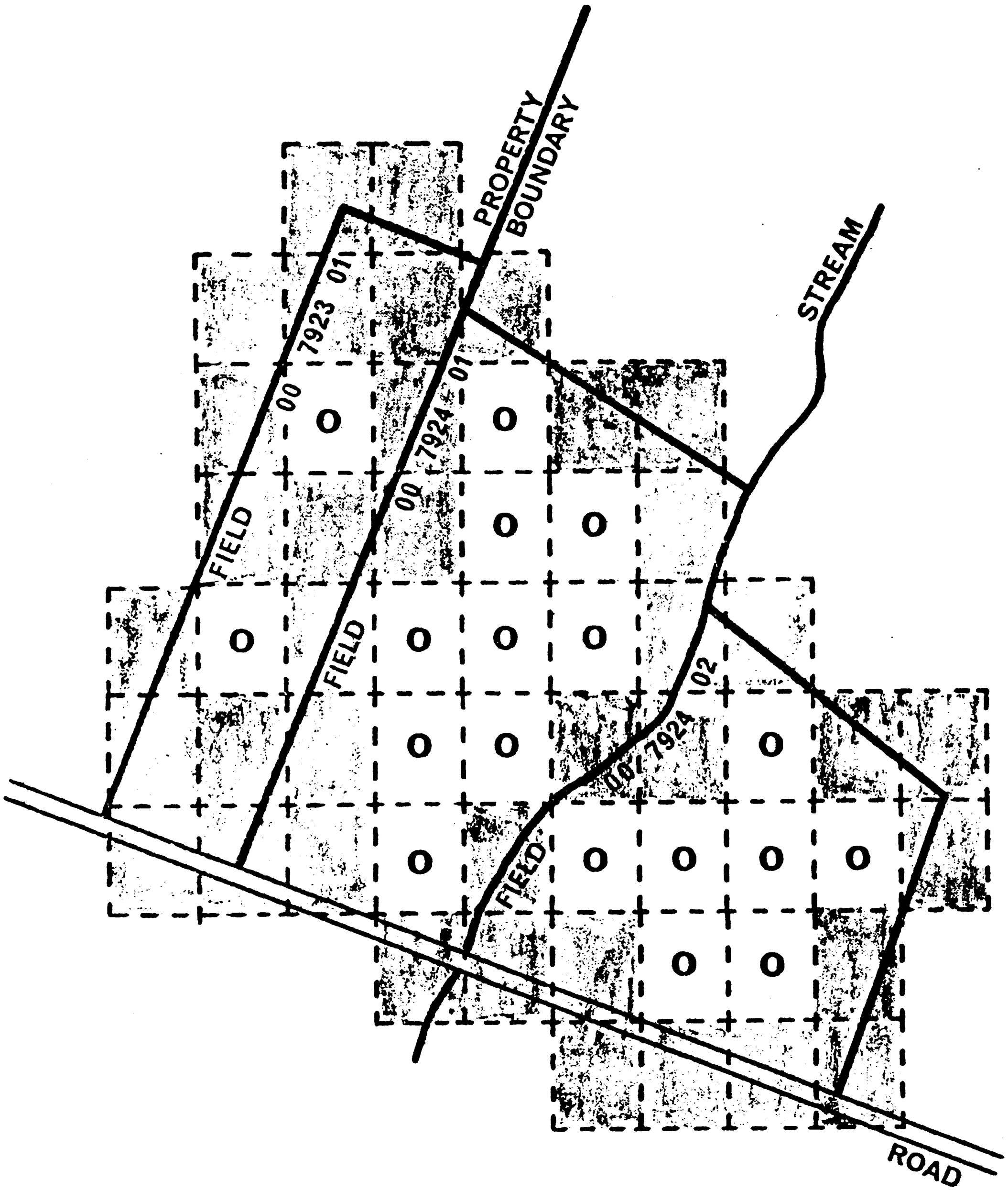


Figure 7. Landsat pixel pattern covering three fields. Pixels from Landsat A, B, and C cover area of 59 x 79 m; Landsat D, scheduled for 1981, will have pixel area approximately 40 x 40 m. Note that only those pixels entirely within a field are useful for crop identification, these are marked with an O

hectares) a large proportion of pixels will overlap the boundary and hence their data will be of no value. This is illustrated in Figure 7. Thus for fields of a few hectares the area determination will be no better than an "eyeball estimate" by an experienced countryman.

To overcome this shortcoming, it is proposed that a farm field inventory be compiled in preparation for the Landsat monitoring program. A project to do this is discussed in Section 3.4.

Given a data base with reasonably accurate field boundaries and areas and given prior knowledge of the crops anticipated in a field the Landsat analysis would then consist of finding a few pixels having coordinates well within the boundaries of the field and of comparing the observed spectral signature with the spectral signatues of the two or three crops expected to be in the field on the date of the overpass. It would take some time and experience to build up this data base, but once built up the monitoring process would not be costly.

The acquisition of Landsat imagery at nine day intervals requires clear weather at the time of the overpass; if fog or haze happens to obscure a county during two or three successive overpasses at a critical stage of the growing season, no useful imagery will be acquired, and it will not be possible to make a crop forecast or to up-date the data base. Thus a back-up source of imagery is essential. As it is too costly to maintain a high performance aircraft with crew and equipment on standby, it is proposed that a "tactical facility" (probably a light aircraft) alternative be developed. This alternative is discussed in more detail in Chapter 4.

3.4 Proposed Project to Develop a Crop Monitoring Program.

3.4.1 Developments required prior to implementation of the crop monitoring program.

The major development required in order to use Landsat imagery effectively for an on-going crop monitoring program in the Maritimes is the establishment of the farm field data base (See Fig.6). This data base would contain the coordinates of the boundaries of all the fields to be monitored and a record of the crops grown recently on each field as well as a list of crops that it is reasonable to expect. In time there would be various other data in the file on each field but only the coordinates and the expected crops are needed for Landsat monitoring. Ways of establishing this data base will be discussed subsequently.

Assuming that hardware such as the Image 100 plus general purpose software for processing CCT's (computer compatible tapes) from Landsat are available, there will still be a need for a modest amount of additional software. This additional software will be needed in order to correlate the location of the fields (as stored in the field inventory) with the imagery, and to test for the expected crops. It is implicit of course that the algorithms of the spectral signatures of all the expected crops are readily available.

3.4.2 Establishment of a Farm Field Data Base

As mentioned above a data base containing the coordinates of all fields and a list of crops to be expected in each field is a pre-requisite to an effective crop monitoring program in the Maritimes. This is necessary for several reasons -- one reason is because many of the farms in the Maritimes are "pockets" in a large expanse of forest. Another reason is that many of the fields are relatively small (5 to 10 hectares) and quite often irregular in shape. As discussed in section 3.3 it is not practical to rely on Landsat for getting the areas of these fields.

Using the property mapping as a base, the farm field mapping would be done in much the same way that the property mapping itself has been done. In place of a team of property mappers working county by county, there would be a team of farm field mappers working county by county. They would call at each farm and, along with the farmer, delineate the boundaries of his fields on the photomap base of the property maps. At the same time the type of crop currently growing in the field would be ascertained and, if possible, the type of crop grown in the preceding two years would be noted.

Subsequently, in the office the boundaries of the fields would be digitized and the boundary data along with the field identifier, the property number, the current crop and the preceding crop information would be encoded for filing in the agriculture data base.

To detect changes in field boundaries, the area of each field would be computed from the Landsat imagery: if it fell within specified limits it would be assumed that no change had been made in the boundaries of the field and that the entire field was in crop; if the Landsat area fell outside the limits then it would be flagged for an audit check by either a tactical facility or a ground inspection.

Recognizing that, to date, crop inventories in the Maritimes have been based on data compiled by Statistics Canada from questionnaires, it is proposed that the establishment of the farm field data base be completed prior to the next decennial census (1981). Thus an objective -- and presumably quite accurate -- measurement of all crop-growing areas and of the types of crops could be compared with the census data. There would then be a good link between the data collected in the past by questionnaire and the data to be collected in the future by remote sensing.

3.4.3 Resources Needed

(a) Data collection for the farm field mapping. Assuming that there are approximately 4000 farms in each province, it is estimated some 2000 person-days would be needed for the field work and some 1000 person-days for the routine part of digitizing the boundaries and encoding the attribute data (crops, etc.) for each province. This estimate is valid only for those fields in counties for which property mapping and photo-mapping are available; for areas where these items are not available it will be much more difficult to develop an effective monitoring program.

It is anticipated that the routine part of this could be done by students during the summer, possibly as a Canada Works program; 3000 person-days is equivalent to about 12 person-years. In addition there would be costs for field travel, for materials, etc. which, as a first approximation, can be estimated as equal to the salaries and wages for the job.

At first glance this may seem to be quite a large expenditure, however it should be noted that the total for farm field mapping of all three Maritime provinces would be considerably less than the cost of the forest cover mapping for New Brunswick alone.

(b) Hardware and software for the data base. There are many "horror stories" about the endless costs associated with the development of a digital data base. However, now that there are many data base systems in operation and that there are also some turn-key (ready to use) systems on the market, there is no need to start an "endless development" venture. As an in-depth discussion of this topic calls for an extensive investigation of applications, it is considered to be beyond the scope of this study.

(c) Monitoring by Landsat. There are two aspects to the monitoring program:

(i) Linking the imagery to each field.

(ii) Interpreting the imagery.

In view of the fact that one of the objectives of CCRS is to use Landsat for crop monitoring, it is reasonable to expect that considerable assistance would be provided by CCRS. In addition, within the region there are at least three centres which, given a modest level of assistance, can contribute to the solution of this problem. At one of these, there is expertise in solving the positioning problem — that is, in correlating the pixels from each overpass with the corresponding area on the ground; at the other two, there is expertise in the spectral signatures of the crops of the region. Given a total of some eight to ten person-years for development, there is good reason to expect that, assuming a complete data base has been compiled, an effective monitoring program could be operational.

In summary, although at first sight it would appear that considerably more effort will be required to achieve effective application of remote sensing for agriculture than for forestry, it should be recognized that the proposal for agriculture includes basic farm field mapping whereas in forestry the basic forest cover mapping is already available.

4. FACILITIES FOR TACTICAL APPLICATIONS OF REMOTE SENSING IN THE MARITIMES

In Chapters 2 and 3 a comprehensive regional long-term remote sensing program in aid of agriculture and forestry has been discussed. Although for many purposes imagery from the Landsat overpasses at nine day intervals is adequate, there are many problems which can only be dealt with successfully if pertinent information is provided within a few hours or, at most, a few days. It is quite appropriate to call these activities "tactical applications" to distinguish them from the "strategic applications" discussed in the preceding chapters.

Indeed, in discussing remote sensing with users and potential users, the need for "instant imagery" came up repeatedly. Most of the needs originated with those associated with agriculture, but there were some from forestry and environmental monitoring as well and a few from other disciplines. A few examples of actual and potential applications are:

- forest fire spotting and monitoring;
- assessment of damages after natural disasters;
- identification and monitoring the spread of certain crop infestations; and
- surveys of soil moisture content and of drainage patterns.

The tactical application of remote sensing is distinctly different from the stategic application in many respects:

- it usually deals with a singular, quite well defined problem;
- the problem in question is geographically localized (if it is wide-spread, it can easily be subdivided into smaller units);
- the information sought must be collected within a short time period, even on a set date or time of the day; and
- local authorities or private individuals have a direct interest in the problem.

If the problem is different, so must be the solution from a technical as well as from an administrative point of view.

The technical requirements anticipated are as follows:

Sensors: The photographic camera will, no doubt, be the most commonly used sensor. Almost invariably large scale imagery is needed although stereo coverage may not always be essential. Usually a single camera will suffice, however, the use of multispectral cameras (70mm, 35mm) because they are more readily available, cheaper and easier to operate than the large format survey cameras and they do not have to be mounted permanently in an aircraft. The use of old mapping cameras is discouraged because most of them were not designed to take colour photographs and thus the image quality will probably be inferior. Natural colour, and colour infrared film will be the prevailing emulsion type employed. Occasionally an infrared scanner or a thermovision camera may be satisfactory.

Platform: Any type of light aircraft in which a small camera can readily be mounted will usually be satisfactory. For some applications the camera may be hand held.

Photographic Facilities: Capability to process colour imagery is essential.

Image Analysis Facility: It is anticipated that most of the interpretation will be performed manually and that the emphasis will be on the qualitative rather than the quantitative aspects. Each user should be equipped with simple instruments such as stereoscopes, projectors, filters, sketchmaster etc.. In addition, interpreters should have access to more sophisticated instrumentation such as microdensitometers, colour additive viewers, etc..

Although some of the tactical applications are routine, and hence can be standardized, programmed, etc., many are anything but routine. For the latter, the user of remote sensing data must be involved at every stage from planning to interpretation. Therefore, all users should be familiar with the fundamentals of remote sensing. Larger organisations that are frequent users of remote sensing techniques can perhaps consider the establishment of in-house facilities, however the establishment of commercial services that acquire cameras and accessories, have access to aircraft and can perform routine image analysis should be encouraged to serve the general remote sensing needs of a region. The presence of a resource person in each region, who can advise in non-routine uses is also important.

As in most ventures, the key to success is expertise. Ultimately, each user group will acquire the necessary knowledge, however, this is a slow process. Apart from the traditional patterns of short courses, and of home-study the best way to build expertise is by the exchange of ideas between users. Such a knowledge transfer is very effective because it is based on experience. At the outset, frequent workshops should be organized, in small groups, where people with successfully accomplished tasks share their experiences with others.

A small nucleus for tactical application of remote sensing already exists in the Maritimes. There is some basic experience at at least two academic institutions, the Nova Scotia Land Survey Institute and the University of New Brunswick. An assortment of equipment also exists in a variety of places. Several interested individuals rent light aircraft and use small format cameras to acquire imagery for interpretation. Several entrepreneurs have acquired cameras and accessories and offer aerial photography services. A partial list of remote sensing resources in the Maritimes is given in Table 2.

Finally, it should be pointed out that facilities established for tactical applications of remote sensing will be of help and benefit in the strategic applications in various ways. For example, the use of tactical applications creates a wide-spread awareness of remote sensing and since most tactical applications show immediate benefits to users, it helps to establish the creditability of remote sensing. In addition these facilities can assist in the gathering of "ground truth" data to support strategic application projects and can be used to acquire "fill in" data for gaps that occur in the imagery coverage of these projects.

TABLE 2

PARTIAL LIST OF REMOTE SENSING RESOURCES IN THE MARITIMES

NAME	CONTACT PERSON	EQUIPMENT
GOVERNMENT		
N.S. Dept. of Land and Forests	E. Bailey E. MacAulay	Cessna 180 Skywagon single engine aircraft with panoramic side window. Service ceiling 5900 m (19 500 ft).
Maritime Resources Management Service	Neale Lefler	B and L Zoom Transfer Scope, Photographic Laboratory with copy camera.
N.B. Research and Productivity Council	D. Clarke	AGA Thermovision camera.
P.E.I. Dept. of Agriculture	Norbert Stewart	1 Nicon 35 mm camera.
EDUCATIONAL INSTITUTIONS		
U.N.B. Forest Resources Dept.	W.H. Hilborn S. Oliver	1 Hasselblad 500 EL camera with intervalometer and synchronizer (50 mm lens 12 and 70 exposure magazines), camera mount for installation in aircraft through side door.
PRIVATE SECTOR		
Chatam Air Service Ltd.	C. Banks	2 Cessna 310, 1 Piper twin engine, service ceiling 19 500 ft. Plans to acquire a turboprop aircraft with service ceiling of 29 000 ft. 1 Wild RC 10 mapping camera with statoscope. Photographic lab. in operation by end of 1978.
Miramichi Air Service Ltd.	J. Seely	Ph 22 and 172 aircraft, K-17B Fairchild camera (230 mm format), photographic lab.
Trainor Surveys ((1974) Ltd.	J. Trainor	Cessna single engine aircraft (camera port ready by spring 1979), Hasselblad 500 EL camera (80 mm lens, 12 and 70 exposure magazines).

5. RENEWABLE RESOURCE INFORMATION SYSTEM FOR USE IN THE MARITIMES

The need for more intensive management of the forest and agriculture resources in the Maritimes is slowly but surely being recognized by the public, by officials at all levels and by the elected representatives. Until recently this recognition was mainly in the form of lip service but the approval of several sizeable General Development Agreements for this purpose confirm that the need has been recognized in the most definite way possible.

In some of the studies leading to these Agreements the need for information was spelled out explicitly, in others it is only implicit.

In principle the need for information on land was recognized by the inclusion of "Information" when the Land Registration and Information Service was formed some six years ago. Although the final phase of the four phase LRIS program was only vaguely defined, it was however realized that it could not be achieved without a sound base of control surveys, photomaps and property maps. These are now in hand.

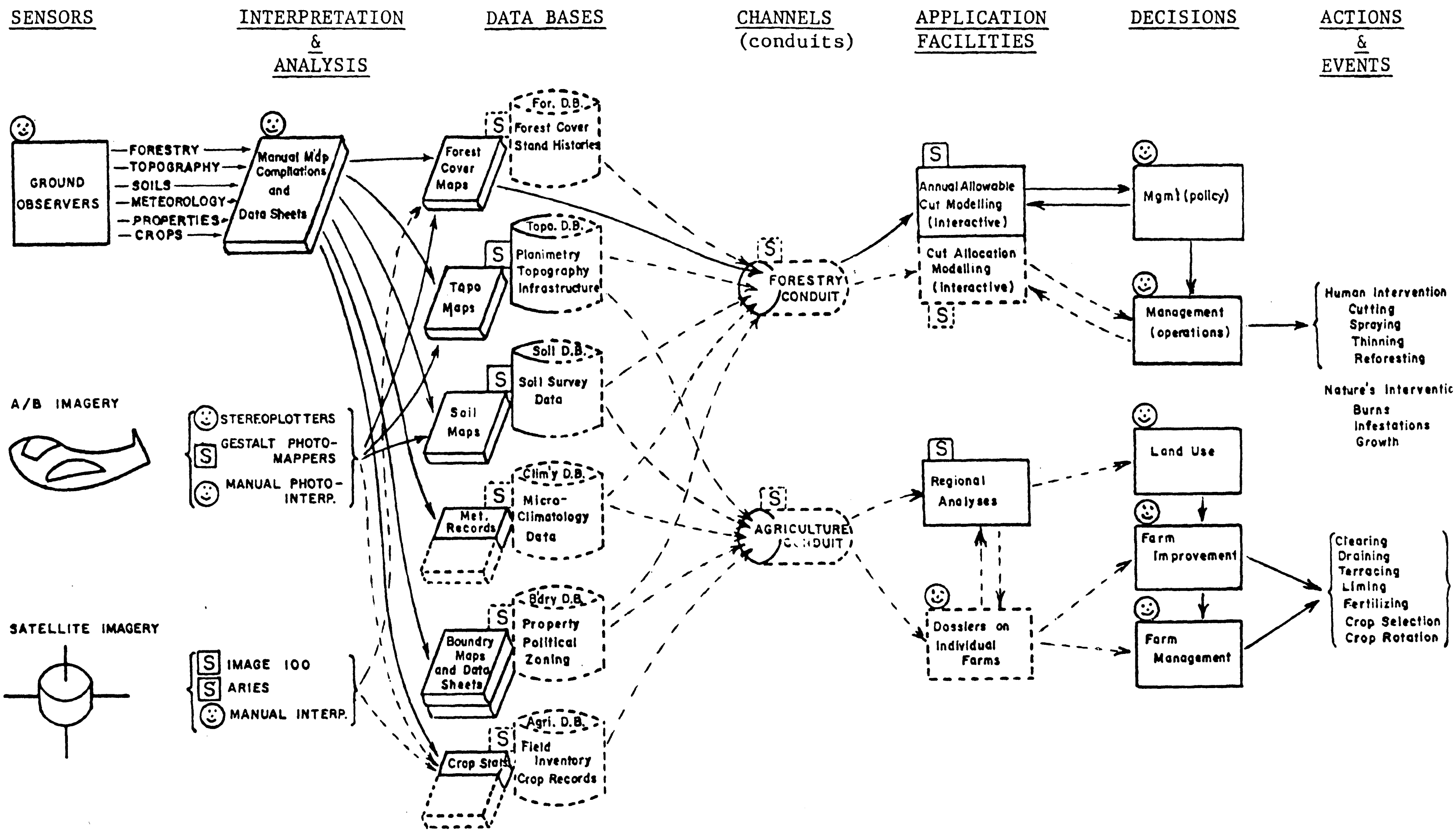
At the federal level the principle was recognized some 20 years ago by the creation of the Canada Land Inventory which in turn led to the development of the Canadian Geographic Information System. Some 10 years ago the need for a data base on soil was recognized by Agriculture Canada and subsequently CANSIS (Canadian Soil Information System) was developed. Also in topographic mapping at the federal level the need for a digital data base of map information was recognized some ten years ago and steps to produce digital maps were initiated. The roles of CCRS (Canada Centre for Remote Sensing) in land information and of the Forest Management Institute and the Forest Fire Research Institute have been discussed above.

Despite the identified needs, the establishment of ground control, resource maps and property maps and the existence of the several large, sophisticated land-related systems developed by the federal government, there is neither a clear concept nor any semblance of a consensus on how the needs for information management should be met.

How can the concepts be clarified and a consensus developed? My suggestion is that a workshop team of well-informed members from each concerned agency be formed. This team would be asked to define a renewable resource information system for use in the Maritimes. It is suggested that their initial meeting be for at least two weeks and that subsequent meetings be held as necessary and that their final report be submitted within three months of the start of the workshop.

As a basis for discussion, one version of an integrated renewable resource information system is shown in Figure 8. This, obviously, has been derived by simply continuing the proposed forest information shown in Figure 1 with the proposed agriculture information system shown in Figure 6. It is recognized, of course, that this is only a first draft and that much work remains to be done to achieve an effective renewable resource information system.

A RENEWABLE RESOURCE INFORMATION SYSTEM



Signifies major human input
Signifies a major software package
Existing facilities or data
Proposed facilities or data
Present data flow
Proposed data flow

FIGURE 8

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i. In Chapter 1, it is concluded that the creation of a Regional Centre or of Regional Centres for Remote Sensing in the Maritimes at this time should not be encouraged. As an alternative to Regional Centres regional needs should be identified and the resources in the region should be coordinated to meet these needs.

ii. It is concluded that for the potential application of Landsat data in the Maritimes to be realized two major projects should be undertaken:

(a) A forest monitoring program

(b) A crop monitoring program

iii. It is concluded that facilities for tactical applications (light aircraft, etc.) of remote sensing are needed to complement satellite facilities.

iv. It is concluded that for the program suggested in (ii) above to be effective a clearly defined Renewable Resource Information System for the Maritimes is necessary.

6.2 Recommendations

It is recommended that:

i. A Workshop to define a Renewable Resource Information System be held as soon as possible.

ii. A project to develop a forest monitoring program be started as soon as possible. As the collaboration of several groups is required, it is preferable the coordination and the principle funding be the responsibilities of a regional agency such as LRIS; if this is not feasible, then it is suggested that the N.B. Dept. of Natural Resources and the N.S. Dept. of Lands and Forests assume responsibilities for it.

iii. A project to develop a crop monitoring program be started as soon as possible. As the collaboration of several groups is required, it is preferable the coordination be the responsibility of a regional agency such as LRIS; if this is not feasible, then it is suggested that the three Departments of Agriculture jointly assume the responsibility for the project.

iv. The evolution of facilities for tactical applications of remote sensing be encouraged utilizing the facilities of private enterprise as much as possible.

APPENDICES

A. INTRODUCTION (CHAPTER 1 OF THE MANUAL OF REMOTE SENSING)
BY ROBERT N. COLWELL

B. THE ALBERTA REMOTE SENSING CENTRE
- FROM MATERIAL PROVIDED BY CAL D. BRICKER

C. THE ONTARIO CENTRE FOR REMOTE SENSING
- FROM MATERIAL PROVIDED BY VICTOR ZSILINSZKY

D. PROPOSAL FOR EXPERIMENTAL AERIAL PHOTOGRAPHIC PROJECT, CAPE BRETON HIGHLANDS 1978

E. LIST OF PERSONS CONTACTED IN THE PREPARATION OF THIS REPORT

Appendix A

Chapter I (from the Manual of Remote Sensing). Introduction. by Robert N. Colwell.

Note: One copy in full color is included with the copy no. 1 of this report. This copy was part of Robert N. Colwell's lecture notes handed out in a course attended by the author of this study. Two xerox copies have been made and are attached to copies no. 2 and no. 3 of this study.

As this is copyright material additional copies of this report will not contain this appendix. Readers are advised to consult the Manual where they will find the illustrations in full color.

APPENDIX B

The Alberta Remote Sensing Centre
(From material provided by Cal D. Bricker)

1. The objective of the Centre
2. Summary of the number and type of users
3. Impact
4. Budget
5. Staffing
6. Floor plan
7. Equipment
8. Paper by Cal D. Bricker entitled "The Alberta Remote Sensing Centre: A Provincial Facility".

1. The objective and the activities of the Alberta Remote Sensing Centre -

Objective: The objective (role) of the Centre, an autonomous remote sensing center within the Canadian remote sensing program, is to administer, coordinate and develop remote sensing in Alberta.

Activities -

i. It assists all provincial users in the acquisition, application and analysis of remotely sensed data for the survey and management of Alberta's natural resources.

ii. The Center's facilities are available free of charge to Albertans - provincial government, federal government, educational institutions, private industry and the interested private citizen.

iii. The Center deals with all aspects of remote sensing excepting conventio aerial photography. This includes both Landsat and airborne multiband applications. The interpretation facilities are, of course, available users of aerial photography.

iv. The Center does not carry out research projects, but assists those who do. The staff are not "experts" in the multidisciplinary fields and uses of remote sensing. But, as they work closely with so many remote sensing agencies and persons throughout North America they can come up with most answers or make referrals to those with the answers. This centralization and coordination concept has proven advantageous.

2. Summary of the number and type of users -

Since the Center opened in June 1974 6,620 users have been recorded.

Users are listed in four categories. The following numbers are for the 1977-78 fiscal year: Alberta Government 964, Federal Government 46, Educational Institutions 621, and Private Industry 488 and private sector 29. Total: 2,148.

A user is one person in one day who utilizes our facilities. He may spend a short time in consultation or ten hours on the equipment. Either way he is recorded as one (1) user.

3. Impact of the Center -

No formal documentation as such, but many, many letters of appreciation and an increasing use being made of the facilities.

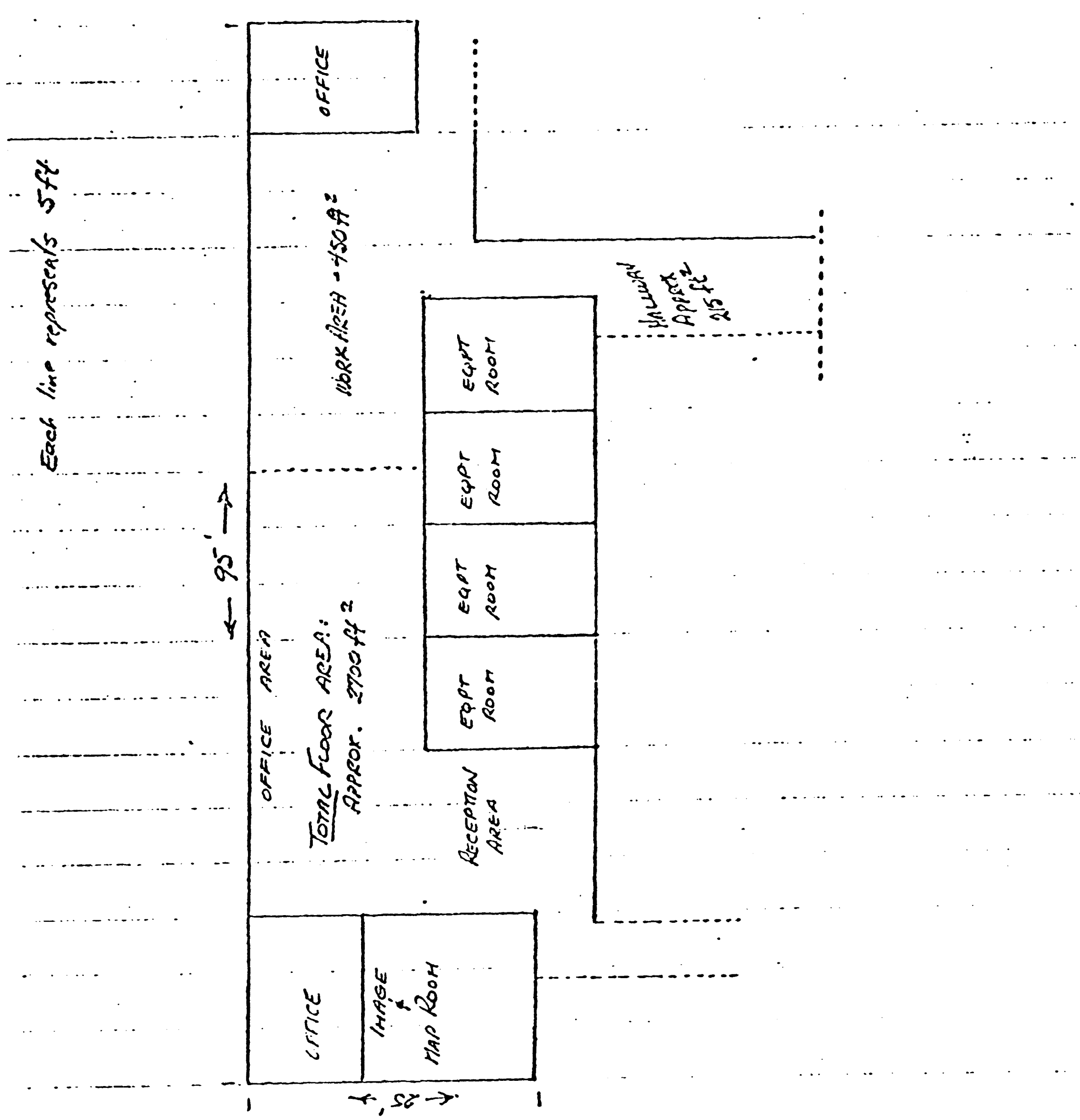
4. Budget -

The operating budget for 1977-78 was $136,000.00. The budget varies from year to year. As the number of Center users and their experience and requirements increased, new techniques and analysis equipment became necessary. This necessitated the staff spending more time assisting and advising users and operating the equipment. It also meant that the staff, in order to keep current with the state of the art (science), spent more time in acquiring experience and training. This is of course only possible by attendance at seminars and liaison visits to other remote sensing agencies, particularly in the United States. This type of staff training paid dividends, not only in personal knowledge, but in establishing contacts. Equipment purchases and travel vary from year to year. The only purchase of an expensive item of analysis equipment in the past two years was last year, an additive color viewer - I^2S, at some $35,000. Also included in the 1977-78 budget was funding to support Remote Sensing Demonstration Projects. Only part of this sum was actually expended.

5. Staffing -

Three technical staff and one secretary who also handles technical aspects of our operation. Total: four.

6. Floor plan -


OFFICE
WORK AREA ~750 ft²
Each line represents 5ft
95'
HALLWAY APPROX 215 ft²
EQPT ROOM
EQPT ROOM
EQPT ROOM
EQPT ROOM
OFFICE AREA
TOTAL FLOOR AREA: APPROX. 2700 ft²
RECEPTION AREA
OFFICE
IMAGE & MAP ROOM
25'

7. Equipment -

The Center's specialized imagery analysis and other equipment is available cost free to anyone. Staff assistance and advice in its use are provided.

Time on each item of equipment must be booked in advance.

Microdensitometer

Spatial Data Systems Model 703-32. A 32 color density slicer. A transparency (preferred) or paper print is viewed by a television camera, the various grey tones and brightness levels are converted to colors and displayed on a color screen. A control panel adjusts the color display to allow any part of the grey scale to be analyzed in greater detail. A digital readout indicates the area of any color or combinations of colors as a percentage of the total picture area. The color display can at any time be instantly recorded in color by using the Center's Polaroid and 35 mm copy cameras. Users are required to supply their own 35 mm and Polaroid color film rolls if the copy cameras are used.

Multispectral Viewer

International Imaging System I^2S Mini-Addcol Multispectral Viewer - Model 6040PT. A viewer/projector/recorder/tracer multispectral additive system that displays an enlargement of the original image on an inclined screen for analysis, photographic recording and drawing image detail on tracing materials. Up to four 70 mm Landsat or airborne multiband or multidate transparencies may be viewed, color coded, and recorded singly or in combinations as 6.7X color paper prints. The viewer has a projection magnification capability of up to 20X for viewing on a separate screen.

Interpretoscope

Zeiss/Jena Interpretoscope. A versatile 15X zoom stereoscopic analysis unit with facilities for scanning, height finding and scale correction between images. Two interpreters can simultaneously and cooperatively analyze stereopairs or film strips in either paper or transparency form.

Transferscope

Bausch and Lomb Zoom Transferscope Model ZT4. A binocular optical transfer unit for transferring imagery data onto a map, imagery or other data base. Most combinations of smaller or larger imagery scale to data base scale can be rapidly and accurately matched by the unit's 14X zoom capability and selection of .75X, 1X, 2X and 4X lenses. with a maximum image to data base ratio of 7:1.

Four Film Light Table

Richards Direct Viewing Light Table. A versatile four film model. Displays in parallel position for comparative viewing imagery simultaneously acquired in different wavebands and film types. Accomodates four rolls or individual frames in all processed forms.

High Power Stereoscope - Light Table Combination

Bausch and Lomb 240 Zoom Stereoscope and Richards MIM System #2. A direct viewing light table for simultaneously viewing film rolls or individual frames in all processed forms. An attached Bausch and Lomb spotting stereoscope provides continuous variable magnification in stereo and mono to allow small scale imagery to be analyzed at very large magnification.

Stereoscopes

Mirror and lens stereoscopes with height finding attachments for basic analysis.

Electronic Planimeter

Numonics Graphics Calculator Model 253-116. An electronic planimeter for accurately measuring areas from any type of graphic display (aerial images, maps, plans or similar material) at various scales with readouts in user-required measurement units.

Landsat Imagery Viewer

A 32X enlargement viewer to assess Landsat imagery from ISISFICHE (microfiche) received from the Prince Albert Satellite Station a few days after each orbital pass over Canada.

Data Terminals

An on-line terminal to the Canada Centre for Remote Sensing's Technical Information Library allows requestors to expeditiously, and at no cost, obtain technical documents on remote sensing and data on Landsat scenes of Canada to users specific requirements.

A video computer terminal tied into the Canada Geographic Information System (CGIS) at Environment Canada in Ottawa. The CGIS is based primarily on Canada Land Inventory (CLI) map data, and can compare and plot selected CLI variables and values (forestry, recreation, agriculture, etc.) in a graphic map format. This interactive system was designed to assist land use and resource planners in decision-making by providing pertinent and instant land information. Three specialized data sets (one of the Red Deer region and two of the Edmonton Regional Planning Commission), which include more than just CLI variables, are now readily accessible to provide system demonstrations as well as land information. Data from other Alberta CLI map sheets can be accessed on request.

Presented at B6
The American Society of Photogrammet
Fall Convention, Phoenix Arizona
Remote Sensing Session
October 29, 1975

8. THE ALBERTA REMOTE SENSING CENTER: A PROVINCIAL FACILITY

Cal D Bricker
Alberta Remote Sensing Center
Alberta Environment
Edmonton, Alberta

ABSTRACT

The Province of Alberta recognized the importance of remote sensing and established an autonomous remote sensing center within the Canadian remote sensing program to administer, co-ordinate and develop remote sensing in the province.

A need for a provincial center became evident with the proliferation of remote sensing projects, little or no exchange of data between scientists and the necessity to develop practical applications.

The Alberta Remote Sensing Center's facilities are available free of charge to anyone in the province - provincial government, federal government, educational institutions, private industry and the interested private citizen.

The Center's role is to assist all provincial users in the acquisition, application and analysis of remote sensing in the survey and management of the Alberta environment. Aircraft projects are flight planned and co-ordinated into a provincial program to eliminate duplication. The Center has specialized interpretation equipment and offers staff assistance in its operation. A library of aircraft and satellite imagery is maintained and a LANDSAT Quicklook facility allows the viewing of scenes shortly after reception by the Canadian Satellite Station. A technical library and document retrieval system is available. Facilities of the Center routinely travel the province. The Center's education program sponsors symposia and conducts courses and lecture series.

The establishment of the Center was an advantageous step in the development of the provincial remote sensing program.

INTRODUCTION

The Alberta Remote Sensing Center of Alberta Environment was established in 1974 to enhance Albertan ability to utilize remote sensing for the survey and management of the province's environment. Although autonomously operated by the province, the Center closely co-operates with and utilizes the facilities of the Federal Government's national remote sensing program, and maintains close liaison with remote sensing agencies in and outside the country.

Historically, air photo interpretation progressively became, and understandably so, disciplinarily oriented to the exclusion of co-operation between users, particularly in the acquisition of the photography. With the advent of remote sensing, scientists individualistically began developing techniques for its application to their particular discipline.

The implementation of the Canadian Government's remote sensing program made satellite and aircraft multispectral imagery readily available. The airborne program committed to the development of remote sensing within the scientific community of Canada afforded scientists the opportunity of having projects flown to their specific dictates. After the first year of operation, it became apparent that there was a need to provide a provincial center to administer and co-ordinate the airborne program and other aspects of remote sensing within the province for the use and benefit of Alberta users.

The situation was, of course, not unique to Alberta and had been foreseen in the concept of the Canadian Remote Sensing Program which promoted the establishment of regional or provincial remote sensing centers.

CANADIAN REMOTE SENSING PROGRAM

The Federal Government established a Planning Office supported by fourteen advisory scientific working groups to study Canada's possible participation in the United States Earth Resources Observation System project and the development of a Canadian remote sensing program. A Canadian Advisory Committee on Remote Sensing was also appointed to advise and assist in meeting the objectives of the Canadian program. The working groups and advisory committee, representing federal and provincial governments, universities and industry continue to play an important part in the Canadian program. In 1971 a national facility, the Canada Centre for Remote Sensing, was established to administer Canada's remote sensing program. Its facilities include a satellite receiver station, data processing, applications and data acquisition divisions. Its airborne program for the acquisition of multispectral imagery is available on request to anyone to have remote sensing projects flown.

ALBERTA REMOTE SENSING CENTER

The administration of resources in Canada is a provincial concern and remote sensing projects in Alberta are mainly carried out by provincial scientists with a knowledge of the local area. The Canada Centre for Remote Sensing's satellite and airborne programs were being extensively used by Alberta scientists, but in an unco-ordinated and uneconomical manner. Airborne projects were flown at the request of provincial agencies and scientists with little co-operation between requestors. This was understandable as the program was new, not widely known and a provincial facility did not exist to assist scientists who each dealt directly with the Canada Centre for Remote Sensing.

As Alberta government departments were using the programs, a committee was appointed to assess remote sensing for the needs of all sectors of the province. A survey was distributed. The results indicated a need to utilize remote sensing and a requirement for a provincial agency to administer and co-ordinate the province's program.

The committee recommended that a remote sensing center be established within the Alberta government to provide a service to everyone in the province. To ensure that the Center would not become disciplinarily aligned it should be service oriented and structured to work in close co-operation with provincial government departments, federal government agencies, universities and private industry. The provincially autonomous center should co-operate closely with the Canada Centre for Remote Sensing, other provincial centers and international agencies. The Alberta Remote Sensing Center was officially established in early 1974.

THE CENTER

Located in the capital city, Edmonton, the Center is in close proximity to government departments, educational institutions, and the majority of provincially based federal government agencies and private industry. It is service, not research oriented and its facilities available free of charge to anyone in the province. In the first year of operation it was used by over 1,500 persons. The Center's facilities include:

Interpretation Equipment

First line interpretation equipment for the analysis of LANDSAT and aircraft multispectral imagery is available seven days a week with staff advice and assistance in its operation.

Airborne Program

For scientists desiring to have remote sensing projects flown by the Canada Centre for Remote Sensing or other facilities, the Center's staff provides advice and assistance in the selection of aircraft sensors, flight planning, cost calculations and handles the administrative procedures to ensure acquisition of the imagery required. The center co-ordinates all requests for flying into a single or twice yearly provincial program. Operational flights are co-ordinated between the Canada Centre for Remote Sensing and each requestor on a day-to-day basis to ensure, where required, imagery and ground truthing procurement are simultaneous.

Where multidisciplinary projects are involved, aircraft imagery is obtained by the Center for its library and is available for study. Airborne flights of a priority nature are handled on a need-arise basis. A record of all Alberta's coverage is maintained and flight indices and technical data are distributed to interested persons.

The Center facilitates the exchange of reports and information concerning projects flown in the province.

LANDSAT Program

The Center provides a mail, telephone or in person LANDSAT order facility to persons wishing to select imagery processed and distributed by the federal government. Scenes may be selected from a LANDSAT catalogue, computerized catalogue up-dates and a microfiche library. At the Prince Albert Satellite Station LANDSAT multispectral imagery is automatically recorded on photographic film and processed in microfiche form - ISISFICHE, by Integrated Satellite Information Services Ltd. Each day's Band 6 coverage of Canada is received at the Alberta Center within 24 - 48 hours of being recorded and is immediately available for viewing as a 32x enlargement. This allows not only first phase interpretation but provides an opportunity to preview each scene before ordering by assessing the image quality and pin-pointing the location of cloud cover. As ISISFICHE imagery is catalogued by day number, orbit track and image center scenes may be simultaneously viewed for comparative study.

The Center's Imagery Library contains LANDSAT black and white contact prints of the entire province and repetitive scenes of selected areas in all wave bands and color composite renditions. Transparencies are being phased in as they provide a more interpretative product.

Technical Information Service

A Technical Information Library and direct link to the Canada Centre for Remote Sensing's Technical Information Service and Remote Sensing On-Line Retrieval System allows requestors to expeditiously and at no cost obtain technical documents on remote sensing.

Training Program

The Center actively sponsors educating and training in remote sensing. Courses, symposia and lectures are sponsored throughout the province. The fourth in a series of Alberta Remote Sensing Training Courses will be conducted in February 1976. Lectures for this one week course are provided by foremost remote sensing scientists from across Canada and the United States. Included is a display of aircraft and sensor equipment. Registration is open to anyone and to date has always been over-subscribed. The Center also co-sponsors and actively supports the training activities of other agencies. It hosted the Third Canadian Symposium on Remote Sensing in Edmonton and co-sponsored the International Symposium on Remote Sensing and Photo Interpretation in Banff, Alberta.

Many universities, colleges and technical schools have tours of the Center and staff lectures incorporated in various course curricula. A lecture program at the high school level to acquaint and interest staff and students with remote sensing is underway. As part of the information program, a newsletter is regularly produced and widely distributed. Training films and training materials are available on free loan to any organization or person, and a LANDSAT color composite mosaic of the Alberta mountains and foothills has been constructed, printed and distributed.

Road Show

As Alberta is a large province and the Edmonton based Center is not readily available to all users, the Center's facilities, excepting large items of equipment, regularly visit other cities in the province.

CONCLUSION

The Alberta Remote Sensing Center provides a service and saving to Albertans using remote sensing as a tool in the survey and management of the environment. It has largely eliminated the duplication of provincial projects by providing an information link between scientists and agencies using the Canada Centre for Remote Sensing's remote sensing program. The Center has been a positive step in the development of the province's remote sensing program.

APPENDIX C

The Ontario Centre for Remote Sensing
(From material provided by Victor Zsilinszky)

1. The objective of the Centre
2. Staffing
3. Funding
4. Equipment and inventory of imagery
5. Projects under way in 1977-78
6. Extracts from paper by Mr. V. Zsilinszky, Associate Director, O.C.R.S., presented at the Workshop on remote sensing of soil moisture and groundwater in Toronto, Nov. 8, 1976.

1. The objectives of the Ontario Centre for Remote Sensing -

To provide a highly specialized service for the collection, processing, interpretation, and development of applications, of remote sensing data, as provided by the airborne program of the Ontario Forest Resources Inventory, by the Centre's own supplementary aerial photographic capability, and by the federal government and the U.S. earth-resources satellite programs. The Centre's purpose is to investigate and implement the practical usefulness of remote sensing data to resource and environmental management and land use planning in the Province of Ontario. This objective is to be achieved primarily through undertaking projects by which to satisfy existing information requirements of managers and developers, through the development of new remote sensing methodologies.

The objective thus described is composed of seven sub-objectives:

i. to set priorities on all requests within the province for federally supplied remote sensing data. Note: Mr. Zsilinszky reports that there has been no call for activity on this sub-objective;

ii. to provide an overview of the provincial program to ensure that duplication does not occur;

iii. to provide advice to government agencies on the effectiveness and suitability of remote sensing applications presently in use while developing and publicizing new applications;

iv. to provide as required, specialized equipment as well as specialized interpretation services beyond the existing capabilities of ministries;

v. to evaluate and modify remote sensing hardware to be used in the development of new data gathering and interpretation techniques;

vi. to conduct research and training programs in remote sensing data processing and interpretation systems and to maintain liaison with other agencies in Ontario with similar interests;

vii. to maintain a central remote sensing image library.

2. Staffing -

At the peak of the summer season a total of 31 including seasonal and contract employees have been on staff. The "permanent" staff includes:

one thermography specialist
one geotechnical engineer
one environmental specialist
two land use capability specialists
one research officer, engineering
one research officer, forestry
four technologists and technicians
three supervisors
~~one director~~
two secretaries
three supervisors (one geomorphologist;
two foresters)
one director (forester)

Contract and seasonal staff may include foresters, geomorphologists, technicians, draftsmen and summer students.

3. Funding -

The total budget for fiscal year 1977-78 was $940,000. This included $80,000 for capital equipment. Of this, some $360,000 was "recovered" through projects done for various provincial government departments. Both of these figures include $200,000 for completion of a special project on surficial geology mapping of Northern Ontario; thus the "steady state" budget would be considered as $740,000 for salaries and operating costs.

4. Description of Equipment - O.C.R.S.

1 ISI-150 Image Analyzer ($100,000)
1 Wild A-9 Stereo-Plotter with digitizer ($80,000)
2 Zoom Transferscopes ($10,000)
2 Zoom Stereoscopes ($24,000)
25 Mirror Stereoscopes ($25,000)
8 Light tables ($5,000)
1 Electronic planimeter ($4,000)
1 Muirhead weather satellite imagery receiver ($16,000)
1 Densitometer ($3,000)
2 Refrigerators ($2,000)
2 Freezers ($2,000)
1 Foliage penetrating Radar Altimeter ($30,000)
4 Nikkormat cameras & accessories ($5,000)
6 Nikon motorized camera systems ($25,000)
5 Hasselblad camera systems & magazines ($30,000)
2 Vinten camera systems ($9,000)
5 Aerial camera mounts ($5,000)
1 Aerial exposure meter ($4,000)
2 Tape recorders ($3,000)
1 Audio visual system ($12,000)
1 Stereo projector system ($6,000)
2 *AGA Thermovision 750 ($80,000)
4 *Prob-eye thermo systems ($32,000)
2 Vehicles ($13,000)
2 Enlargers ($22,000)
1 Black & white printer ($10,000)
1 Aztec D aircraft (on lease - value $55,000)
1 Norpak RGP 3050 Digital Image Analysis System with PDP 11/34 Minicomputer ($110,000)

Total value of present equipment $722,000

*Also made available to the Centre, by the Ministry, except during the forest fire season.

Inventory

Airphoto file (624,000 photos)	$925,000	
Landsat imagery file	20,000	
Maps	25,000	
Films	12,000	
Darkroom	5,000	987,000
		$1,709,000

Equipment to be Acquired

(within next 4 years)

Components to Digital image analyzing system	($240,000)
Airborne Program	($ 55,000)
Thermography	($ 48,000)
Total	$343,000

5. Projects under way in 1977-78 -

Examples of the projects are:

i. Commencement in 1977 of the completion of the surficial geological mapping of Northern Ontario, the mapping of the wetlands of the James Bay/Hudson Bay Lowlands, and the preparation of the first comprehensive physiographic description of Northern Ontario, comprising 90% of the province.

This program, conducted using Landsat satellite data, aerial photography and selective field sampling, is scheduled for completion in 1983.

ii. Evaluation of forest regeneration success from Landsat imagery and from low-altitude aerial photography.

iii. Mapping and measurement of areas of forest damage using Landsat imagery as the primary data source; estimation of timber loss.

iv. Development of an aerial forest sampling system.

v. Development of a method of large-scale forest inventory by computer analysis of Landsat data.

vi. Development of a methodology for the application of airborne thermal scanning to the detection of building heat loss, as a contribution to the Ontario Government's energy conservation program.

6. Extracts from a paper by Mr. V. Zsilinszky, Associate Director, O.C.R.S., to the Workshop on Remote Sensing of Soil Moisture and Groundwater, Toronto, November, 1976 -

"The remote sensing community is composed of two different groups:

- one which is concerned with acquisition technology, and thus contributes to the creation of remote sensing data;
- the other which is concerned with the art of application. It interprets the raw data and converts it into information to solve a particular problem.

I shall call the first group data makers and the other group interpreters.

Technology for data makers has been advancing rapidly, and data acquisition has become a well-established and continuing program. This program, however, manufactures a new product that has to be marketed. The marketing of this product very much relies on effective demonstration of its usefulness and its low cost. Such demonstration is chiefly the job of the interpreters.

So far, marketing has been falling behind production.

I can think of several reasons for this.

Interpreters are generally specialists within various scientific disciplines. They are the people in direct contact with both the data maker and the potential client. However, there are presently very few of them, a fact which handicaps extensive P/R work.

These interpreters cannot launch aggressive market development without adequate financial strength. The data makers have provided moral support, along with increasingly costly raw material. Funds have not come generously from potential clients either. Who are these clients? Politicians, executives and managers. Due to the lack of adequate demonstration, they have not yet seen enough to trust remote sensing."

"I simply wish to point out that we (scientists) are not communicating with the potential client whom we have to impress and who actually wants to be convinced that remote sensing works!

This communication gap is largely responsible for the fact that the involvement of most provincial governments in applied remote sensing is still minimal. Yet it is logical to me that it is government's obligation to invest in the pioneering of operational remote sensing, since it is responsible for the management of resources."

APPENDIX D

PROPOSAL FOR

EXPERIMENTAL AERIAL PHOTOGRAPHIC PROJECT

CAPE BRETON HIGHLANDS 1978

Nova Scotia Department
of Lands and Forests
Forest Inventory Section

April, 1978

PROPOSAL FOR

EXPERIMENTAL AERIAL PHOTOGRAPHIC PROJECT

CAPE BRETON HIGHLANDS 1978

The Forest Inventory Section of the Nova Scotia Department of Lands and Forests is now using normal true color aerial photography (1:10 000 scale) operationally for forest cover type mapping. Previous developments within the Department have proven that forest insect damage can be more easily and more accurately delineated and measured from color infrared photography (using small scale 1:63,360). These programs have also indicated that color infrared photography could be more suitable for use in regular forest cover type mapping because of an apparent color differentiation enhancement. To date, however, experimentation in this regard has been restricted to small scale photography, and a most suitable film-filter combination which would maximize forest parameters has not been established.

Recently, the Forest Inventory Section is becoming more involved in damage disaster monitoring (spruce budworm defoliation, forest fire damage, surveys of wind throw damage, etc.). Because of the wide spread nature of these forms of damage coupled with the large area requirements of regular forest inventories, it would seem desirable to develop an aerial photographic sampling technique which would allow accurate measurement of stand parameters for inference over larger areas.

The purpose of this proposed aerial photographic experiment then, is to compare various types of large scale (1:10 000 and 1:5 000) imagery to:

1) determine which type of imagery (true color, color infrared and heat sensitive scanning) and at which scale 1:10 000 and 1:5 000 is most suitable for mapping and classifying forest insect damage (particularly spruce budworm defoliation)

2) compare three film/filter packages for color infrared (2443) film to determine which gives an image most suitable for forest parameter measurement

3) evaluate color infrared imagery for use in regular forest type classification with comparison to normal true color photography. Also, to evaluate the various types of imagery and scales to determine the mensurational accuracy and suitability of using aerial photography in detailed forest sampling.

Flight Requirements

The total required imagery for each of the two scales will be: normal true color, 3 different filter exposures of color infrared and a continuous heat sensitive infrared scan. As the available aircraft from C.C.R.S. are restricted to 2-9 x 9 inch camera ports, the experiment will require 2 passes on each flight line for each scale, a total of 4 passes for the project. The sensor film combinations required for each pass are as follows:

First Pass - 1 camera (9" x 9" format) equipped with a six-inch focal length lens for true color film

1 camera (9" x 9" format) equipped with a six-inch focal length lens and filter package "A" for color infrared film (2443)

1 scanner (heat sensitive infrared)

Second Pass- 1 camera (9" x 9" format) equipped with a six-inch focal length lens and filter package "B" for color infrared film (2443)

1 camera (9" x 9" format) equipped with a six-inch focal length lens and filter package "C" for color infrared film (2443)

Filter Packages

Filter Package "A" *

Filter Package "B" *

Filter Package "C" *

* Final selections of filter have not yet been completed. Mr. Jack Flemming of C.C.R.S. is presently studying three images (chosen in consultation between Mr. E. MacAulay, N.S. Dept. of Lands and Forests and Mr. E. MacLaren, N.S. L.S.I.) to determine the required filter packages for duplication. These will most likely be the packages used.

Time Requirements - Because of the critical exposure and sun angle requirements of color infrared film and the need to coinside the flight with maximum spruce budworm defoliation the proposed flight is restricted to the period August 1, 1978 to August 31, 1978.

Ground Truthing - Permanently located plots from both provincial and federal forest surveys will be used as ground truth locations. All of these plots located in the survey area (attached sketch) will be field measured in the summer of 1978.

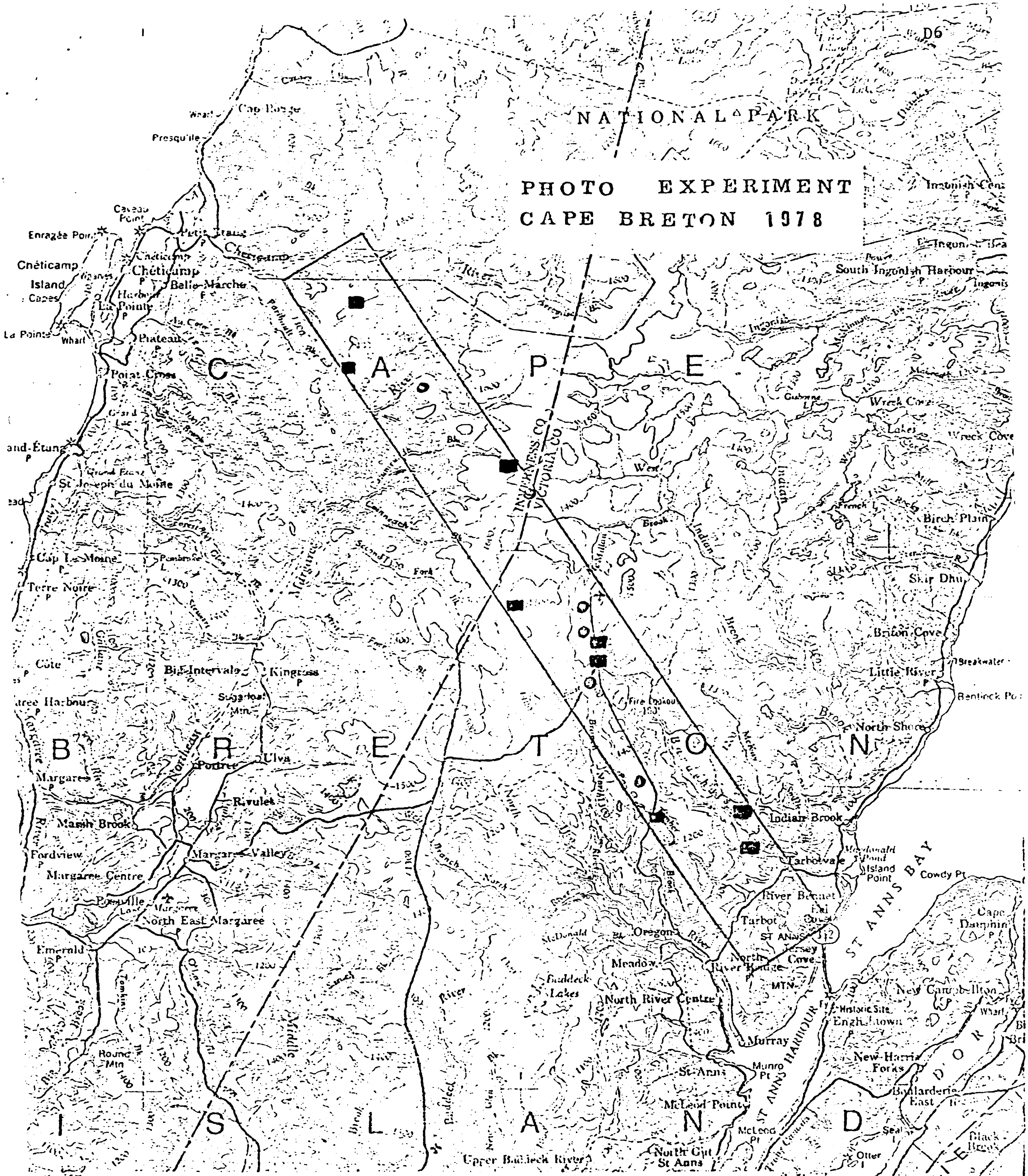
Image Requirements -

1 - 9 x 9 inch contact print and

1 - 9 x 9 inch positive transparency for each frame exposed.

Also a continuous heat sensitive scan analogue and 8 level slices for each scale.

Additional Requirement - As a reference check and for comparison with previous imagery, one flight line (center line 1:10,000) will be flown for a photo scale 1:50,000 for true color and color infrared using filter package "A". Both cameras equipped with a six-inch focal length lens.



LEGEND

PROJECT AREA

FEDERAL PERMANENT SAMPLE PLOT

PROVINCIAL PERMANENT SAMPLE PLOT

Supplementary to

Proposal for Experimental Aerial Photographic Project

Cape Breton Highlands 1978

RE: <u>Filter Packages</u>

It is very difficult to adjust color balance in color infrared film, because of a very restricted sensitivity latitude. However, it is proposed that filter package "A" will be designated to approximately "normal" infrared enhancement (according to CCRS criteria). Filter packages "B" and "C" are designated to produce an image with somewhat greater infrared enhancement and somewhat reduced infrared enhancement compared to that considered "normal" (filter package "A"). The result then should yield imagery with a spread in infrared enhancement and therefore allow comparison through those images with regard to the measurement and identification of forest parameters. The Film/Filter packages proposed are:

package "A" ("normal") - film with an IR balance of 27 to 30; exposed through a Wratten 12 or equivalent filter (525 nanometers)

package "B" (de-emphasized IR sensitivity) - film with an IR balance of 27 to 30; exposed through a Wild Pan 500 filter or equivalent (500 nanometers)

package "C" (enhanced IR sensitivity) - film with an IR balance of 27 to 30; exposed through a Wratten 12 plus a CC20B filter combination.

APPENDIX E

LIST OF PERSONS CONTACTED IN THE PREPARATION OF THIS REPORT

Mr. Thomas Alfoldi
C.C.R.S.

M. Hervé Audet
Service de la Cartographie
Ministêre des Terres et Forêts
Québec

Mr. Ed. Bailey
Manager, Research
Dept. of Lands and Forestry, Truro

Dr. Gordon Baskerville
Professor
Forestry Faculty
UNB
Fredericton, N.B.

Dr. Jean Beauben
Centre de Recherches Forestières des Laurentides
Service Canadien des Forêts
Ste. -Foy, Québec

Dr. Gerry Beke
Head, Atlantic Soil Survey Unit
Agriculture Canada
Truro, N.S.

Mr. Richard M. Belyea
Maritime Forest Research Centre
Environment Canada
Fredericton, N.B.

Mr. Jack Bidlake
Dept. of Natural Resources
Fredericton

Mr. Cal. D. Bricker
Alberta Centre for Remote Sensing
Edmonton, Calgary

Mr. Ron Brown
C.C.R.S.

Mr. Franklin Cardy
Director, Water Resources
Dept. of Environment
Fredericton

M. Robert Darveau
Darveau, Lussier, Grenier and Associates
Quebec City, P.Q.

Dr. Eugene Derenyi
Dept. of Surveying Engineering
U.N.B.

Mr. C. Bradley Fay
M.R.M.S.

Mrs. Don Fisher
ISIS Ltd.
Price Albert

Mr. Jack Fleming
C.C.R.S.

M. Gaston Germain
Directeur, Service de l'Inventaire
Ministêre des Terres et Forêts
Québec

Dr. A.F. Gregory
Gregory Geoscience Ltd.
Ottawa

Dr. Thomas Hall
Forest Management Branch
Province of New Brunswick
Fredericton, N.B.

Prof. Wm. Hilborn
Faculty of Forestry
U.N.B.

Mr. John Hilchey
Supervisor of Land Use Programs
D.O.A. & M. (N.S.), Truro

Mr. William A. Hodgson
Plant Pathologist
Agriculture Canada
Fredericton, N.B.

Mr. Roy Irwin
Prince Albert Satellite Station

Mr. Jack Johnston
Director, Soils and Crops Br.
D.O.A. & M. (N.S.)
Truro, N.S.

Dr. P.H. Kourtz
Forest Fire Research Inst.
Environment Canada
Ottawa, Ontario

Mr. Charles Kirby
Northern Forestry Research Centre
Canadian Forest Service
Edmonton

Prof. Norman Kissick
Faculty of Forestry
U.N.B.

Dr. P.A. Lapp
Philip A. Lapp, Ltd.
Toronto

Mr. Neil Lefler
M.R.M.S.

Dr. Alec Mack
Land Resource Research Inst.
Agriculture Canada
Ottawa, Ontario

Mr. John Mallory
Dept. of Environment
Province of New Brunswick
Fredericton, N.B.

Dr. Larry Morley
Director-general
C.C.R.S.

Dr. Peter Mosher
Department of Agriculture
Fredericton, N.B.

Mr. Ron McInnis
Manager, Crop Insurance Agency
Charlottetown
P.E.I.

Mr. Ernie McLaren
N.S. Land Survey Institute
Lawrencetown, N.S.

Dr. Murray Neilsen, Director
Maritime Forest Research Centre
Fredericton, N.B.

Mr. John L. Nowland
Soil Correlator, Eastern Canada
Land Resource Research Inst.
Agriculture Canada
Ottawa, Ontario

Mr. Kevin O'Neill
C.C.R.S.

Mr. S. Pala
O.C.R.S.

Mr. Fred Peet
Public Works Canada

Mr. Ralph Redmond, Director
Forest Management Branch
Province of New Brunswick
Fredericton, N.B.

Dr. Robert Ryerson
C.C.R.S.

Dr. G. Saini
Soil Physicist
Agriculture Canada
Fredericton, N.B.

Dr. Leo Sayn-Wittgenstain
Director
Forest Management Institute
Environment Canada
Ottawa, Ontario

Mr. Thomas Sifton
Director, Lands Branch
D.N.R.
Fredericton, N.B.

Mr. Vern Singhray
N.S.L.S.I.
Lawrencetown, N.S.

Mr. Burtt Smith
?orest Management Branch
Province of New Brunswick
Fredericton, N.B.

Mr. Norbert Stewart
Dept. of Agriculture
Charlottetown

Mr. Wm. Switzer
Chief, Data Systems Div.
Environment Canada
Ottawa

Mr. Jean Thie
Lands Directorate
Enviornment Canada
Ottawa

Mr. W.R. Trenholm
Co-ordinator, Agricultural Land
Planning Section
Dept. of Agriculture
Fredericton, N.B.

Dr. Cheng Wang
Soil Scientist
Agriculture Canada

Dr. Mac Weaver
Regional Director
Agriculture Canada
Fredericton, N.B.

Mr. Fred Welling
Manager, Forest Inventory
Dept. of Lands and Forest
Truro, N.S.

Mr. John Wightman
Vice-principal, N.S.L.S.I.
Lawrencetown, N.S.

Mr. Floyd Wilson
Land Use Service Centre
Charlottetown

Mr. Gordon Young
Woodlot Service Ltd.
Fredericton, N.B.

Mr. Victor Zsilinszky
Ontario Centre for Remote Sensing
Toronto, Ontario

Mr. Harold Zwick'
C.C.R.S.