Energy, Mines and Resources Canada
Canada Centre for Remote Sensing

Énergie, Mines et Ressources Canada
Centre Canadien de Télédétection

RESULTS OF A BENEFIT-COST ANALYSIS OF THE CCRS AIRBORNE PROGRAM

Robert A. Ryerson

Research Report 81-1
February 1981

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RESUME

Le présent rapport contient une analyse détaillée des bénéfices, du coût et de la nature de l'application de projets aéroportés de télédétection du C.C.T., choisis parmi ceux qui ont été exécutés jusqu'en 1978, inclusivement. Les bénéfices concrets, confirmés par les usagers et signalés ici, totalisent entre 9 et 15 millions de dollars (dollars de 1978), et 3,7 millions en bénéfices soutenus. Bien que tous les projets n'aient pas été rentables, la plupart ont du moins permis de récupérer leur coût. Grâce à une étude attentive des présents rapports, il est àespérer que d'autres usagers éventuels de la télédétection aéroportée seront en mesure de mieux évaluer l'applicabilité éventuelle de la télédétection à leurs problèmes de collecte de données.

Abstract

This report provides a detailed analysis of the benefits, costs and nature of the application for a sample of the CCRS airborne remote sensing projects flown up to and including 1978. Tangible benefits verified by users, and reported here, total $9 million to $15 million (1978 $) and $3.7 million continuing benefits. Although not all projects resulted in benefits, most did at least return their costs. Through careful study of the reports presented here, it is hoped that other potential users of airborne remote sensing will be able to better assess the potential applicability of remote sensing to their own data collection problems.

Acknowledgements

The author would like to acknowledge the assistance of the many users who co-operated in the study and the staff of Airborne Operations who contributed in many ways. Mr. N. Saccone, a Co-op Geography student from the University of Waterloo did the cost calculations and pre-contact summaries for all projects.

Special Note on the Index

In addition to the normal Table of Contents there is a comprehensive index to the user benefit reports by the Keywords used in the CCRS Remote Sensing On-line Retrieval System (RESORS). This index begins on page 92.

INTRODUCTION

One of the recommendations of the CCRS Airborne Project Assessment (Cihlar, 1978) was that a comprehensive cost-benefit analysis be undertaken of specific airborne remote sensing projects. This report provides such an analysis. Following sections outline this paper's purpose, the methodology devised and the results of the benefit analysis.

PURPOSE OF THE STUDY

The study's purpose was to conduct a survey of a sample of external users of the output products of four CCRS projects, i.e., Aircraft Operations and Maintenance, Airborne Data Acquisition Operations, Air Analogue System, and Air Photographic Products, in order to determine:

a) the user's evaluation of the benefits and impact of the output products of these projects defined to the extent possible in terms of:

i) demonstrated one-time benefits achieved to date;

ii) recurring benefits achieved through the application of operational systems;

iii) estimated benefits projected from demonstrated applications to identical problems elsewhere; and

iv) spin-off from CCRS supported projects to industry and other agencies; and

b) topical areas of high benefit for marketing attention.

METHODOLOGY

It was assumed that the output products were sent to the user in the form of imagery. Other outputs such as technical advice and research were not considered. We did not weigh the benefits of the CCRS airborne data acquisition approach against other means of obtaining the same remotely sensed data. It was assumed that the central concern was the value of image data acquired by CCRS and transferred to users, as well as the follow-on provision of services by industry. Alternate costs of data collection using the most favourable method were calculated despite the possibility that the user might not consider using the alternative due to its cost. The difference between alternate cost and remote sensing (RS) cost was considered to be a net benefit.

Project Selection

Up to and including 1978, 1062 individual projects were flown by Airborne Operations. A number of these were for sensor tests, navigation tests, and internal sensor research projects, but they have not been analyzed in this study. Even without these projects,

there were still 870 done for external users. Since it was not possible to contact each user, with the time and manpower resources available, projects were selected which appeared to have high potential benefits, and/or where users had already reported demonstrated benefits, had requested flights several times, or had acquired large quantities of data. Although all users have routinely been asked to comment on the benefits of using the data, very few have responded. Project selection was therefore an arduous task.

The following sources have been reviewed to select the 230 projects for potential detailed study:

a) the CCRS visual library;

b) the CCRS airborne project assessment report by Cihlar (1978);

c) reports in the CCRS Library's RESORS System;

d) cumulative project list; and

e) individual project files, which contain all correspondence on each project, and often provide a more complete project description than the other sources available.

When one source indicated a potential or demonstrated benefit, all other sources of information on that project were reviewed. Source (e) was not reviewed in its entirety. Table 1 reviews the selection of projects.

Table 1

Selection of Projects for Study

Total Projects flown before 1978			1062
Internal Sensor/Aircraft tests			192
Flown for users			870
Preselected (biased sample Projects			50
Sources Reviewed:	CCRS Visual Library		
	Cihlar Report		
	RESORS		
	Project List		
	Part of CCRS Project Files		315
Subtotal for Detailed Analysis 50 + 315 = 365			
	no apparent benefits	135	
	should contact	230	
Of the 230 "should contact:	Could not locate		44
	No/late response		20
	Not contacted (time limit)[1]		50
	Zero benefit		23
	Preselected		50
	Review included		43
			230

[1] The majority of the "not contacted" class were not contacted because of time constraints on the author. Some were known to have resulted in significant savings, while others were similar to those included here and therefore judged expendable when time constraints were considered.

Procedure

CCRS (McQuillan, 1975) and other agencies have performed a variety of benefit analyses and have identified a number of problems in applying benefit-cost methods to RS. Some of these problems are also discussed in a Federal Government document (Treasury Board, 1976) outlining acceptable methodology. A principal tenet of these and other documents on cost-benefit analyses emphasizes that the calculation of dollar values for intangible benefits, such as "a better environment", is very difficult; therefore, a verbal description is usually better. A second difficulty often associated with benefit estimates is that these can appear to be too high or may seem to be based on questionable assumptions. Such calculations can (and should) be called into question, particularly when they are written by a group which may be biased. To avoid such a bias and at the same time provide a realistic word description, it was decided to request users to verify all statements and numbers.

As Cihlar (1978) found, many users were difficult to contact: many had moved (some abroad), changed positions or could not be located. It was also found that most users who could be located, when approached "cold" and then asked to specify benefits, generally had no concept of the benefits they had obtained. Consequently, they usually underestimated benefits. Where firm, unambiguous and realistic-appearing benefit estimates were not available, the following procedure was adopted after project selection and location of the user (steps a) to e) were carried out before contact with the user):

a) Read all background material available.

b) Calculate actual costs and note cost recovery charges.

c) Calculate costs using best/usual alternative methods known to us. (Alternate methods are those to which users would routinely have access, such as ground methods and the widely available panchromatic black and white airphotos.)

d) Calculate benefits as the difference between (b) and (c) above (i.e. cost of actual and alternative methods) by considering data acquisition costs, interpretation costs, inherent value of the remote sensing data, and any other factors which may yield intangible benefits.

e) Identify spin-off projects and potential for wider application.

f) With this information at hand, contact the user by telephone and ask questions based on the preliminary assessment. The user would either support the calculations, modify them, refuse to confirm them, refer us to an end user of the data for verification, or give reference to another who could verify the alternate method cost calculation. In the latter cases, the individuals referred to were then contacted in the same fashion.

g) Once benefits were obtained, the data were analyzed and a summary of the benefits described for the project(s) was sent to the user. (See Appendix A). He was asked to return these with corrections and comments. Each user was offered confidentiality, and several requested it. Where the user has not responded, the project is not included - several have not replied to telephone follow-ups and second letters.

Cost Accounting

Where industry costs were quoted by the user, these were accepted and referenced. Otherwise all costs are the 1978 CCRS operating costs for the aircraft, crew per diem expenses, and consumables. The CCRS costs are based on hours of flight between base-target-base. The 1978 hourly aircraft costs used in the cost calculations are: CF-100 - $1,000; Falcon - $1,000; Convair - $1,000; and DC-3 - $700. Crew per diem was considered to be $250 per night. Where several projects were flown on one sortie, transit costs were shared between projects.

These rates or costs are based on total hours of aircraft use including internal research projects. The hourly rates are possibly higher than those found in industry for the same year, since CCRS costs are based on lower total annual operating hours combined with fixed costs similar to those found in industry.

Benefit Accounting

There are only two types of benefits which are relatively easy to determine:

a) cost of RS vs. other methods of data acquisition where alternative methods exist, and

b) cost of analysis of RS used in the project vs. alternative methods.

Unfortunately, the list of those benefits which are more difficult to calculate is much larger, and includes:

a) cost of RS vs. other methods for data acquisition where there are no feasible alternate methods because of cost;

b) value of improved decision making attributable to RS data; i.e., benefits due to "new information" which could not be obtained by alternate methods;

c) benefits attributable to RS due to avoiding environmental damage;

d) benefits relating to the use of RS for baseline studies to avoid future costs resulting from fraudulent damage claims or for assessing environmental changes resulting from resource exploitation;

e) benefits attributable to RS for public awareness of such issues as heat loss and energy conservation,

f) benefits relating to the use of RS to settle insurance claims more rapidly;

g) use of RS in a research program, for example, in elucidating environmental inter-relationships;

h) development of expertise using CCRS flights which have subsequently resulted in large area application (and savings) using commercially acquired imagery. (Most of these are difficult to locate if the primary user is outside the Federal government).

i) benefits related to the saving of time in field data collection

j) benefits related to the use of RS in education:

k) benefits related to earlier discovery of mineral deposits than would have been the case using conventional methods; and

l) benefits related to foreign sales of sevices by Canadian companies based on knowledge and experience gained in the CCRS Airborne Program.

Each of the above categories was encountered in the inventory of demonstrated benefits. Where a user was willing to place a value on RS, there was no difficulty. However, the user does not always have a dollar value which can be reported with accuracy. In such cases intangible benefits are quoted. All benefits and costs are quoted in 1978 dollars.

Four of the replies were identified by users as confidential. They concerned geological prospecting and biophysical/enviromental monitoring studies. They are discussed below in general terms.

All non-confidential reports are reproduced in either English or French by topic in alphabetical order of project leader as Appendix A in this report. An index in Appendix A cross references the reports by topic and the respondent's name.

RESULTS

1. Introduction

By the close-off date for the benefit analysis 93 projects done for thirty-seven individual users had been returned. Six users did not respond to the report and covering letter sent to them.

The areas reported in Appendix A in which significant benefits were realized through the use of airborne remote sensing include Environmental Impact Studies, Land Use Mapping, Forestry and Agriculture, Geology, Hydrology, Water Quality and Energy Conservation.

The benefit reports have been put into eight topical groups in Appendix A: these are Engineering and Environmental Impact Studies, Land Use Mapping, Forestry and Agriculture, Geology Applications,

Hydrology, Water Quality, and Energy Conservation. Confidential reports not appended fall into Environmental Impact (1) Hydrology (2) and Geology (2). Each of the confidential reports deal with multimillion dollar decisions, or benefits in that order of magnitude. They are rolled into the totals below.

Of the forty-three individuals contacted to whom benefit reports were sent, there were six who had not replied as of February 1, 1981. (Original plus follow-up letters were not answered.)

2. Engineering and Environmental Impact Assessment

This was the largest group of responses ... ten users and twenty-two projects. For most, dollar benefits could not be specified except to say that more information was collected at less cost. For these, total costs (including those costs recovered by the crown) were $203K ($203,000). Cost recovery charges were $94K.[1]

Reported dollar benefits include only a portion of realized benefits. There has been no attempt made to evaluate dollar value of the decision to build a dam (a confidential report), the value of better data for decision making, or the value of obtaining new information through airborne remote sensing when such information was unlikely obtainable by alternative methods. Even without these intangible benefits, dollar benefits range from a low of about $500K up to $1,575K at a cost to the Crown of $110K. From both the tangible and intangible benefits it would appear that this application area is one in which airborne sensing should be more actively marketed by industry.

3. Land use studies

There were four projects and four users in this area. One of the four final users was a secondary user of the data. Dollar benefits have been specified primarily as related to other types of data collection. For the four projects, total costs were about $34K. Cost recovery charges were about $7K — most of the flying was done before cost recovery charges were levied.

Reported dollar benefits were between $475K (minimum) and $1,170K. Possible benefits over alternate methods as high as $6.2 million are indicated, but at the same time it was noted that the costs of some alternate methods are so high as to be unrealistic, no one would consider them. Again, airborne sensing has made the previously impossible, possible.

From the tangible and intangible benefits given, land use mapping for any area the size of a small city (Brandon, Manitoba, population 35,000) or greater would be done most cost effectively by colour or colour IR airborne data.

1 All numbers are rounded

4. Forestry and Agriculture

Forestry and Agriculture are not particularly well represented in this study of airborne remote sensing. There are thirty-two projects from five users. It is assumed that airborne agriculture remote sensing applications are cost effective since Prairie Agri Photo Limited has been supplying a growing market in this area for five years. Other uses have also been reported. Forestry has proven to be a cost-effective application area for airborne sensing.

The total costs for the projects were $187K, while cost recovery charges were $66K. Tangible benefits for the airborne remote sensing program were said to be in the "hundreds of thousands of dollars" for one forestry project, $250K for another, (plus a $250K contract to industry) and from a minimum between 160 to 280K for an agricultural project. Intangible benefits could be even higher. The fact that imagery supplied by industry is now being routinely used in forestry and agriculture gives an indication of the value of the work done through the CCRS airborne program.

5. Geology

There were three users and three projects directly under geology. Several others in the section on Engineering are related. Of the three, two involve commercial exploitation of deposits located with the imagery and were considered confidential by the respondents. The total cost of the three was $17.3K, with cost recovery charges of $9.4K. Minimum benefits (over alternate survey methods) are in the vicinity of $290K. Benefits relating to the specific deposits would see annual benefits of up to $750K, with a more generous accounting of survey related benefits up to $500K.

It is unfortunate that the specific uses cannot be detailed here, since such dramatic savings and significant finds have resulted.

6. Hydrology

There were eleven projects and five users in this area. Three projects for two users were confidential. The confidential projects involved avoiding major evironmental problems associated with floods (recommended construction of a dam) and averting ground water contamination. The total cost of all projects was $65K, with cost recovery of $19K. The estimate of benefits ranges from $6,255K to $11,260K for one time benefits, with $2,600K recurring annual benefits associated with the dam's construction.

7. Water quality

There were eleven projects for five users. Total cost of all projects was $18K, with cost recovery of $12K. In this group, users could not always specify firm benefits associated with the work.

Activities that these projects contributed to, but which were not put into tangible benefits included: reasearch in oil spill dynamics; study of water movements to plan sampling; water supply planning for the city of St. John, New Brunswick; reduction of mercury contamination in the Lake St. Clair area (water supplies for Detroit and Windsor); and identification/monitoring of aquatic plant growth in recreational lake areas. All of these obviously have significant benefits, however, none were quantified.

Minimum benefits stated for the group exceed $225K. Given the importance of the intangibles above, the tangible benefits are obviously less important.

8. Energy Conservation

There were ten projects flown for five users at a total cost of $56K, with cost recovery of $21K. The major benefits were in public awareness programs and in identifying industrial/commercial roof damage ($15-20 million of such damage was identified on one mission). The return in energy savings after a public awareness program has been calculated at 4:1 by the Ontario Centre for Remote Sensing (costs include staff, publicity and imagery). Although the major benefits have apparently been achieved by B.C. Hydro, except for a few cases do they have documented energy savings, they believe that the amount of energy saved "is open to speculation". In any case, these projects have generated continuing energy savings of over $350K per year for about two dozen structures. With probable energy savings related to the repair of the $15-20 million of roof damage in British Columbia, the value would move into the millions of dollars. Intertech Remote Sensing Limited, a Canadian remote sensing service corporation, has flown large areas for energy awareness programs for some of these users as well as for others. There have been significant energy savings and industrial activity sparked by the CCRS Airborne Program in this area.

9. Some Generalizations on Benefits

Based on the analysis of Appendix A, certain generalizations can be made about the benefits associated with airborne remote sensing:

1. Normal colour imagery at the same scale as panchromatic (black and white) costs 10% more to acquire commercially but yields savings of up to 50% in interpretation costs.

2. Interpretation costs almost always exceed image acquisition costs for regional land use or biophysical mapping, for areas greater than approximately 1000 to 2000 square kilometers).

3. Less experienced (and less costly) specialists can interpret colour imagery than are required to interpret panchromatic imagery, with similar or better results.

4. New 1:60,000 colour infrared (CIR) photos can be obtained at less cost for large area coverage than 1:24,000 panchromatic photos, under suitable cloud free conditions.

5. 1:60,000 CIR contain as much or more information about type of vegetation cover as 1:12,000 to 1:24,000 panchromatic. (project 77-113; M.D. Thompson, personal communication).

6. The larger the scale, the larger the handling, storage and reproduction costs. (It takes 100 1:12,000 photos to cover one 1:120,000 image and more than 3,000 1:12,000 photos to cover one LANDSAT frame).

7. Many data collection problems involving intensive field data collection or sampling will benefit from the use of airborne remote sensing either to plan field work better, or to reduce it.

8. Almost any thematic mapping done with black and white panchromatic photography can be done more efficiently (when interpretation and image acquisition costs are included) with colour, colour infrared, or in limited cases, thermal infrared sensing.

9. Where field seasons are short, or geographic areas of interest are inaccessible, airborne sensing is very cost effective compared to field methods, and often is cost effective compared to aerial sketch mapping.

10. Many airborne sensing missions provide valuable archival data relating to the environment in general, environmental change and episodal events. As such, one set of airborne remote sensing data is often used by several different information collection agencies for quite different problems. Therefore a central clearing-house for imagery is suggested for municipal, provincial and federal agencies who may have a need for such data.

To put these points in perspective, one can compare 1:10,000 panchromatic prints and 1:60,000 CIR transparencies for acquiring biophysical data for 28,000 km^2 (11,000 square miles), using the values obtained from Thompson (1978) and the user report for 77-13 in Appendix A. Table 2 clearly illustrates that even purchasing and interpreting existing black white imagery is, in the end, more expensive than acquiring and interpreting specialized colour infrared imagery - even in the far north of Alberta. Now, with the technical problems of using CIR largely solved (Fleming, 1979), there would appear to be little reason not to use this data source in the future for thematic mapping.

Table 2

Cost Comparison (1978) 1:60,000 CIR
vs. 1:10,000 Black and White Photography

	1:10,000 Pan Print	1:60,000 CIR Transparency
New Image Acquisition Cost (Based on contracts/quotes for northern Alberta).	$198,000	$40,000
Purchase Existing Imagery ($1.25/print; $6.00/transparency).	$ 27,500	$ 3,750
Interpretation Costs for Map of Vegetation (after Thompson).	$ 57,600	$28,800
Number of Images for Area.	22,000	625

A BENEFIT ASSESSMENT OF THE CCRS AIRBORNE PROGRAM

Considering only the responses in Appendix A summarized below, the total tangible benefits attributable to the 93 CCRS airborne projects done for thirty-seven users contacted range from $ 9 million to $ 15.5 million, with recurring annual benefits of over $3.7 million per year. These projects cost a total of $633,000 ($633K), with cost recovery charges (which were returned to the Crown) of $228K. The net cost to the Federal Government for these 93 projects was therefore $435K.

From Appendix A one can see that although some projects were found to deliver no benefits, most generated at least enough benefits to cover their costs.

The total benefit generated by the airborne program is open to speculation. Fifty of the projects reported on here were selected because they were suspected to have high benefits. Analysis verified this in some but not all cases. An important fact is that some of those which did show high benefits (>$100K) were unknown to the author before the analysis. On the otherhand one major benefit was from a secondary user of the data. There is no way of knowing or accurately assessing how many secondary users exist or how many other "unknown" high benefit projects. However, it should be noted that of those not selected, some are known to have had high benefits, such as the start of a new firm doing acquisition and analysis, mapping buried pipelines in Alberta, energy awareness in Quebec, land mapping

in British Columbia, forestry in Nova Scotia, etc. It can be argued that the sample is biased, but not that it is completely biased to include all of the known and suspected high benefit projects.

From the above, and Table 1, it is obvious that total benefits determined in this project cannot be confidently expanded directly to derive total benefits of the entire program using, for example, the number of projects sampled compared to the total. There are two biases: to the 50 high visibility and high benefit projects for 9 users selected beforehand; and to more recent projects (since it proved impossible to trace some earlier users with the resources of this study).

SUMMARY AND CONCLUSION

The report provides a detailed analysis of the benefits, costs and nature of the application for a sample of the CCRS airborne remote sensing projects flown up to and including 1978. Tangible benefits verified by users and reported here total $9 million to $15 million (1978 $) and $3.7 million continuing annual benefits. Although not all projects resulted in benefits, most did at least return their costs. Through careful study of the reports presented here, it is hoped that other potential users of airborne remote sensing will be able to better assess the potential applicability of remote sensing to their own data collection problems.

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APPENDIX "A"

USER BENEFIT REPORTS

A.1 ENGINEERING AND ENVIRONMENTAL IMPACT STUDIES

PROJECT: 76-49

USER: Mr. A. Bohn
B.C. Research Council
3650 Westbrook Mall
Vancouver, British Columbia
V6S 2L2

Work done for Cominco Mines, Pine Point, NWT

LOCATION: Pine Point, North West Territories

OBJECTIVE:

1. To inventory forestry stands (healthy vs. deteriorating);
2. To document drainage patterns of natural waters and discharge waters through extensive muskeg areas;
3. To provide baseline documentation of undisturbed forest and muskeg.

COSTS:

Falcon Total Hours 4.2	$4,200
Transit Hours *2.9	
Consumables	1,295
Per Diem	393
TOTAL COST	$5,888
COST RECOVERY CHARGES	$3,230

DISCUSSION: This is an example of a study that began with one set of objectives but, after the imagery was received, additional uses were made of it as further interest was generated. In all cases the remote sensing data is difficult to separate in terms of its utility from the many other data sources integrated into the study.

This is one of the cases identified in which the remote sensing data were acquired to obtain a visual as well as an interpreted (map) record of vegetation before development (on part of the site) and after development (on part of the site) by the developer -- in this case Cominco Mines Limited. Such data are useful to companies who want to ensure that they have accurate baseline information against which they can monitor the effects of their operations, or which they can use as evidence should debatable charges of environmental damage arise.

BENEFITS: The imagery provides a public record of the 600 square mile area around the Cominco site for purposes of environmental monitoring. A follow-up study is being considered for 1982 or 1983.

*Shared with other projects

Alternative ways to obtain the data were by helicopter (10 - 20% of the area was checked by this method during other work), very expensive traverses (which would cover only a small sample of about two percent), or utilizing the more inaccurate panchromatic imagery. Existing pan imagery dating back twelve years was used for base maps, but it contained less than 50% of the detail and was much more difficult to interpret than the colour and colour infrared data. Alternatate methods of full coverage aerial photography would at best have been three times the Falcon flying costs.
In addition to the vegetation study planned, thermal data were acquired and used in studies of waste water and its thermal variability. The thermal data were also found to be "exciting and very interesting" by the exploration geologists associated with the mine at that time. (Present Cominco staff were not involved in the study and cannot provide corroboration of this aspect of the data's use.)

The data set as a whole was found to be useful for the hydrological aspect of the study. Similar information could not be obtained from any other data source at such a low cost per unit area.

PROJET: 73-67
74-106
75-71 et 72
76-46
78-65

UTILISATEUR: M. Pierre Laframboise
Direction Aménagement régional
Société de développement de la Baie James
800 est, boul. de Maisonneuve, Place Dupuis
Montréal, Québec

(514) 284-0270

ENDROIT: Territoire de la Baie James, Québec

OBJECTIF: Recueil de données de base, étude et surveillance du milieu

RESULTATS: Les données de 1973 ont été obtenues à titre expérimental alors que le CCT n'avait pas encore perfectionné la collecte des données sur des émulsions fausses couleurs. Ces données n'étaient pas de haute qualité et elles ne furent pas utilisées.

Les données acquises lors des vols subséquents se sont avérées de bonne qualité. Elles ont servi en partie à constituer un dossier photographique de certaines zones qui devaient être affectées par les travaux hydroélectriques. Il s'agit en particulier des tronçons aval et des estuaires des grandes rivières de la baie James. Les autres ont permis d'effectuer les études de base au niveau de L'environnement et de l'aménagement ou pour certains projets spécifiques. On peut donner en exemple l'établissement de cartes de végétation, les études biophysiques le long de corridors routiers, l'inventaire et le réaménagement des sites affectés par la construction de la route Matagami/LG 2/Fort George. Une évaluation détaillée de la qualité et du contenu des données de 1973 à 1975 inclusivement fut publiée en plus des rapports portant sur des projets spécifiques.

REMARQUE: Ce groupe de projets est le plus grand, en terme de milles linéaires et de région couverte, de tous les projets aéroportés entrepris pour un utilisateur de l'extérieur.

REMARQUE (SUITE) Les coûts des vols les plus récents sont séparés de ceux des premiers projets, lesquels furent considérés inutiles.

COUTS:

1973-74

Falcon	Heures 23.7	Coût	$23,700
DC-3	Heures 19.6	Coût	13,720
Biens périssables*			8,500
Par Jour*			2,080
		COUT TOTAL	$48,000
		RECUPERATION DES COUTS	$12,440

*Ces chiffres sont approximatifs -- les dossiers étaient perdus pour 1974

1975-77

Falcon	Heures 33.9	Coût	$33,900
DC-3	Heures 18.3	Coût	12,810
Biens périssables			12,750
Par Jour			1,360
		COUT TOTAL	$60,820
		RECUPERATION DES COUTS	$38,580

(Ajouter 1978: Total: $14,731.50)

AVANTAGES: Les avantages découlant de ces projets peuvent être répartis en quatre catégories: avantages par rapport aux autres méthodes de collecte des données; expérience acquise dans la collecte de données par télédétection; enregistrement des conditions environnementales avant le développement; surveillance du milieu et aménagement. Divers groupes (publics et privés) ont tiré profit de ces avantages et utilisent régulièrement ces données (l'utilisateur nommée ci-dessus a été le principal contact en télédétection durant cette période).

1. Avantages par rapport aux autres méthodes de collecte des données

   Une partie importante des inventaires et études d'environnement réalisées sur le Territoire de la Baie James constituait en quelque sorte une première par leurs objectifs, leur envergure et l'ensemble des techniques et moyens modernes utilisés. Il n'est généralement pas possible d'évaluer les avantages de la télédétection par rapport aux techniques conventionnelles car le type d'information recherché était différent.

Dans les cas où la comparaison est possible, la qualité de l'information obtenue par télédétection est supérieure.

2. Expérience

L'expérience acquise par l'utilisation de ces données est décrite dans divers articles de symposiums et publications techniques. Des lignes directrices ont été établies pour la collecte des données pour divers utilisateurs, au Québec et ailleurs au Canada. Plusieurs publications sont disponibles dans les deux langues officielles. L'expérience acquise a trait autant à l'acquisition qu'à l'interprétation des images.

3. Enregistrement des conditions environnementales

L'imagerie constitue un précieux enregistrement des conditions environnementales ayant existé avant le développement. L'information sur l'environnement physique contenue dans cette imagerie est beaucoup plus détaillée que ce qui aurait pu être obtenu sur des images panchromatiques, pour une même échelle. L'évaluation des modifications causées à l'environnement par le développement sera facilitée par la comparaison avec ces données.

4. Surveillance du milieu/aménagement

Les données obtenues par télédétection ont directement contribué à l'étude des incidences environnementales suite à la construction de la route d'accès à la Baie James, à la planification du réaménagement des sites affectés (gravières, carrières, etc) le long de celle-ci, à la sélection de tracés de route, à des études de développement etc.

Une difficulté majeure pour évaluer les avantages présents et futurs des données de télédétection acquise sur le Territoire de la Baie James réside dans l'immensité du projet et dans la diversité des applications: environnement, aménagement, hydrologie, ingénierie, etc.

PROJECT: 75-105

USER: Dr. J. Kemper
(formerly Canadian Wildlife Service)
Head, Environmental Assessment
Alberta Department of Environment
9th Floor, Oxbridge Place
9820 - 106th Street
Edmonton, Alberta
T5K 2J6

403-427-237

LOCATION Peace River (Dunregan) Alberta

OBJECTIVE: To map vegetation and habitats in the baseline survey of a proposed hydro-electric dam development site.

COSTS:

Falcon	Transit Hours	2.3*		
	Local Hours	.8	Total Cost	$3,100
Per Diem*				212
Consumables				1,069
			TOTAL COST	$4,381
			COST RECOVERY CHARGES	$1,553

* Shared with other projects

RESULTS: Maps of vegetation and habitat for various fauna were prepared for 140 km of River valley. In addition, a permanent record of conditions was obtained for a multi-million dollar hydro-electric development.

BENEFITS: "Without remote sensing, the project would cost so much, it wouldn't have been attempted." Costs for the vegetation component alone would have been $30,000-$40,000 because of the severe terrain. (Access was only at several points or by floating the river.) The first benefit then is in lower data collection cost. The ability to generalize from several cross valley transects for under canopy work was also facilitated.

Black and white photographic data would not be as useful as the multiband data. From the former only a general inventory could be done. From the remote sensing data, specific communities, even clones of aspens, could be mapped.

One research observation by Dr. Kemper may have wide possible application: Thermal data at finer resolution above sand bars may show gradations in sand bars which are directly related to evaporation from them -- which in turn is related to differences in elevation as small as one foot. For areas of shallow water in flat terrain this could be a very useful monitoring tool related to flooding, etc. Thermal data also showed the mud flats/land interface.

The government has now decided to go ahead and have requested development proposals from power companies. The remote sensing data collected far ahead of time will provide (with newer imagery) invaluable short term historical detail on slumping in the area. (The area is prone to slumping and this is a major problem to consider in site location.) It should be noted that the whole area was covered by remote sensing in anticipation of the recent decisions.

FOLLOW-ON: The user in his position at Alberta Environment intends to begin using colour infrared imagery on a regular basis.

COMMENT: This project demonstrates the very long period of time often required to see the pay-offs of a given remote sensing project. Although the area was flown in 1975, the decision to build the dam did not take place until mid 1980, and it will be completed some years later. Only in the next few years will the value of the data become apparent.

PROJET: 76-23

UTILISATEUR: G. Nijdam
Hamel, Ruel et Associés

Hôtel de ville
Boîte postale 398
Drummondville (Québec)
J2B 6W3

819-478-4111

ENDROIT: Cantons de l'Est (Québec)

OBJECTIF: Dresser la carte des conditions d'humidité du sol et de drainage dans une zone agricole.

RÉSULTATS: La télédétection a produit d'excellents résultats, tant sur film infrarouge couleur que sur balayeur linéaire en infrarouge. Les zones dépourvues de tuyaux de drainage et celles où les tuyaux étaient mal installés ont toutes été décelées dans cette région qui est caractérisée soit par de graves pertes de récoltes soit par un rendement potentiel réduit dus tous deux à l'humidité du sol. Environ 735 milles carrés de la zone de 1 050 milles carrés étudiée sont consacrés à l'agriculture. On avait déjà conclu (bibliothèque d'images) que pour cette région, de détection au sol ne fourniraient pas des données d'une aussi bonne qualité que la télédétection. De plus, les travaux sur le terrain coûteraient 100 dollars par mille carré (deux jours-hommes). L'interprétation des images faisait partie d'une étude sur la tuyauterie et le drainage effectuée par les personnes qui s'occupaient de la planification du drainage. Les images ont constituées une source de données se prêtant à l'intégration: le coût de l'interprétation était inférieur à ce qu'il aurait été si l'on avait intégré les données recueillies au sol. (Voir lettre au dossier 76-23).

COÛTS:

Avion:	$ 3,140
Bien périssables	404
	$ 3,544

RECUPERATION DES COÛTS: $3,600.00

AVANTAGES: Ces travaux auraient été effectués de toute façon. Nous ne pouvons donc pas en attribuer les avantages à la prise de décision. La télédétection nous a permis de mieux couvrir une zone plus étendue, à moins de frais. Les informations obtenues étaient de trente à cinquante pour cent plus précises qu'elles ne le seraient par l'emploi d'autres méthodes, compte tenu de l'utilisation des images du mois de mai.

La valeur en serait supérieure dans plusieurs secteurs; elle serait inférieure pour quelques autres.

Les avantages sont calculés par rapport aux méthodes l'étude sur le terrain existantes qui coûtent 100 dollars par mille carré (2 jours-hommes). Il semble que les coûts des études sur le terrain soient trop bas. Les calculs suivants ont d'abord été effectués en utilisant comme base les prévisions données et ensuite en incorporant les coûts des travaux sur le terrain fondés sur les prévisions de coûts pour la voiture, le personnel et les frais généraux de deux personnes, en utilisant les coûts sur le terrain de 1978 établis par d'autres utilisateurs.

Calcul modéré des avantages par rapport aux méthodes d'étude sur le terrain

1050 x 118 ($1978)
Plus 30% de précision obtenue

TOTAL modéré: $161,000

Calcul réaliste des avantages par rapport aux méthodes d'étude sur le terrain
($20/jour voiture, $100 par jour personne y compris les frais généraux)

1050 x 220	$231,000
Plus 30% de précision obtenue	69,000
TOTAL réaliste	$300,000

Rapport entre modéré et réaliste 45:1 (Modéré)
83:1 (Réaliste)

PROJECTS: 77-36, 37 and 38

USER: Mr. D.B. Patterson & Mr. K. Campbell
Alberta Environment
9820 - 106 Street
Edmonton, Alberta
T5K 2J6

403-427-6218

LOCATION: Various in Alberta

OBJECTIVE To evaluate remotely sensed imagery and data of Alberta mining areas for the purpose of determining its possible uses as a planning and monitoring tool. Special emphasis will be placed on reclamation and the possible use of the imagery and data for determining the status of reclamation programs. Where applications are determined to be operational, methodologies will be developed.

RESULT: The data shows definite potential as a monitoring and planning tool especially in the areas of reclamation and mine planning.

COSTS:

Falcon Hours	24.5	Cost	$24,500
Hours Transit	19.9*		
Consumables			2,896
Per Diem			1,811
		TOTAL COST	$29,207
		COST RECOVERY CHARGES	$ 4,748

*These costs are based on the total cost Ottawa-Target-Ottawa two times.

BENEFITS: Work by Alberta Environment, showed the data's usefulness for a wide variety of purposes. (These were presented in a paper at the Fifth Canadian Symposium on Remote Sensing.)

The colour and false colour infrared data were given to the coal mining companies involved. They were encouraged by the potential uses identified and spent over $100,000 in 1979 and 1980 to acquire colour and/or false colour infrared imagery from private contractors. The data were used for planning re reclamation maintenance (i.e. assessing where reclamation is progressing well and where not -- and why), and mine planning.

Any tool which helps to meet reclamation requirements sooner, is extremely valuable to the mining industry. All mine operators are required by provincial legislation to give a security deposit to the government. When the land is reclaimed, the mine operators have the deposit returned. Reclamation itself, costs at least $2,000 per acre. If these costs can be minimized because of decreased maintenance costs and more efficient planning then the economic status of a mine is improved. This benefit is normally passed on to affiliated industries. The result is a benefit to the overall market and not just the remote sensing industry.

The net benefit to date to the RS industry is over $100,000. Further studies are aimed at more directly incorporating proven remote sensing technology into the reclamation process and developing methodologies specific to reclamation. It can be assumed that future benefits to the mining operators, environmental specialists and the RS industry will increase proportionately as methodologies are developed. With the potential for use in Oilsands operations identified, the total benefit to the remote sensing industry should exceed the million dollar figure within the next half decade.

PROJECT: 74-28

USER:
Dr. D.W. Anderson
University of Saskatchewan
Soil Science
Saskatoon, Saskatchewan
S7N 0W0
306-343-2283

Work Done For:
D. Murray
Elliot Lake Lab
CANMET, EMR
Box 100
Elliot Lake, Ontario
705-848-2236

LOCATION: Estevan, Saskatchewan

OBJECTIVE: Inventory the soil materials and vegetation of coal mine spoils in the Estevan area

RESULT: This work was done as part of a larger study of mine waste reclamation in Canada. (See publication title below.) They were able to characterize vegetation cover, but not plant species or quality of plant using the 1:15,000 imagery. The data were quite effective in the area, and were used for some of the local planning of reclamation of disturbed land. The value of the data's subsequent use as a base map of disturbed land and for planning could not be quantified, although it did have significant utility. Dr. Murray noted that the data has some use for environmental monitoring, which must be done now on a regular basis. The report by Dr. Anderson did not either recommend or not recommend remote sensing since this was not part of the contract requirement.

COST:

DC-3	Total Hours 2.3* Cost	$ 1,610
Consumables		266
Per Diem*		129
	TOTAL COST	$ 2,005
	COST RECOVERY CHARGES	$ 470

*Shared with other projects

BENEFITS: In addition to the unquantifiable benefits of decisions on reclamation using maps derived from the data, the cost savings stated by Dr. Anderson were said to be ten-times the cost to him -- or $4700 (or $6580 1978$) over using traverses and field methods. Although the traverse method would provide more accurate specie identification, the resulting maps would not be as accurate in the spatial context. This results in a doubling of the data's value to $12,000 over alternate methods.

The quantifiable benefits over costs are $9,995 -- yielding a benefit to cost ratio of 6:1.

COMMENT: The application of remote sensing data for mining spoil reclamation monitoring and evaluation has been important in some isolated cases in the United States. Remote Sensing should be more widely advertised in Canada if inexpensive methods using colour infrared film are now available in industry and can be demonstrated as efficient.

PUBLICATION: The report describes the entire program involving twenty projects: Pit Slope Manual Volumes 1 and 2, Reclamation by Vegetation, Pit Slope PRoject, Minerals Research Program, Mining Research Laboratories, CANMET REPORT 77-31, EMR. Canada.

PROJECT: 77-13

USER: Dr. R.A. Hursey/Dr. B.A. Khan[1]
Research Manager
Land Systems
Alberta Oil Sands Environmental Research Program (AOSERP)
Alberta Environment
15th Floor, Oxbridge Place
9820 - 106th Street
Edmonton, Alberta
T5K 2J6
403-427-3943

Contractor: M.D. Thompson
Intera Environmental Consultants Limited
7015 Macleod Trail S.E.
Calgary, Alberta
403-253-8895

Also contacted: Dr. F. Gilbert
Department of Zoology
University of Guelph
Guelph, Ontario
519-824-4120

LOCATION: Oil sands region of Northern Alberta.

OBJECTIVE:
1. to provide vegetation and surficial geology 1:50,000 base maps for use by field workers and others doing work in the oil sands region
2. to evaluate RS data sources compared to more conventional sources for providing the above.

RESULTS: Thirty-two maps were produced, including thirteen new 1:50,000 base maps and substantial revisions of the remaining nineteen. Detailed vegetation and geology maps were produced rapidly and accurately from 1:50,000 colour infrared images. A thorough comparison between image types was produced. The implications of the speed and ease of interpretation are quite significant. (see below)

COSTS:

Aircraft Transit	$ 5,600
Aircraft target/Local	7,400
Crew Per Diem	1,125
Consumables	7,000
	$21,125
COST RECOVERY CHARGES	$24,164

BENEFITS: Data Acquisition: coverage of area at 1:12,000 (normal scale given by Thompson et al) would require 10010 line miles. Using 1976 costs as a basis (which at $14/line mile are the lowest line mile charges recorded anywhere in Canada in 1975-76), the total alternate cost would be $165,365. The Commercial estimate (Thompson et al, 1978) for 1:60,000 CIR is $40,000. Ground data collection costs are discussed below.

NET SAVING: $125,000

Data Interpretation: (Source: Thompson et al and letter on file.) The surficial geology and vegetation maps were done in 45 hours for each sheet -- a saving of 45 hours over other methods for each of 32 sheets. At $20 per hour[2]

2 maps types x 45 hours x 32 maps x $20 = $57,600.

Vegetation maps and surficial geology maps may be done with aerial photographs at low altitude, but more field work is required than with colour infrared. Maps are generally not prepared using field work alone because of cost and accuracy.

NET SAVINGS: $57,600

ADDITIONAL BENEFITS: Users who are studying terrestrial vegetation for wildlife habitat studies can cut field work costs by up to 40% through the use of colour or colour infrared imagery at scales up to 1:30,000. Such significant savings are not realized in the study of aquatic vegetation habitats although colour imagery would be valuable for discrimination of plant species at scales up to 1:10,000. Conventional ground work costs for the AOSERP area for four animal species (mink, otter, and beaver and muskrat) would be about $200K over three years:-- or about $20 per square mile. This would be based on a 1 to 2% sample. Sampling areas were selected from the vegetation (forestry) maps/imagery available and aerial reconnaissance. This is a major use of the imagery. Dr. Gilbert, the source for the above, believes that in the long run there is a possibility of cutting much of the field work to little or nothing if proper standards for interpretation and analysis can be developed for the remote sensing data and the relationship of habitat types to animal populations can be determined. It should be noted that none of this would be possible without the work on colour infrared imagery exposure control done by Air Ops. (See Fleming, 1978)

Benefits Potential	$20,000 - 40% reduction in terrestrial habitat studies' costs - 20% reduction in aquatic habitat studies' costs - 50% reduction in all field work costs for wildlife surveys/habitat analyses

Total Demonstrated Benefits $200,000

Notes: [2] The $20 per hour is derived from an independent source as the cost for interpretation services

[1] The material here has been reviewed by Dr. Gilbert and Ms Thompson with a letter from Dr. Khan quoted in detail in the attached.

VALUE OF DATA TO USERS:

The following material is from a letter from Dr. B.A. Khan to R.A. Ryerson, March 8, 1979.

"The project was designed to produce 1:50,000 maps describing existing conditions (i.e. a static picture of the vegetation), with the assumption that the habitat types and boundaries will be refined as required in future years. It is expected that many type boundaries will shift as additional detailed information is obtained, but this first phase provided a first approximation of baseline conditions.

Researchers working in specific areas and requiring more detailed information on habitat will use these baseline working maps and refine them to suit their purpose. The maps have been designed with a telescoping legend and will allow a degree of uniformity from study to study while at the same time providing a first approximation.

These phase I maps also prove to be valuable as they now stand as a larger scaled representation of vegetation and surficial geology. (I should also mention that soils maps are also being prepared for the AOSERP study area at a scale of 1:50,000 using the ecological or biophysical approach. This is being carried out under project LS2.1.)

All of the 1:50,000 maps (vegetation, surficial geology, and soils) completed up to the end of the 1977-78 fiscal year were included with the interim reports and sent to our distribution list of major libraries and depositories across Canada. In addition, master copies of these maps have been given to the Map and Air Photo Distribution Centre, Alberta Energy and Natural Resources for distribution to the public.

Replying to some of the specific questions in your letter is rather difficult. One reason for this is that the mapping has not yet been completed -- we expect to have the remainder of the surficial geology and vegetation maps available by late spring 1979, and the soils maps by late spring 1980.

For example, it is hard to estimate the number of people in the field who have worked with the maps. Most of the researchers who work with the Land System have had the maps supplied to them or have access to them. The reclamation project used them to locate areas of vegetation suitable as seed sources and at least five other projects used the maps to help locate study plots in representative areas. Requests for the maps for researchers in the other systems have been numerous, and a large number of requests from outside AOSERP have been made. There have also been requests from different areas for help in ordering copies of the imagery itself, generally for specific portions of the study area and usually by other line agencies (e.g. Alberta Parks, Recreation and Wildlife; Canadian Wildlife Services; University of Calgary). I estimate that the use of the maps is fairly wide, particularly with AOSERP and other agencies, but their value will be far greater when the whole area has been completed.

Current plans for follow-up studies are at this point preliminary and subject to funding approval. One possibility we are considering is establishing relationships of the present vegetation types to the lower story vegetation. This type of information would be of great value to people involved with Wildlife research or management.

The mapping project which has been the primary user of the imagery was budgeted at $80,000.00 for the 1977-79 fiscal year (covered by the report attached) and $100,000.00 for the 1978-79 fiscal year in which the field checking will be carried out and the remainder of the study area mapped. (For your information, the AOSERP budget for the first four years of the Program -- 1975-76 to 1978-79 -- has been approximately $4 million/year: not more than $2 million from the Federal Government and not less than $2 million from the Provincial Government.) It is not possible to give a much more detailed breakdown at this time."

From the above letter we can conclude that the information has been widely used, and will be even more widely used this summer. It has saved field expenses, allowed more rapid completion of environmental studies, and has led to considerable time savings in this area where field seasons are short, conditions are harsh, and an ambitious project must be completed at as low a cost as possible within a limited time frame. Although total value of the data is not yet known, it has already been useful, provides an excellent environmental baseline data set, and was acquired at no cost to CCRS and at low cost to AOSERP. Eventual benefits associated with this data set related to reclamation, monitoring and geology could reach millions of dollars.

PROJECTS: 76-43 and 76-44

USER: Dr. J.B. Millar
Canadian Wildlife Service
Prairie Migratory Bird Research Centre
115 Perimeter Road
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 0X4

(306) 665-4087

LOCATION: Several test sites in southern Alberta and Saskatchewan

OBJECTIVE: To determine the amount of information which can be obtained from different types of remote sensing regarding:

1) the character of both wetland and upland vegetation;
2) the presence of water in densely vegetated wetlands.

These are for use in studying the feasibility of establishing a Prairie-wide program evaluating year to year changes both natural and man-made, in waterfowl and other migratory bird habitats.

RESULTS: Remote sensing data provided some information not as readily available from field work or black and white imagery (vegetation in water, spatial distribution of vegetation). Other data usually required, such as detailed maps of plant species, are only available from field work. In general remote sensing data yielded results faster than other methods. Using transparencies alone has proved to be difficult in the field...purchase of prints from transparencies is too expensive.

COSTS:

Falcon Transit Hours	7	cost	$8,800.00
Local Hours	1.8		
Consumables			1,383.00
Per Diem			747.00
		TOTAL COST	10,930.00
		COST RECOVERY CHARGES	2,176.00

BENEFITS: The costs of doing sampling on the ground are high. "With remote sensing there is a saw-off: there is less detail with remote sensing but a larger area can be covered with less manpower and less field work." The benefits would favour a remote sensing program for a large area study. Remote sensing at small scales (1:60,000) could also be used to help select fewer but more representative test sites for detailed ground study. However, no methods are regularly used now because of budget cuts -- they are now "depending on the United States Fish and Wildlife Service who are doing photography in their major areas of interest". They hope to do annual surveys on a limited basis some time in the future.

PROJECT: 73-45

USER: Dr. D. Welch
(Formerly of University of Winnipeg)
Lands Directorate
Environment Canada
Ottawa, Ontario
K1A 0H3

613-997-2320

LOCATION: Red River (Winnipeg), Manitoba

OBJECTIVE: The data were to be used for basic research in geomorphology and remote sensing applications.

COST:

Falcon Local Hours	.5		
Hours Transit	2.8*	Total Cost	$3,300
Consumables			131
*Per Diem			163
		TOTAL COST	$3,594
		COST RECOVERY CHARGES	131

DISCUSSION: This is an example of data obtained for use by a university researcher which was used to study a research problem in a specific discipline (geomorphlogy, in this case) as well as to do some work in remote sensing applications research. Dr. Welch noted that "since the work was aimed at basic research, it is difficult to discuss cost effectiveness". None-the-less the data were used for one reported application as well as several others by secondary users.

RESULTS: Excellent data were obtained and they were useful in research work, teaching and for a spin-off environmental impact study related to evaluating the effects of dumping snow in the Red River. Further research work planned on meanders was not carried out since the Principal Investigator left the University to join the Federal Government.

BENEFITS: Although cost-effective applications are not expected soon after basic research begins, it is the nature of remote sensing data that cost-effective applications can make use of data collected for research in an entirely different area. This happened in this case.

* Shared with other projects

The user co-operated with two colleagues to do an environmental impact assessment of snow dumps on the river shore-line. The remotely sensed data were useful in that:

1) By giving an overview of the entire study area a classification scheme was easily derived;

2) They lessened field mapping work to two days in a boat;

3) Colour data showed more detail than panchromatic data; and

4) The interpretation results as verified in the field were very accurate.

Several other individuals contacted the user about the data for other studies. Copies were subsequently ordered from the National Air Photo Library by other secondary users interested in features such as the Netley Marsh at the south end of Lake Winnipeg.

PROJECTS: 74-50
75-20
76-15
77-50

USER: Dr. S.L. Iverson
Whiteshell Nuclear Research Establishment
Pinawa, Manitoba
ROE 1LO

204-753-2311

OBJECTIVE: To evaluate remote sensing for detecting and monitoring radiation vegetation damage.

COST:

Falcon and DC3	Total Hours	15.4	Total Cost	$12,190
Consumables				1,748
Per Diem				686
			TOTAL COST	14,624
			COST RECOVERY CHARGES	$ 2,863

RESULT: Low altitude colour IR was very useful for recording vegetation damage -- including levels of damage.

BENEFITS: Over the eight year program they monitored radiation effects very closely on the ground: The remote sensing data provides a useful pictorial record. The project is experimental and as such it is difficult to show benefits of remote sensing in this context beyond that it provides the only possible permanent visual record of the whole site.

FOLLOW-ON: The remote sensing work has not yet been published. Some consideration is being given to supporting graduate work using the data set and (perhaps) a new flight.

This study is another of a series which demonstrates the usefulness of colour infrared for vegetation studies.

A.2 LAND USE

PROJECT: 71-20/71-76

USER: H.D. Steiner (71-20 and 71-76)
University of Waterloo*

M.H. MacLeod (71-20)
Ontario Ministry of Transportation*

R. Middleton (71-20)
Department of Mines (Ontario)*

All have since moved. Mr. MacLeod was reached at Zeiss Canada Limited. Dr. Steiner, this author's Ph.D. advisor from 1971 to 1975, used the imagery for teaching and research

LOCATION: All of the users were located in Southern Ontario.

OBJECTIVE: The imagery was to serve a variety of uses: geological studies, crop studies, and as a basis for a geo data base of transportation, rivers and hydro lines.

RESULTS: No results could be determined for the first two objectives since the users (Middleton and Steiner respectively) could not be located. It is presumed from this author's knowledge of Steiner's work that the main use was for teaching.

Mr. MacLeod used some imagery to provide a geo data base for Metro Toronto showing road, rail, rivers and hydro lines. This experimental project, aimed at developing conversational geo data bases hinged on road location, was dropped before completion.

A secondary use was in Gierman and Ryerson's work on the mapping of land use in the Great Lakes Basin to co-incide with the 1971 Census.

COSTS:

14 Hours of CF100 =	$14,000
Film	3,000
	$17,000

DISCUSSION: If the work had gone ahead as planned by MacLeod it would have covered 35,000 square miles using 500 stereo models in place of over 25,000 models required if normal imagery was to be used. In the test area two models were used in place of 100. To acquire standard imagery for the test area alone would be about $2,500. For the entire area, standard imagery would cost about $290,000. Since the study was not continued, no actual benefits can be stated. Given information available at the time, the application was very cost effective.

The major benefits associated with this study are from the secondary use of the imagery for land use activity mapping in Ontario for the International Joint Commission. A total of ≈200 images, covering >10,000 square miles were purchased, interpreted and information output for $75,000 (1974$). Since one-third of the area was mapped from satellite, two-thirds of the cost or $50,000 can be attributed to the use of the airborne RS: this becomes $70,000 (1978$). The total cost including RS data costs becomes $87,000. Part of any demonstrated benefit is also attributable to the Canadian Geographic Information Systems (DOFE) existing data base which was updated by the use of airborne RS.

The cost of the US methodology based on contracts signed in 1974 (≈ 300,000) and 1977/78 (≈ 50,000) can be attributed to airborne cost savings in a similar manner -- one-third vs two-thirds. In 1978$ this becomes $470.5K. These data were produced three years late, with one-half as much data, and twice as much error as methods developed for use with airborne remote sensing by Applications Division staff at CCRS. (See papers and correspondence on file.) If we ignore the lateness we can assume that the data are at best one-half to one-quarter as good as, and at worst completely useless compared to the airborne RS derived data. (Only the airborne derived data met the user's original specifications.) Considering degraded data as an additional cost, we obtain costs of alternate methods used in the United States ranging from $941,000 to $1,882,000.

BENEFITS: The demonstrated benefits (benefits less costs) range from $854,000 to $1,708,000 over the U.S. methods. Of this, one-half or $425,000 to $850,000 can be attributable to CCRS. The alternate methods available in Canada would have cost well in excess of $5,000,000 and would not have been used because of the high cost. Without CCRS airborne remote sensing the entire basin would have been mapped by the U.S. agency, with a consequent loss of experience to Canadian land use specialists. A publication on this work was the major Canadian contribution at the International Symposium on Remote Sensing and Land Use, Phoenix, Arizona 1975.

NOTES: Secondary users are difficult to identify because of records kept by NAPL. Here we can see a secondary user received a benefit of over $2,000 per image purchased after discounting the original acquisition cost.

Exchange rates on U.S. dollar costs vs. Canadian dollar costs are not included.

PROJECT: 76-19

USER: Mr. R. Brown
Manitoba Department of Municipal Affairs
Municipal Planning Branch
402-338 Broadway Avenue
Winnipeg, Manitoba

Work done on Contract: Mr. Tom Wingrove
Underwood McLellan Limited
1479 Buffalo Place
Winnipeg, Manitoba
R3T 1L7
204-284-0580

LOCATION: Brandon, Manitoba

OBJECTIVE: To use high level remote sensing to establish a base for land use types and transportation networks, as well as mapping of the natural environment.

RESULT: Excellent quality maps of 2,500 square miles were prepared on time and within budget using colour infra-red imagery. These have since been used for regional development planning. There were some difficulties with the small scale -- it created problems in transferring detail. The use of the 3.5 inch lens caused some exposure problems: this lens is no longer recommended for CIR film.

COSTS:

Aircraft Transit	$2,500.00
Over Target	1,250.00
Crew Per Diem	300.00
Consumables	1,170.00
	$5,220.00

COST RECOVERY CHARGES $4,645 or $5,481 (1978$)
COST TO GOVERNMENT 0

BENEFITS: The cost of alternate new black and white panchromatic imagery at 1:25,000 scale to allow interpretation of features of interest would be for 1200 line miles at 16.50/ line mile (1978$), or $19,800.

Benefit-Cost Ratio for Acquisition

Over Airborne Imagery: $19,800 vs 5,220 4:1
saving of $14,580

Over field work (8x) $158,000 vs 5,220 30:1
saving of $152,780

The cost of interpretation was said to be 20% less, even with the stated difficulties. The cost of the interpretation contract was $7,500 (1976$) or $8,850 (1978$) . A saving of $22,000 was therefore realized. Minimum Direct Saving $16,780
Maximum Direct Saving $153,000

PROJECT: 75-111

USER: L.E. Milton
Regional Planning and Research Division
Edmonton Regional Planning Commission
Baker Centre, 106th Street
Edmonton, Alberta
(Now with Ontario Hydro, Land Use and Environmental Planning Department, 416-592-3975)

LOCATION: Edmonton

OBJECTIVE: Land use inventory and provision of more detailed land capability information than is available from CLI.

RESULTS: Image acquisition costs were estimated at the "same as black and white panchromatic imagery with better accuracy". In this case speed of interpretation was increased 50% with no loss in accuracy -- or higher accuracies could be obtained at the same speed. Ground methods are eight to twenty times as expensive as panchromatic imagery, depending on the type of data to be collected. Much of the required data could not be collected from black and white panchromatic imagery. One half of the 406 nm of imagery requested was acquired: this still was very useful.

COSTS:

Data Acquisition:	2 hours	- $ 2,000.00
Ferrying (shared):	1.7 hours	1,700.00
Imagery:		500.00
Per Diem (shared):		275.00
	TOTAL COST	$ 5,475.00
	COST RECOVERY	$ 1,117.00

DISCUSSION: Alternate methods would be ground work, or 1:30,000 panchromatic imagery (combined with detailed ground work). Note that the costs of interpretation are similar to those quoted by D. Thompson (77-113) with respect to the differences between higher altitude colour imagery is lower altitude panchromatic imagery at twice the scale. If the whole area had been covered, the total cost would be $8,500.00. Panchromatic imagery for the partial area would cost $9,745.00, and for the whole area, about $18,600.00. (All values converted to 1978 dollars: panchromatic imagery costs based on ICAS value of $19.26/line mile.).

BENEFITS: 1. Over Panchromatic Imagery:

Acquisition $9,745 vs $5,475	- $4,270.00
Interpretation (7.5 mi^2/hr. vs 15) at about $160/day 28 da. vs 56 da.	≈ $4,500.00
	$8,770.00

2. Over ground methods $\left(\frac{8 \times 20}{2}\right)\left(9745\right) \approx \$136,400.00$

Therefore, the benefit of airborne RS is in the order of 2:1 over simple aerial photographs.

Airborne methods of <u>any type</u> yield significant benefits over traditional methods: B/C ratios as high as 14:1 over ground based methods are the norm.

SOURCES: Visual library and letters on file.

SPIN OFF: The project leader, in his new position at Ontario Hydro recently acquired colour imagery of 5,500 sq. miles of southwestern Ontario at an increase in cost of 10% over panchromatic imagery. There is an estimated improvement in efficiency in interpretation of 10% to 50% over panchromatic imagery, depending on which one of 5 kinds of data is being interpreted. The interpretation speed benefits over panchromatic imagery alone approached $42,000. Considerable interest has been expressed by government agencies in borrowing and purchasing selected portions of this coverage. Colour imagery is advantageous over panchromatic when discussing and explaining environmental planning issues with the general public, and would be justified on this ground alone.

PROJECT: 74-27

USER: Mr. J. Wightman
Vice-Principal
Nova Scotia Land Survey Institute
Lawrencetown (Annapolis County)
Nova Scotia
902-584-2226

LOCATION: Annapolis Valley, Nova Scotia

OBJECTIVE:
1. To acquire data for teaching purposes;
2. To use data for land use planning;
3. To use data for recreation planning;
4. To be used for expressway route evaluation studies.

COMMENT: In addition to 74-27 a number of other projects have been used in conjunction with the earlier flight. These include 73-198 and 225 (not acceptable, originally, because of haze), 78-82 a SAR project, and 79-39.

RESULTS: One or more of the available imagery sets have been used for educational purposes, public presentations, demonstrations and a number of applications to local or regional problems. The 1974 imagery, augmented by more recent experimental data, has been the primary data set.

1. Educational Uses. The imagery has been used in various studies and projects by students in Remote Sensing, Property Mapping, Planning and Photogrammetry at the Nova Scotia Land Survey Institute.

2. Land Planning Uses. The imagery (duplicate copies acquired from NAPL) has been used by a planner and engineer doing valuations and planning restraints for a land bank in Bridgetown, N.S. The local Planning Commission has also used the data in preparation of town plans for several municipalities. In the last two years these same data have been used by the highway design engineer working on the expressway extension from Kingston through the Annapolis Valley. The Provincial Departments of Agriculture and Municipal Affairs have also used these data to map the agricultural zone (classes 2 and 3 land capability), its present land use, and extent.

3. Agriculture and Vegetation Studies. The growing season in the year in which the data set was acquired was late by two weeks and was very wet. The data were used to study micro-drainage in fields for the farm community. A short course was conducted for both farmers and wood lot owners (a total of thirty) with regard to spot corrections for drainage. A number of changes made by land owners resulted in improved crops and better production. There has also

been some use of the data for shade tree mapping ... an important consideration to the towns and villages which maintain trees in public open space, particularly given the spread of Dutch Elm Disease to the area and the budgets for tree removal now being approved by the County Councils. Project 74-73, reported on elsewhere, has also been used in these and related studies.

4. Environmental and Other Studies. All of the remote sensing data sets have been used in conjunction with aerial photography from 1945, 1955 and 1967 in an historical environmental impact study by a consulting firm for the Tidal Power Corporation. Four maps of the area, trends, etc. were mapped in a very short period of time. Given the urgency of the study, it could only have been done with archived imagery. Another 1979 study was done using the recent data for a marsh impact study. The reclaimed marsh, a highly productive area has had some problems with residual salts in the soils. This and other production related problems were studied using the remotely sensed data. Another use cited for the existing data is the mapping of Acadian "cellar rims" ... the ruins of the original Acadian homes and farmsteads for archaeological purposes.

A number of other uses of imagery have been made by the Federally Funded Remote Sensing Centre operated at Lawrencetown. These include various types of land mapping and related applications. One example of a special purpose study was the location of abandoned automobiles which are considered to be an eyesore in this popular tourist area. These maps have subsequently been used by a private contractor to plan and execute the removal of the cars.

COSTS: 74-27

DC-3	Total Hours 7.3 Cost	$5,110
Consumables (approx.)		600
Crew Per Diem*		400
	TOTAL COST	$6,110

BENEFITS: The multiple use of this one data set for studies in agriculture, land use planning, urban forestry, teaching, archaeology and environmental impact has resulted in savings of many thousands of dollars compared to field work (where such is feasible) or even compared to the normal black and white imagery acquired in the past (for similar purposes) at larger scales and greatly increased costs for interpretation. A major factor in the savings is the multiple use afforded by remote sensing data compared to black and white panchromatic imagery.

A conservative estimate at alternate field and air photo data collection methods would be in the vicinity of $20,000 to $30,000 excluding image interpretation. The savings associated with interpretation of remote sensing compared to normal photographic data are similar to those quoted elsewhere ... double the productivity.

Although much of the benefit can be attributed to the existence of the remotely sensed data, additonal benefits must be assigned to the organizational structures (educational institution and local remote sensing centre) which have encouraged a wide use of one data set for a range of problems.

This particular set of examples shows the multiple use characteristic of remote sensing, the value of archives, and the importance of direct contact between users and specialists.

This project illustrates four fundamental characteristics of airborne remote sensing:

1. it may serve a variety of users if scales and time of year are carefully chosen;

2. archived data are used often and well;

3. locally based remote sensing interpretation espertise is important in fostering the use of data;

4. it can be cost effective for even small areas at large line mile charges provided that adequate attention to user co-ordination is given.

A.3 FORESTRY AND AGRICULTURE

PROJECT: 76-67

USER: Mr. R.G. Ballance, B Sc F
Grounds and Roads Specialist
Directorate of Base Maintenance
101 Colonel By Drive
Ottawa, Ontario
K1A 0K2

Telephone: 613-992-6749

LOCATION: CFB Gagetown, New Brunswick

OBJECTIVE: To ascertain whether military training areas have been adequately treated with herbicide and to determine which areas should be treated next year to kill brush.

RESULT: The colour infra-red data were useful for assessing the aerial spray effectiveness and for planning future missions. Careless spraying, areas missed completely, and contractor's equipment malfunctions were visible.

COST:

DC-3 Transit Hours	6.7	Cost	$5,320
Local Hours	.9		
Consumables			1,028
Per Diem			320
		TOTAL COST	$6,668
		COST RECOVERY CHARGES	$1,730

BENEFITS: The work began as an experimental effort to evaluate remote sensing. Although it has proven useful and the aerial photography illustrated that areas sprayed by helicopters were controlled better than those flown with fixed wing aircraft, it has been difficult to justify special purpose remote sensing flights. The present procedure is to make use of regularly (every five years) acquired imagery to plan and (to a certain extent) monitor spraying effectiveness. Field work is still necessary; the extent of field work for planning is as great as ever.

It is difficult to assess the dollar impact remote sensing has had. The total budget for spraying (monitoring is only a small part) is $350,000. Remote Sensing would be an excellent tool if costs are reasonable. Only 3-4000 hectares per year need to be flown.

PROJECTS: 75-101 and 76-25

USER: Mr. R. Bowlby
Northern Affairs
200 Range Road
Whitehorse, Yukon
Y1A 3V1

LOCATION: Various in Yukon.

RESULT: The optimum type of data for forestry studies in the Yukon have been decided upon (as a result of these data) to be 1:50,000 colour infrared. (1:20,000 colour and colour IR were obtained in these projects.) A contract has been let to use the data to type forests in much of the area. The typing map will then be used to delineate commercial timber stands ready for harvest now and for various years into the future. As well, the data will be used for fire protection around settlements, planning, volume analyses, etc.

There have been several spin-off uses as outlined below.

COSTS: (1978$)

Falcon Total Hours	14.5	Total Cost	$14,500
Transit Hours	7.8		
Consumables			21,247
Per Diem			661
		TOTAL COST	$36,408
		COST RECOVERY CHARGES	$33,326

BENEFITS: These data have contributed to the beginnings of a remote sensing monitoring of the Yukon's forests. Although the data were used only in a cursory fashion in forestry until recently, they have led directly to a 1980 contract for about 1600 line miles of CIR at 1:50,000 and plans for a further 3000 line miles in 1982. These contracts will have a value in excess of $125,000 to Canadian industry* If traditional panchromatic data were used at 1:20,000, costs would be double for acquisition and higher for interpretation. The preliminary work will thus likely save in excess of $250,000 in acquisition and interpretation of new data.

SPIN-OFFS: Archived data has been consulted an average of 30-40 times per year in Whitehorse. It has been used for highways, air strip and gravel quarry location and planning. Mines have been major users (25 users in one two month period) to locate

*Precise contract values or estimates cannot be released until final contracts are signed.

Note: 1980 flying was not done as a result of poor weather - flying is now planned for 1981 and 1982

old buried stream channels for establishing claims for gold mining. (The CIR is very useful for this activity.) Other uses have included planning of recreation, sub-divisions, septic tank placements, settlement location, etc.

COMMENT: The number of spin-off users gives an indication of the number of users one could expect to consult other large coverage high quality airborne remote sensing data sets when they are archived locally and made easily accessible. Although benefits cannot be specified for these users, they are obviously high -- perhaps higher then those accruing to the original user.

PROJECT: 76-56 and 77-66

USER: Mr. J.M. Finnis
B.C. Forest Service
Parliament Buildings
Victoria, British Columbia
V8V 1X5
604-387-5965

LOCATION: Various in British Columbia

OBJECTIVE: To locate western spruce budworm infected areas for planning spraying operations.

RESULT: Previous imagery (75-94) was acquired which had a useful application for Douglas-fir tussock moth spraying in 1975-76 and formed the basis for a planned spruce budworm spray program in 1977. (Called off one week before spraying was to begin.)

COSTS:

Falcon Transit Hours	8.4	Cost	14,400
Local Hours	6.0		
Consumables			2,270
Per Diem			927
		TOTAL COST	$17,597
		COST RECOVERY CHARGES	$13,648

DISCUSSION: This is the operational follow-on for a series of projects begun by Dr. John Harris of the Pacific Forest Research Centre.

BENEFITS: 1) Primary benefits are related to improvements over the normal methods for identifying spray blocks for insect infestations which used black and white photography as a base for sketch maps done by observers in low flying aircraft. Compared to colour airborne remote sensing imagery, these conventional methods provided poorer maps, less detail, and inaccurate historical record (see below), and poor reference information for pilots. The remote sensing allows for precise location spray blocks, a lower volume of spray, and lower line miles. The cost savings have not been quantified for the tussock moth spray program. The spruce budworm program which was to cover 40,500 hectares. was cancelled as a result of public pressure. The preparatory work for line placements was done with much more confidence...areas of habitation and non-forest uses and areas not infected were to be avoided. Given the

sensitivity of environmental groups and others to the possible side effects of spraying the confidence attached to remote sensing derived spray block maps is very important. If the spraying program had gone ahead the benefits of carrying it out more optimally would be large, but mostly intangible relating to avoiding future side effects and damage suits.

2) The spruce budworm infestation collapsed in 1978. The pest has re-appeared every ten to fifteen years: The images acquired will be kept as a record of the most recent outbreak. Unlike sketch maps, the images provide an accurate record of degree of infestation, exact spatial extent, and environmental conditions at the outbreak site. These images, combined with imagery and the study of the next outbreak, will aid in the study of the spread of the budworm, reasons for its location, and perhaps point to more effective correction/control of the problem. If future outbreaks can be controlled or contained the value to the B.C. Forest industry could be in the millions of dollars: The remote sensing imagery acquired in the series of project for Dr. Harris and Mr. Finnis is a first but important step in the solution of the problem.

PROJECT: 72-46, 47, 55, 105, 106
73-53, 55, 57, 185
74-43, 44, 107
75-94

USER: Dr. J.W.E. Harris
Pacific Forest Research Centre
506 West Burnside Road
Victoria, British Columbia. V8Z 1M5
604-388-3811

LOCATION: Various in British Columbia

OBJECTIVE: To evaluate the usefulness of small scale aerial photography for assessing forestry insect infestations. (The original work was in support of Landsat studies -- then the Principal Investigator discovered that the small scale data was itself useful.)

RESULT: A number of significant research findings and reports resulted. For example, it was found that for counting bark beetle damaged trees, one requires larger scale imagery, while for delineating beetle damage and defoliation, smaller scale imagery can be used. As a direct result of these projects airborne imagery was requested by the British Columbia Forest Service (see 76-56 and 77-66) and used to plan western spruce budworm spray blocks and Douglas-fir tussock moth spraying near Kamloops in an operational mode. Colour imagery is required on this and other types.

COSTS:

Falcon -- Transit Hours 24.85	Cost	$38,150
Local Hours 13.3		
Consumables		2,272
Per Diem		2,077
TOTAL COST		$42,499
COST RECOVERY CHARGES		$ 4,490

DISCUSSION: This is an example of research which has been transferred to users based on close association between researchers and user programs. There have been no reports on relative value of remote sensing compared to other methods such as sketch mapping, although one will soon be available. The results from the remote sensing method are obviously so much better for certain applications that they have been adopted without cost analyses. Any benefit estimates are guesses.

BENEFITS: There have never been any benefit calculations or comparisons of data value. Dr. Harris has stated that with different pests there are a variety of requirements-- usually light aircraft/helicopters are used to sketch

areas of infestation on topographic maps. Generally, airborne remote sensing provides data at the same cost as these other methods, or perhaps at slightly higher cost -- however much more information is available. How much more information has never been calculated. They know it is enough more to warrant using the data for operational application. For example, the imagery has been used by Mr. Finnis of B.C. Forest Service on a "full cost recovery basis"...and they have used some private industry, supplied imagery for operational programs. (See 76-56 and 77-66.) The total research program can be said to have been a success in terms of savings and/or better data generated for agencies with an operational mandate. Total payoffs for this program could eventually be measured in terms of hundreds of thousands of dollars (See 76-56 and 77-66).)

PROJECTS: 72-21
73-173 and 192
74-58, 61, 62, 63, 72 and 80
75-9
77-28, 30, 31 and 32

USER: Dr. A. Mack, Head
Agrometeorology Section
Research Branch
Agriculture Canada
Ottawa, Ontario
K1A 0C5

613-995-9039

LOCATION: Various in western Canada

OBJECTIVE: To provide background information for the study of spring wheat inventory from Landsat imagery.

RESULT: The data have been used to augment and verify field data as a record of crops and their conditions over a long period of time in a variety of sites representing the agricultural regions of western Canada. Data are now acquired by industrial contractors.

COSTS:

Falcon/CF100	Total Hours 72.7	Cost	$72,700
	Transit Hours 43.5		
Consumables			6,386
Per Diem			4,807
		TOTAL COST	$83,893
		COST RECOVERY CHARGES	$13,136

BENEFITS: Full benefits are yet to be realized since the ultimate aim is the development of a satellite based crop information system. However, without the airborne sensing and the specific capabilities of colour infrared film for crop condition and type assessment, the research activities of CDA and their various contractors related to satellite crop information systems would have been severely handicapped. These data allowed verification/measurement of crop type and acreage for comparisons to results from satellite analyses. Field data collection for the period 1972-77 cost about $120,000. Without airborne remote sensing these would have cost two to three times as much to ensure absolute accuracy of field identification and area measurement.

These data are considered valuable enough that they are now being collected by commercial aerial survey firms at full commercial rates.

The data have provided a long time record for other research studies related to crop rotations, cropping practices, soil management, crop yield prediction (from satellite sensing and other methods), and related biophysical studies.

The data were also used in the USA for crop predictions by the Spring Wheat Project and LACIE.

A.4 GEOLOGY APPLICATIONS

PROJECT: 73-2

USER: Mr. T.K. Krishnan
Supervisor
Exploration and Development
Iron Ore Company of Canada
Box 1004
Schefferville, Quebec
G0G 2T0

418-585-9311

LOCATION: Schefferville, Quebec

OBJECTIVE: An interdisciplinary assessment of the mining districts in the Schefferville area.

RESULTS: The data were of excellent quality and contributed to exploration, mining activities and environmental studies in the area.

COSTS:

Falcon Total Hours	7.1	Cost	$7,100
Consumables			706
Per Diem			355
		TOTAL COST	$8,161
		COST RECOVERY CHARGES	$ 706

BENEFITS: The acquisition of the colour infrared data "was one of the best things to have happened in geological work in the area". "The imagery has proved to be useful not only in adding to our understanding of the Labrador Trough, but also in the day-to-day exploration and mining activity." The highest altitude data has provided "an excellent synoptic view of the area, unlike any imagery obtained before".

The primary economic value of the data was to avoid a lot of needless survey. Chronaflex 5X enlargements were prepared for $20 each. These eliminated "thousands of dollars of survey field work over the years". In addition, savings have resulted from using the data to plan equipment movement using the most efficient routes through the natural environments of the area.

The specific uses of the data for exploration and success achieved are considered to be proprietary. Some general statements can, however, be made. The imagery has proved to be the best source for showing the tectonic asymmetry of the Labrador Trough, and has been valuable in general structural and terrain analyses.

"One of the encouraging aspects seen on the mosaic is that the environmental damage caused by nearly a quarter of a century of mining activity in the area is less than what one would expect". The major problem is "in the immediate vicinity of the mines because of the waste dumps. Outside of the mine areas, where survey lines were bulldozed for clearance, there are encouraging signs of the vegetation recovering". These data can serve as a baseline for monitoring the environment in the future.

Although the analyses of the thermal data were not successful, a recent contact with McGill University will see more detailed analyses performed as part of the remote sensing program there.

Photographic IR data were also obtained over another holding of the Iron Ore Company of Canada through private industry. In both cases, these data are still being used on a regular basis in all phases of the mining/ exploration operation.

Although total benefits related to field work reduction, exploration success, equipment movement, and environmental monitoring can not be released, they are clearly substantial. Savings in survey and equipment movement alone are in excess of $100,000.

Much of the material in direct quotes comes from a report filed with CCRS by the user. (RAR)

A.5 HYDROLOGY

PROJECTS: 74-39 and 73-113

USER: W. F. G. Cardy, Director
Water Resources Branch
New Brunswick Department of
the Environment
P. O. Box 6000
Fredericton, New Brunswick
506-453-2353

LOCATION: St. John River near Fredericton

OBJECTIVE: To map the extent of flood at peak of flood and to record sediment sources.

RESULT: This is an example of fast CCRS reaction to an emergency situation. The imagery has served a variety of purposes: a rare display image of a one in 300 year flood at its peak; a stage-storage input into a volume survey (done with airborne data and LANDSAT data with CCRS Applications Division assistance); preparation of flood line maps; and location of sediment sources.

COSTS:

2.3 hours	$ 2,300.00
Consumables	100.00
	$ 2,400.00

COST RECOVERY CHARGES $325.00

DISCUSSION: The user noted (visual library) that short of "calling out several thousand surveyors at two days notice" no other methods existed to collect this significant data. Lower level aerial photography was collected one day later, but did not record the same information with the same ease of interpretation or accuracy. It was also after the peak and therefore of limited utility in comparison. The CCRS reaction was on twenty-four hours' notice.

In recent conversation (letter on file) the user noted that no other methods of instantaneous flood line map data collection were available. Field methods with surveyors could have cost $1 million but are only feasible in theory.

Similarly, for the volume survey, no other methods beyond remote sensing could have been considered because of cost: the total cost of this work (including all CCRS expenses and analysis equipment costs) was under $10,000. Alternate methods would cost much much more.

A third benefit area is the display use of the imagery to show the possible extent of flooding for those who wish to build on flood plains. Mr. Cardy commented to the effect that "one look at the picture was all many people need."

A fourth use of the image is for scientific study and the historical record of the peak of a one in 300 year flood. Without the quick response from CCRS the imagery could not have been obtained: low level imagery contracted for the flood season to industry was another day later.

The fifth benefit relates to the study of sediment sources and flow lines which relate to erosion and water quality research.

BENEFITS: For most of the uses noted above the savings associated with remote sensing compared to any other data source are so high that the user was unable to specify firm figures. Theoretical alternative methods such as large squads of surveyors would probably cost over a million dollars. Intangible benefits can be related to decision making: e.g. not to build, flood control, etc. The methods would apply elsewhere where flooding is a problem.

PROJECT: 77-99

USER: Mr. G. Lawrence
Ontario Centre for Remote Sensing
Ontario Ministry of Natural Resources
880 Bay Street
Toronto,Ontario
M5S 1Z8

416-965-8411

Mr. I. Deslauriers
Maitland Valley Conservation
Box 5
Wroxeter, Ontario

LOCATION: Lucknow, Ontario

OBJECTIVE: To detect ground water discharges through aerial thermography. (Paper of this title prepared by OCRS, Nov. 1978)

COSTS:

Falcon Hours Transit	0.7		
Local Hours	3.	Total Cost	$3,700.
Consumables			102.
		TOTAL COST	$3,802.
		COST RECOVERY CHARGES	$1,721.

RESULTS: Ground water discharges could be located to a high degree of accuracy through aerial thermography. Accuracy was even higher than that expected from field crews on the ground.

BENEFITS: Dollar benefits have not been calculated but the aerial thermography method is known to be much less costly and much more accurate and faster than alternative **field** survey methods.

Field work would involve walking all streams in the study area around Lucknow -- a total of over 110 miles. Aerial photography would be required as well as a truck, field expenses, property owner contact, etc. For an area of 12 x 25 miles there would be over 500 rural property owners to contact -- which alone would require 15-20 man days. Total expenses (including truck, expenses, salary, etc.) of $250 per day would be expected, for three or four months ... or $15-20,000. The result would not be

as accurate and certainly not produced as quickly as with remote sensing and ground checks. The cost of sensing methods including field checks and interpretation would be less than half the cost of field methods.

The major benefit is subsequent use of the inventory data which can be produced so quickly. The imagery provides a "hard copy" which shows many features related to zoning and water quality potential for wildlife management, water supply management, and other activities. The image derived inventory also indicates the relative value of streams for erosion control and upgrading when only a fixed amount of funding is available. These data and decisions based on them (such as land purchases for quality management) would not be as effective if derived in some other way.

SPIN-OFFS:

Surveys of several other sites have been contracted out at commercial rates for other similar studies.

A new one year program around Toronto is also related. Concerns about landfill sites for both normal and industrial wastes have heightened with the Love Canal incident in neighbouring New York State. A study of using IRLS to study leachates or potential discharges from landfill sites and possible sites is underway. This new application follows directly from the earlier study.

PROJECT: 75-64

USER: *W.E. Taylor
Saskatchewan Research Council
Saskatoon, Saskatchewan
S7N 0X1

306-664-5458

LOCATION: Saskatchewan

OBJECTIVE: To demonstrate the usefulness of remote sensing to Band Councils on three Indian Reserves and to provide the Band Councils with up-to-date coverage.

RESULTS: Sources of drinking water and commercial timber stands were identified on the imagery.

COSTS:

Total Hours	8.0	Cost	$8,000
Consumables			534
Per Diem			453
		TOTAL COST	$8,987
		COST RECOVERY CHARGES	$1,854

BENEFITS: The remotely sensed data provided useful baseline data for the reserves. (No such data existed prior to this image acquisition.)

Commercial timber areas were identified on the colour infrared photography. (This could have been done with conventional aerial photography at approximately double the scale -- and thus at higher cost.)

Good sources of water were found, at a saving of $40,000 over conventional methods.

*Mr. Taylor was Saskatchewan's principal contact with the Canada Centre for Remote Sensing's Airborne Operations. Although listed as "user" others were invariably involved in the projects as well.

PROJECTS: 75-67 and 85

USER: *W.E. Taylor
Saskatchewan Research Council
Saskatoon, Saskatchewan
S7N 0X1

306-664-5458

LOCATION: Regina (75-67 and Bruno (75-85), Saskatchewan

OBJECTIVE: To locate a single reliable water source (acquifer) for Regina and Bruno as a replacement for several small water well fields.

RESULTS: Water sources and problems with existing potential water sources were pinpointed using the colour infrared imagery.

COSTS:

Falcon	Total Hours	11.4	Cost	$11,400
	Transit Hours	10		
	Consumables			391
	Per Diem			670
			TOTAL COST	$12,461
			COST RECOVERY CHARGES	865

BENEFITS: There was a great reduction in field work to locate the aquifer of higher quality water in the Bruno area. These acquifers may only be two hundred feet wide (one side of a square acre) -- the density of auger holes to locate such small features would be very high. (Five dollars per foot, up to 100 feet per hole). Even at one hole per square mile, cost for the 195 square miles covered by the images in the two areas would exceed $100,000. Even with this density there is no guarantee of success.

Conventional aerial photography was not found to be useful in the search for these acquifers.

*Mr. Taylor was Saskatchewan's principal contact with the Canada Centre for Remote Sensing's Airborne Operations. Although listed as "user", others were invariably involved in the projects as well.

PROJECTS: 74-13 and 33; 75-65

USER: W.E. Taylor
Saskatchewan Research Council
Saskatoon, Saskatchewan
S7N 0X1

306-664-5458

LOCATION: Qu'Appelle Valley, Saskatchewan

OBJECTIVE: To prepare lay- oriented guides (called GEOLOG) for various areas in Saskatchewan.

RESULTS: The lay- guides are more easily understood and provide better information as a result of the remote sensing data. There have also been spin-off projects.

COSTS:

Falcon	Total Hours 15.4	Cost	$15,400
	Transit Hours 14		
	Consumables		699
	Per Diem		997
		TOTAL COST	$17,096
		COST RECOVERY CHARGES	$ 1,711

BENEFITS: The area is of major interest from a geological and hydrological point of view. The field guides use data interpreted from the imagery and, for some maps, use the colour and colour infrared images as a map base.

The imagery was incorporated into a number of other projects which had a need for environmental data which could not be supplied by the multi-temporal conventional aerial photography available for the province. The significant benefits from these other projects are still continuing, while new uses are also being found. The imagery serves as a data base which may be consulted as the need arises by a variety of users. To date it has been used to study landslides, hydrological problems and other phenomena. It is especially useful in the densely populated resort area for environmental monitoring. Studies related to the fish hatchery have also

*Mr. Taylor was Saskatchewan's principal contact with the Canada Centre for Remote Sensing's Airborne Operations. Although listed as "user" others were invariably involved in the projects as well.

used it. Other new studies using the data include ground water studies for this fish hatchery (with savings similar to those quoted for projects 75-76 and 85), discharging of waste water from the hatchery, and road relocation to avoid springs and related road damage.

Landslides are very relevant as near-surface water movement is the key to landslides in the area and IR does the job in delineating problems.

Spin off benefits may total over $100,000.

A.6 WATER QUALITY

PROJECT: 72-125

USER: Dr. W. Harrison
University of Toronto
(Now Argonne Laboratory, see correspondence)

Additional Contacts: Mr. M. Fingas and C. Ross
Environmental Emergency Branch
Fisheries and Environment Canada
997-3921

LOCATION: Flown in St. Lawrence Estuary

OBJECTIVE: To assist in the development of a model of oil slick spreading and development.

RESULT: Excellent imagery was obtained. According to the user the required information "could not be obtained by any other method." (See file: CBS 72-125). Again, according to the user, these data were also "useful" for "an environmental impact assessment for a proposed super tanker port at Riviere-du-Loup". Mr. Fingus and Mr. Ross stated that the port concept was withdrawn for economic reasons before the impact assessment and that although the RS derived information at that time may have been useful for port planning for spill consideration, it is no longer useful because other methods developed for finding and tracking spills are more efficient. (See below for a discussion on the role of RS in the development of these new methods.)

Mr. Fingus and/or Mr. Ross noted (see correspondence on file CBS 72-125) that RS was used to:

1. Calibrate the spread portion of the spill model used in the "Environment Risk Index for the Siting of Deep Water Oil Ports" (DOFE, 1976) (Specifically Project 72-125).

2. Verify and calibrate that recently developed oil tracking buoys were in fact in oil. (The buoys trace the movement only: RS provides the "hard copy" of spread... although this information is not considered necessary.) (A 1976 project in the Bay of Fundy.)
3. RS was done around Montreal to assist in a clean-up operation.

4. Air photographs (usually black and white) are used for shoreline vulnerability studies to identify areas which should be looked at on the ground.

5. An air photo was used as evidence to prosecute a foreign ship in the St. Lawrence. (A DND colour image.)

COSTS:	DC-3 aircraft	16 hours	$ 11,200.00
	Falcon aircraft	5 hours	5,000.00
	Consumables (estimate)		600.00
			$ 16,800.00

TOTAL COST -- $16,800.00

DISCUSSION: Although one can easily quantify the costs of remote sensing, the value of remote sensing to oil spill research and monitoring is more difficult to estimate. The oil spill specialists are often hard pressed to calculate the costs involved in a clean-up -- most of these do not calculate out of pocket expences, according to Mr. Fingus. Clean up costs spent by the Federal Government alone for just five of the major spills in 1973 totalled over $1,000,000 (in 1978$). One spill cost over $750,000 (in 1978$). Between 1974 and 1976 there were 3,445 oil spills (on both land and water) in Canada (Spill Technology Newsletter Vol. 3, No. 1, 1978).

BENEFITS: This project made a significant contribution to the important area of oil spill monitoring in Canada. Although the dollar value of the contribution cannot be specified by the users, they do agree that the benefits are substantially larger than the costs.

PROJECTS: 75-22, 76-36, 76-37 and 77-54

USER:
D.I. Ross
Water Resources Branch
Great Lakes Surveys Unit
Ontario Ministry of the Environment
c/o 135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

Telephone: 614-965-9657

LOCATION
75-22 -- Douglas Point (Lake Huron), Ontario
76-36 -- Kettle Point to Sauble Beach (Lake Huron), Ontario
76-37 -- Pickering-Toronto Harbour (Lake Ontario), Ontario
77-54 -- Bruce Nuclear Power Development Site (Lake Huron), Ontario

OBJECTIVE:

75-22, 76-37 and 77-54:

1. To establish the capabilities of thermal infrared scanning and its application in thermal plume analysis.

2. To evaluate thermal infrared scanning techniques as an alternative to in-situ physical measurements (Page 4, Ross et al, 1976).

76-36: To establish the contributions of three rivers (Ausable, Maitland and Saugeen) to the nearshore turbidity of Lake Huron.

RESULTS: The data obtained have been useful in the research done by the group and have proved valuable enough that eight additional missions have been flown for this agency by a commercial company. In the case of Project 76-36 it was found that the effects of rivers were negligible and that littoral processes such as wave action, sediment resuspension and bluff erosion were more important in the generating near-shore turbidity.

COSTS: (1978$)

DC-3	Transit Hours	28.95	Cost $31,780
	Local Hours	16.45	
Consumables			3,121
Per Diem			1.464
		TOTAL COST	$36,365
		COST RECOVERY CHARGES	$10,336

TOTAL COST BY PROJECT

77-22 -- $ 5,823
76-36 -- 15,508
76-37 5,256
77-54 9,778

BENEFITS: The benefits are primarily associated with data collection cost: "Airborne thermal infrared scanning has many advantages over in-situ techniques in measuring the horizontal extent of waste heat plumes. The most important of these advantages are cost and the ability to define temperature distribution within the entire plume instantaneously."

The thermal infrared scanning can readily provide information on the behaviour of thermal plumes under a variety of discharge and environmental conditions and therefore be of assistance in designing in-situ sampling programs for the investigation of waste heat impact on the biota and utility compliance with receiving water quality objectives and guidelines..." (provided by the IJC and Ontario Ministry of the Environment) (Page 21, Ross et al, 1976)

An in-situ system that would provide synoptic thermal plume data was estimated to cost about $150,000 for hardware alone and would require a considerable budget for a highly technical staff, general operating costs and transportation from site to site. A part of the operating costs would be associated with thermal data collection, while others are associated with more complex chemical measures possible with an in-situ data collection system but not with remote sensing. In any case, the in-situ device was not procured, but more airborne data collection by a commercial operator was.

Although remote sensing for thermal plume analysis is not yet fully operational, useful data has been collected. More is known about thermal plumes than before. A non-permitted waste heat discharge at one site was found during construction. Current work focuses on using digital IRLS data for waste heat dispersion models. Recent winter data acquisition off the Pickering A.N.G.S. on Lake Ontario was used to initiate a large scale field investigation of winter thermal plume behaviour. Finally, they can plan in-situ measurement stations with more confidence and with more optimum station density than before. Time saved in acquiring in-situ measures is important since they are acquiring data about a dynamic feature and must therefore collect data as fast as possible. In addition, the data collection by ship can run into several hundreds of dollars per day.

It is expected by the user that "the hard dollar benefits will become more apparent from this work within the next few years". This will occur as their development progresses to a fully operational stage from its present status as support to water quality surveillance and waste dispersion modelling. It is anticipated that airborne remote sensing will play an increasing role related to recent changes in water quality management under the 1978 Great Lakes Water Quality Agreement and revised Ministry of the Environment water management objection. Benefits achieved to date far exceed the costs, and the benefits will likely grow in the future.

Although not related to these specific projects, a major beneficial use of remote sensing by this agency is the use of archived imagery for a variety of purposes.

REPORTS:

D.I. Ross, R.M. Chaterjee, and N.D. Herzog "Evaluation of Airborne Thermal Infrared Mapping of Cooling Water Discharges from Generating Stations", Water Resources Branch, Ontario, MInistry of the Environment, Toronto, November, 1976.

Ontario Centre for Remote Sensing, "Nearshore Turbidity Study Eastern Coast of Lake Huron", May 1977.

... Metropolitan Toronto Waterfront Study, May 1977.

D.I. Ross, and J.D. Kinkead, "Selected Aspects of Operational Thermal IR Remote Sensing of Effluents from Generating Station", Presentation at the 19th Conf. on Grt. Lks. Res., Internat. Assoc. Great Lakes Res., University of Guelph, Guelph, Ontario, May 4-6, 1976.

PROJECT: 74-55

USER: T.T. Alfoldi
Canada Centre for Remote Sensing
Energy, Mines and Resources
Ottawa, Ontario
K1A 0Y7
613-995-1210

Work done for: Mr. C.G. Benckhuysen
Marine Equipment Division
Public Works
Sir Charles Tupper Building
Ottawa, Ontario
K1A 0M2 613-998-8171

LOCATION: Lake St. Clair, Southern Ontario

OBJECTIVE: As part of the work for the Working Group on Abatement and Control of Pollution from Dredging Activities in the Great Lakes (reporting to the IJC) -- "to determine whether present conditions indicate greater turbidity from ship traffic or from dredging".
(See discussion of benefits below.)

RESULTS: In a report to the Working Group it was stated that "turbidity plumes of any concentration could be traced up to 594 meters downstream of the dredge ... (and) ... up to 2000 meters downstream of a ship".

COSTS:

DC-3	Total Hours	8.5	Cost $5950
	Transit Hours	6	
	Consumables		1090
	Per Diem		595
		TOTAL COST	$7635
		COST RECOVERY CHARGES	$1200

BENEFITS: The report prepared was used along with others in the five year review of the agreement between Canada and the United States.

Its major use insofar as decision making was to prove that dredging would not be as environmentally harmful as allowing the ships passing through the channel to continue their own "dredging" by the action of their propellers. There was some concern about which was most

harmful since the smallest particles are moved and it is this particle size which is related to the large quantities of mercury found in Lake St. Clair.

Although no quantitative benefits can be associated with the subsequent reduction in mercury in suspension, any reduction of it in the source of drinking water in the Detroit-Windsor area clearly far exceeds that cost of the remote sensing and dredging - given previous experience with mercury pollution elsewhere.

Given the temporal and spatial nature of the plumes being studied, no other practical methods exist for monitoring. The only alternative would be to have many boats taking samples for subsequent laboratory analysis or measurements with expensive transmissometers. The cost would be at least five times greater than the total remote sensing cost with much less precision and without the indisputable record of the difference in the effects of the ships compared to the dredges.

REPORT: Alfoldi, T.T. Remote Sensing of Turbidity Phenonena in Lake St. Clair, November 1974, CCRS, EMR, Ottawa.

PROJECTS: 72-110
73-207 and 208

USER: Mrs. I Wile
Ontario Ministry of Environment
P.O. Box 213
Rexdale, Ontario
M9W 5L1

416-248-3058

LOCATIONS: Kawartha Lakes (72-110)
Chemung Lake (73-208)
St. Lawrence River (73-207)
All in Ontario

OBJECTIVES:

1. To determine extent of Aquatic plant cover in the Kawartha Lakes. (72-110)

2. To map plant densities and if possible plant densities in Chemung Lake. (73-208)

3. To carry out a preliminary investigation of the use of remote sensing for the delineation of aquatic vegetation species and growth areas in a river environment.

COSTS:

72-110 Kawartha Lakes

DC3 Hours Transit	9.3		
Local Hours	5.2	Total Cost	$10,150
Consumables			387
		TOTAL COST	$10,537
	COST RECOVERY CHARGES		387

73-208 Chemung Lake

DC3 Total Hours	5.3	Total Cost	$ 3,710
Consumables			227
		TOTAL COST	$ 3,937
	COST RECOVERY CHARGES		NIL

72-207 St. Lawrence River

DC3 Total Hours	2	Total Cost	$ 1,400
Consumables			177
		TOTAL COST	$ 1,577
	COST RECOVERY CHARGES		177

RESULTS: Project 72-110 and 72-207 resulted in maps of acquatic vegetation in the recreation area covered and of concern to the ministry. Project 73-208

was not used beyond a cursory study since it was found that species could not be mapped without extensive ground data collection.

BENEFITS:

Remote sensing was "the only practical way with so much territory" to meet the immediate need for data on aquatic plant cover and density. The maps of aquatic vegetation were used for planning the management of these high recreational use lakes which were becoming weed infested. (Project 72-110).

Data from Project 73-208 was not used since the remote sensing data could not meet the objectives of the study. It has been concluded as a result of these studies that the simpler photographic remote sensing is very useful and cost effective only if general distributions of aquatic vegetation are required. Furthermore, the imagery provides a permanent record. The cost of data collection on the ground for the area covered in 72-110 would have been 24,000 (1978$)[1] based on an estimate of 150 man/days (50 days for a 3 man crew -- 1 crew chief plus 2 students.

Where specie composition and density of the vegetation are needed so much ground data is required to assist in interpretation that it is less expensive to expand the field data collection and sample. In such cases supplementary remote sensing can serve, however, as a useful permanent record.

Data from Project 73-207 was used in a manner similar to that of 72-110, with similar results.

SPIN-OFFS:

Operation Skywatch in Ontario (described by R. Johnson, 6th Canadian Symposium on Remote Sensing) has been used for obtaining remotely sensed data (obliques) over Presqu'ile Provincial Park for other work by the user.

PUBLICATIONS:

Wile, I. 1973 Use of Remote Sensing for Mapping of aquatic vegetation in the Kawartha Lakes. A.W.R.A Conf. Remote Sensing and Water Resource Management. Proc. No. 17, 331-336.

[1] This cost averages out to $160 per man day -- a lower value than in some other projects for field work, but two-thirds of the manpower was student labour. (RAR)

PROJECTS: 73-217 and 73-126

USER: Dr. D.J. Wildish
Biological Station
Dept. of Fisheries and Oceans
St. Andrews, New Brunswick
E0G 2X0

506-529-8854

LOCATION: Bay of Fundy, New Brunswick Shore

OBJECTIVE: To trace organic pollutants in the Bay of Fundy over a period long enough to identify tidal effects.

COST:

DC3	Hours Transit	5.4*		
	Local Hours	.6	Total Cost	$4,200.
Consumables				257.
Per Diem*				295.
			TOTAL COST	$4,752.
			COST RECOVERY CHARGES	$ 101.

* Shared With Other Projects

RESULTS: Most of the times set up with the aircraft and boat together were wiped out by cloud. As a result, the work as planned was not completed and results were never published. There were several useful findings which are discussed below under benefits.

COMMENT: This is a typical experiment of the type which "did not work" or for which "perfect data were not collected". There were still useful lessons learned which have since been applied in either the same area or by the same agency. (RAR)

BENEFITS: There were three specific benefits -- one direct and two indirect. The benefits of the projects out-weigh their costs when viewed from today's perspective.

1. The colour aerial photographs provide an overview and spatial perspective one simply cannot get at such low cost from a boat. This overview allows for better planning of the very expensive ship cruises and sampling, thus substantially reducing costs. This approach could be developed quite easily for resource mapping where there are opportunities to obtain airborne sensing on short notice (because of weather problems).

2. Higher level smaller scaled imagery is recommended in future for tracing natural sediment at low cost and for learning more about the system under study. (The scale here was 1:22,000.)

3. In the Musquash Estuary circulation patterns were clearly visible. These are useful for development of management models of coastal resources. The spatial data is of particular interest in the estuaries since the freshwater flow is being increasingly used by the City of St. John which draws its supplies from the Musquash catchment. As the City's water use grows, the area is moving from an estuarine marsh with outflows of fresh water to a tidal inlet. The remote sensing data yields information which can help predict the nature of changes and particularly the dispersion characteristics of the Musquash estuary.

FOLLOW-ON: As a result of discussions concerning the benefits of these projects, Dr. Wildish has been put in touch with the N.B. Remote Sensing Committee, one member of which may gain from Dr. Wildish's experience, while another may be able to provide assistance in the form of imagery.

A.7 ENERGY CONSERVATION

PROJECT: 74-135 and 75-115

USER: W.M. Graham
Technical Services, Correctional Service of Canada
340 Laurier Avenue West
Ottawa, Ontario
K1A 0P9
613-593-4637

LOCATION: Cowansville Institution, Cowansville, Quebec

OBJECTIVE: To evaluate remote sensing for detection of heat loss in underground distribution piping from an oil-fired central heating plant. (350°F hot water system)

RESULT: From the imagery three bad areas of heat loss were found and it was decided that the heating pipe system was "shot and not worthy of repair". It was replaced. This was one of the first heat loss projects flown by CCRS.

COSTS:

DC-3	Transit and Local Hours	9.3 Cost	6,510
	Consumables		128
		TOTAL COST	6,638
		COST RECOVERY CHARGES	175

DISCUSSION: The concern with energy costs began when a monitoring of water consumption showed over 1,000 gallons of water (heated and specially treated) were being lost per day. Total heat loss from the water lost was about 3,000,000 B.T.U.'s per day. Normally one expects a loss of a few gallons per day.

Normally the pipe breaks inside the conduit, steam follows the conduit to a man hole, and is then released...no method exists to precisely locate the break in the pipe. The typical approach is to dig up the conduits to inspect the pipe and then replace damaged sections.

When the pipe is dug up there is a chance of further damage. In this case, the pipe went from the heating plant 600 to 700 feet outside the prison walls across open terrain, under a fence, perimeter road, and into the prison's secure structures. Three bad areas of heat loss were found, although interpretation was complicated by bare ground, a variety of cover types, etc. As noted above it was decided to replace the pipe by an above ground system which went underground only at fences and roadways.

BENEFITS: It was decided not to replace portions of the conduit system, nor was it necessary to dig more than a few exploratory holes. (It was assumed that the pipe was in such poor condition that a replacement was necessary to correct all of the problem areas visible.) The operating savings associated with reconstruction

compared to patching are in part attributable to the remote sensing data. Total value would in the the thousands of dollars.

The loss of heated water was stopped...at a saving of 3,000,000 B.T.U.'s per day. Assuming an energy cost of $6.20 per 1,000,000 B.T.U.'s (Source: Enersave Division, Energy Conservation, EMR) over only the heating season (of 200 days) the saving per year is $3,720. Not counting water treatment costs, or construction savings, the total cost was returned in two years of operating funds.

The saving in energy produced from off-shore oil has significance under present and future world energy conditions.

PROJECT: 77-91

USER: Mr. W. Barchard
B.C. Hydro and Power Authority
8th Floor, 1045 Howe Street
Vancouver, B.C.
V6Z 2B1

604-663-3273

LOCATION: Vancouver, British Columbia

OBJECTIVE: To use aerial thermography in residential and commercial energy conservation programs.

RESULT: The largest thermographic energy awareness program ever undertaken anywhere resulted from the use of this project's imagery. The imagery covered 168,000 residences and 20,000 commercial buildings. Of the latter, 3000-5000 have been studied and $15-20 million of roof damage indentified. Follow-on contracts by B.C. Hydro for over 2500 line miles of thermal data have resulted.

COST

Falcon Total Hours		7.1 Cost	$7,100
Hours Transit*			
Consumables			1,460
Per Diem			382
		TOTAL COST	$8,942
	COST RECOVERY CHARGES		$7,297

* Transit Costs Shared
** 1978$

BENEFITS: As noted above, $15 to $20 million worth of roof damage was identified in commercial structures alone. The decision to repair and consequent energy savings, were sparked by this program. Improper use of exhaust fans alone resulted in a $300,000 expenditure per year (1977 energy prices) in one school district alone. Many major building owners actively participated in the program -- including Eatons, Woodwards McDonalds, C.P. Rail, Standard Oil, a number of major apartment complexes and the Bank of Montreal. (The Bank of Montreal is using thermographs in an energy conservation loan display promotion from 1980 flight data acquired by industry.)

Educational institutions have been a special focus of interest. Most school boards have been active -- 115 schools in one board alone. Of seventeen large secondary schools, sixteen were found to have serious roof damage -- over $100,000 each. At Simon Fraser University it was found from the 1977 flight that there were 50 fans operating twenty four hours per day. Correcting this problem, reducing lighting, monitoring thermostats, and other energy saving measures has saved fuel of over $168,000 in one year.

The focus for the residential awareness program has been the shopping mall display in high traffic (125,000-150,000 people per week) malls. Staff are on hand to assist in interpretation, answer questions about insulation and to operate a computer terminal that shows cost vs savings for insulating homes. The major goal of the program is to reach people, make them think about energy conservation and make them "look in the attic". So far over 170,000 people in Vancouver alone have visited the displays. (In a CCRS write-up on one such display it was noted that the displays were laid out to obtain high volume traffic without disrupting the shoppers. Over one evening there were between 40 and 70 people at the display at any given time. Even during the supper hours there were no fewer than 15 in attendance. RAR)

To date the 1977 data have been used in seven public showings (one to two weeks or more each), 20 follow-on displays of two weeks in local libraries and a two year display in the main foyer of B.C. Hydro's Head Office. Even now B.C. Hydro receives calls every day about the thermograms ... which are now tattered with use. Some recent studies indicate that insulation has been increased with the advent of the program. The degree of impact of this one program cannot, however, be isolated from other activities in the field.

After the success of the 1977 flights, an additional 530 line miles were flown by industry in 13 cities in 1978 for (primarily) identifying commercial building energy loss. 1979 contracts were, for the most part, not completed. 1980 contracts call for 2000 line miles over 35 centres. A major problem recently has been turnaround times for data production since such large areas are being flown and available equipment is both old and geared to much less data. The energy awareness loses some "punch" with delays of up to six months in obtaining data.

Additional CCRS flights over small areas for research purposes are being considered. In addition to the follow-on projects being done, advice has been given to a number of others in the energy conservation field in Canada and abroad (Europe, U.S., and Australia).

To date capital construction/repair costs in excess of $20 million have been spurred by the one project, although exactly how much energy has been saved as a result of this one program is open to speculation.

PROJECT: 75-92

USER: Mr. F.W. Carson
Superintendent, Service Operations
McMaster University
Hamilton, Ontario
L8S 4M3

416-525-9140

LOCATION: McMaster University

OBJECTIVE: To detect heat loss at the university.

COSTS:

DC3 Hours 5.3	Total Cost	$3,710.
Consumables		654.
	TOTAL COST	$4,364.
	COST RECOVERY CHARGES	693.

RESULTS: Visual analysis of imagery showed heat line breaks.

BENEFITS: There were direct actual benefits from the data. The major heat loss found was in an eight inch high pressure steam pipe which was built during a period of University growth. The pipe was built oversize to "accommodate future expected growth in that part of the campus". The study of line scanner data resulted in a "re-examination of the whole line". Rather than dig-up and repair the line, they "decided to replace it with a shorter line at a cost of "$30,000". The expected payback of this cost with present energy prices will be five years -- or less as energy prices increase. The capital construction cost was almost seven times the cost of the sensing -- and the savings would likely not have been realized without the scanner data.

In summary the user has called the data "a very valuable tool in their energy conservation program". (That McMaster has cut fuel oil from four million to three million gallons per annum is an indication of their concern and activity in this area. RAR)

SPIN-OFF:

During the contact for this benefit analysis Mr. Carson expressed an interest in now doing more flights and technical assistance. (He sees these as a "fishing expedition" to see if the data will make them think about any additional problems in buildings or rationalizations of various lines. Since McMaster University is a provincial agency I referred him to OCRS. RAR)

PROJECT: 75-113

USER: Mr. J.H. Flowerdew, Head
Engineering Department
University of Guelph
Guelph, Ontario
N1G 2W1

519-824-4120

LOCATION: University of Guelph

OBJECTIVE: Heat loss investigation of university premises.

COSTS:

DC3 Hours Transit	4.9		
Local Hours	.4	Total Cost	$3,710.
Consumables			418.
		TOTAL COST	$4,128.
		COST RECOVERY CHARGES	$ 462.

RESULTS: The data were of use, but not what was expected since they had "unrealistically high expectations". When it was realized that results would not be spectacular, and as experience was gained, they were able to identify the best and worst roofs -- and those "in-between".

BENEFITS: The data and assistance they received were beneficial in that they were able to identify which roofs should have priority in their investigations (given their limited budgets) and repair, and which roofs were functioning relatively well. They also benefited from the "reassurance that certain roofs were very efficient". Although "very hard to put a dollar value on benefits--(they were) above the cost of $4,000".

SPIN-OFFS: Additional work is being considered.

COMMENTS: The following comment is quoted directly from a letter from J.H. Flowerdew to R.A. Ryerson 28,8,80. "In ignorance we expected the data to instantly, effortlessly and unequivocally pinpoint the number, location and types of significant heat-loss problems that our Campus was expected to exhibit, in reality of course it is more a question of identification and on-site investigation of areas that the data indicated were problem areas.

Using this information we were able to establish a repair priority list which we have systemmatically resolved during the past four years. The data also provided valuable information on building environment systems, exhaust systems, our extensive tunnel network, even parking lot lighting.

A large number of people were involved in reviewing the initial data, the Physical Resources Dept. (mainly Engineering and Maintenance), the Energy Conservation Committee, a faculty member and a graduate student who specialize in I-R photography, and Garth Lawrence provided valuable assistance. The fact that the data gave us a clearer idea of what we should be doing, where we should be doing it and in what order of priority is a major benefit, there were others such as the cost avoidance of committing maintenance staff to time-consuming investigations on a large scale, and the non-purchase of certain devices that we were contemplating at one time -- this is certainly worth much more than $4,000, and of course, the data continues to provide assistance for current and future problems."

PROJECTS: 75-133
76-84, 85, and 93
77-6

USER: Mr. G. Lawrence
Ontario Centre for Remote Sensing (OCRS)
Ontario Ministry of Natural Resources
880 Bay Street, 3rd Floor
Toronto, Ontario
M5S 1Z8

416-965-8411

LOCATION: Various locations in Ontario (Lindsay,Stratford and others)

OBJECTIVES:

1. To evaluate heat loss and roof damage for industrial establishments in Cobourg and Exeter (77-6).

2. To evaluate the effect of air temperature on the building heat loss-related information content of aerial thermograms. (76-84)

3. To obtain aerial thermography for use in public awareness programs on energy conservation. (75-133 and others).

COMMENT: All of the thermography projects are treated as one under the same general benefit analysis. For this reason all costs are grouped for all projects.

COSTS:

Falcon	Hours Transit	2.5		
	Local Hours	4.9	Total Cost	$7,400.
DC3	Hours Transit	20.3		
	Local Hours	10.2	Total Cost	21,350.
Consumables				2,608.
Per Diem				610.
			TOTAL COST	$31,968.
			COST RECOVERY CHARGES	$12,238.

COMMENT: There is a larger than normal difference between total cost and cost recovery charges because of the amount of work done before CCRS began charging closer to full cost recovery.

RESULTS: Projects in the heat loss area were a success, although in some cases imagery was not useful. Specific guidelines for using thermal data for

heat loss studies were developed by the user (with some inputs from CCRS). The first major energy conservation awareness use of remotely sensed data in Canada resulted directly from the work of the user. This work has been widely cited in the literature on the subject and has been presented at a number of national and international symposia on heat loss. The Ontario Ministry of Energy was the primary "end user".

BENEFITS:

The work on heat loss could not have been done for such a low unit cost using any of the available ground systems. (At $100 per house using ground methods the savings are in the order of 10 or 20:1.

The major benefit of the whole package, including shopping centre clinics using the thermograms, is in energy conservation awareness. Many people are reached in a short time (during the heating season) at low per unit costs. Follow-up studies by the Ontario Ministry of Energy show that the savings or benefits were already 4:1 in one city only one heating season after the awareness program. Charged against costs were all staff, development work, remote sensing acquisition, etc. Future savings will not have to absorb the start-up costs and should result in larger benefit-cost ratios.

SPIN-OFFS:

Since 1977 OCRS has contracted much of their thermal and other data acquisition to industry. At the same time they have developed their own camera system.

A major indication of the value Ontario has placed on this and other thermal work is that under tight budgetary controls they have justified the purchase of a dual channel infrared line scanner similar to that operated by CCRS. The total system cost is in the order of one-half million dollars.

A second indication of the data's value is a five year, $4 million (1979$) program on heat loss to cover sixty major towns and cities. At the conservative 4:1 ratio (using older energy prices), this program will result in benefits in several years of at least sixteen million dollars -- likely far more. The program will use OCRS equipment, but will be managed in a user department.

COMMENT: These projects have shown substantial benefits in the use of airborne remote sensing by a provincial remote sensing centre. Although CCRS provided the original data, research and development support, and a certain impetus, the major share of benefits now being realized must clearly be attributed to the innovative use of the technology by OCRS. (RAR)

Subject Index: Appendix A

Appendix A in this publication has been indexed alphabetically by major Keywords used in the CCRS RESORS system (Agriculture, Civil Engineering, Water Resources, etc.). Each major Keyword has associated with it a number of sub-Keywords to permit easy access to the breadth and depth of information available in this report.

APPENDIX B

Firms Supplying Airborne Remote Sensing Data Acquisition[1]

A. Members of the Canadian Association of Aerial Surveyors[2]

(1) Aero Photo Inc.
1975 Charest Blvd. West
Quebec City, P.Q.
G1N 2E6
Telephone: 418-683-2231
Telex: 051-31523

(2) Burnett Resource Syrveys Ltd.
2873 Lake City Way
Burnaby, British Columbia
V5A 3A1
Telephone: 604-420-2600
Telex: 04-354648
207-14th st. N.W.
Calgary, Alberta
T2N 1Z6
Telephone: 403-283-0731
Telex: 03-824774

(3) Capital Air Surveys Limited
Pembroke and Area Municipal Airport
R.R. No. 6
Pembroke, Ontario
K8A 6W7
Telephone: 613-687-5586
Telex: 053-34541

(4) Kenting Earth Sciences Limited
380 Hunt Club Road
Ottawa, Ontario
K1G 3N3
Telephone: 613-521-1630
Telex: 053-4173
7070-B Farrell Road, S.E.
Calgary, Alberta
T2H 0T2
Telephone: 403-252-3346
Telex: 038-24712

(5) Northway Gestalt Corporation Limited
1450 O'Connor Drive
Toronto, Ontario
M4B 2V2
Telephone: 416-755-1141
Telex: 06-963518

(6) North West Survey Corp. (Yukon) Ltd.
J.C. Millman Building
17203-103rd Ave.
Edmonton, Alberta
T5S 1J4
Telephone: 403-483-8033
Telex: 037-3039

(7) Photosur Inc.
1130 Sherbrooke St. West
Montreal, Quebec
H3A 2R5
Telephone: 514-288-1370
Telex: 055-61257

(8) Intergrated Resources Photography Ltd.
P.O. Box 2278
Vancouver, B.C.
V6B 3W5
Telephone: 604-681-3505

(9) Terra Surveys Limited
2060 Walkley Road
Ottawa, Ontario
K19 3P5
Telephone: 613-731-9571
Telex: 053-3502

(10) Airquest Surveys Limited
1540 Gamble Place
Winnipeg, Manitoba
R3T 1N6
Telephone: 204-284-3101
Telex: 07-587517

[1]Most of these firms operate in both Canada and abroad

[2]All information provided by D.W. McLarty, President, Canadian Association of Aerial Survryors, March 31,1981.

B. Others contracted by the Federal Government[1]

Intertech Remote Sensing Ltd.
Head Office
2841 Riverside Drive
Suite 202
Ottawa, Ontario
K1V 8N4
Telephone: 613-521-5180
Telex: 053-4307
and at
406, 7015 McLeod Trail
Calgary, Alberta
T2H 1X9
Telephone: 403-253-8895
Telex: 03-824537

Prairie Agri Photo Ltd.
Box 817
Carman, Manitoba
R9G 0J0
Telephone: 204-745-2479

International Range Remote Sensing Ltd.
1355 Nanaimo St.
Kamloops, B.C.
V2B 2W2
Telephone: 604-376-8684

[1]These firms have been contracted by either CCRS or Agriculture Canada.