Ecological Land Classification Series

ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION IN CANADA

CLASSIFICATION ÉCOLOGIQUE (BIOPHYSIQUE) DU TERRITOIRE AU CANADA

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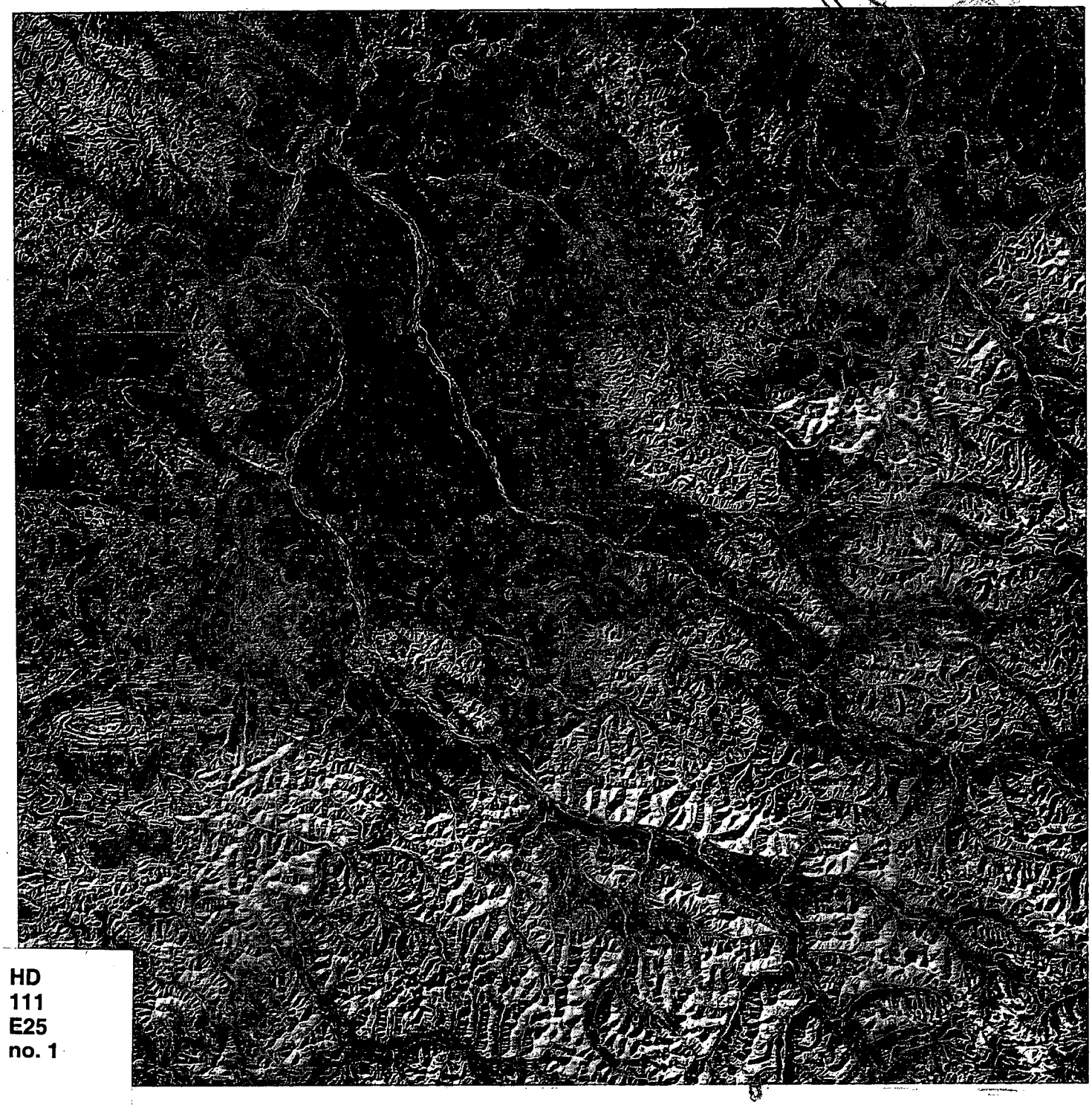

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Série de la classification écologique du territoire, numéro 1

ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION IN CANADA

Proceedings of the first meeting

CANADA COMMITTEE ON ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION

25-28 May, 1976
Petawawa, Ontario

CLASSIFICATION ÉCOLOGIQUE (BIOPHYSIQUE) DU TERRITOIRE AU CANADA

Comptes rendus de la première réunion

COMITÉ CANADIEN DE LA CLASSIFICATION ÉCOLOGIQUE DU TERRITOIRE

25-28 mai, 1976
Petawawa, Ontario

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PREFACE

During its life span (1966-1972), the National Committee on Forest Land (NCFL) provided effective guidance to the Canada Land Inventory Program, and it served as a forum for the discussion and introduction of new trends in integrated environmental management and integrated survey techniques. Under the auspices of this committee, the biophysical land classification system and a wetland classification were developed for Canada by sub-committees chaired respectively by Dr. D.S. Lacate and Mr. S.C. Zoltai.

The growing number of biophysical-type surveys and research carried out for resource management, planning and environmental purposes by provincial, private and federal agencies clearly required a technical coordination committee, similar to the Canada Soil Survey Committee. Recommendations were made to this extent at workshops in Toronto and Winnipeg, attended by representatives from federal or provincial governments, universities and private individuals working on or managing environmental surveys.

A small *ad hoc* committee (representing the Lands Directorate (DOE), Soil Research Institute (CDA), Terrain Sciences (EMR), and the Water, Lands, Forest and Environment Branch (DINA)) in cooperation with the provinces organized the meeting in which the Canada Committee on Ecological (Bio-physical) Land Classification was founded.

At this first meeting held in Petawawa (May 1976), the terms of reference, organization, membership, activities and working groups were decided. The essence of these is decribed in the *Summary of Business Sessions*. In addition, these proceedings give the papers that were presented discussing the present methodology and status of application of biophysical land classification in Canada.

Jean Thie
Chairman
Canada Committee on Ecological
(Bio-physical) Land Classification

PRÉFACE

Tout au long de son existence, le Comité national des terres forestières (CNTF) a été un guide précieux pour le Programme de l'inventaire des terres du Canada et a servi de tribune pour la discussion et l'introduction de nouveaux mouvements dans la gestion intégrée de l'environnement et les techniques intégrées de relevé. Sous les auspices de ce comité, deux sous-comités, présidés respectivement par Dr. D.S. Lacate et M. S.C. Zoltai, ont mis sur pied un système de classification biophysique des terres et une classification des terres humides du Canada.

Le nombre croissant de relevés et de recherches de nature biophysique entrepris pour répondre aux besoins de la gestion et de la planification des ressources et de la gestion de l'environnement par des organismes provinciaux, privés et fédéraux, commandait la création d'un comité technique de coordination, semblable au Comité de relevé du sol canadien. C'était d'ailleurs la teneur des recommandations qui ont été faites lors d'ateliers, à Toronto et Winnipeg, auxquels participaient des représentants des gouvernements fédéral et provinciaux, des universités et des particuliers effectuant ou dirigeant des relevés sur l'environnement.

C'est un petit comité spécial (représentant la Direction générale des terres du MDE, l'Institut de recherche sur les sols du ministère fédéral de l'Agriculture, les Sciences des sols, du ministère de l'Energie, des Mines et des Ressources, et la Direction des eaux, des terres, des forêts et de l'environnement du ministère des Affaires indiennes et du Nord) qui, de concert avec les provinces, a organisé la réunion qui a donné lieu à la création du Comité canadien de la classification écologique du territoire.

A cette première réunion, tenue à Petawawa en mai 1976, le mandat, la structure organisationnelle, la composition, les activités et les groupes de travail ont été déterminés. Ceux-ci sont décrits dan le *résumé des séances d'affaires*. Par ailleurs, ces comptes rendus présentent des documents portant sur la méthodologie actuelle et le statut d'application de la classification biophysique des terres au Canada.

Jean Thie
Président
Comité canadien de la classification
écologique du territoire

CONTENTS

Opening Remarks (Speech given at the Meeting in Petawawa) - R.J. McCormack..... v

Summary of Business Sessions..... ix

List of Participants..... xv

PRESENT STATUS OF ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION IN CANADA

Biophysical land classification in British Columbia: The philosophy, techniques and application - M.E. Walmsley..... 3

A summary of biophysical inventories, proposals and research needs for Saskatchewan - G. Roberts..... 27

Present status of biophysical activities in Manitoba - A.E. Borys..... 31

Research and surveys for biophysical mapping in Ontario - A.N. Boissoneau..... 33

Biophysical classification in Nova Scotia - R.E. Bailey and E.M. MacAulay..... 39

Land inventory programs in Newfoundland - B.B. Delaney and K.J.S. Beanlands..... 45

Biophysical-type surveys in the Department of Energy, Mines and Resources - R.J. Fulton..... 49

Soil surveys in the Canada Department of Agriculture - J.S. Clark..... 51

Biophysical land classification in the Environmental Management Service, Department of the Environment - T.W. Pierce and J. Thie..... 55

DEVELOPMENTS IN CLASSIFICATION METHODOLOGY

Wetland classification - S.C. Zoltai..... 61

An integrated iterative holistic approach to ecosystem classification - G.A. Hills..... 73

A review of coastal classification - N. Lopoukhine and H. Hirvonen..... 99 ✓

The integration of water into ecological land classification - D.M. Welch..... 109 ✓

Recent developments in eco-climatic classifications - B.F. Findlay..... 121

An evaluation of remote sensing techniques for ecological (biophysical) land classification in northern Canada - J. Thie..... 129

CONTENTS (CONT'D)

ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION PROJECT REPORTS

Biophysical mapping in the Mackenzie Valley - S.C. Zoltai..... 151

Eastern Melville Island: Biophysical aspects of a Geological Survey reconnaissance mapping program - D.M. Barnett..... 153

Biophysical land classification in Boothia Peninsula and Northeast Keewatin, N.W.T. - C. Tarnocai and J.A. Netterville..... 159

La cartographie écologique integrée du territoire de la Baie James - M. Jurdant *et al*..... 173

Biophysical land classification of Northern Manitoba - G.F. Mills..... 201

Biophysical land classification of Banff and Jasper National Parks - W.D. Holland..... 221

Biophysical analysis of the Yukon Territory - E.T. Oswald..... 239

The use of biophysical analysis in land use planning - P.H. Rennick..... 245

Integrated survey of biophysical resources in national parks - P. Gimbarzevsky..... 257

OPENING REMARKS

R.J. McCormack
Director General
Lands Directorate
Department of the Environment
Ottawa, Ontario

It is a pleasure to welcome many old friends to this meeting. Many of you here were associated with a predecessor, the National Committee on Forest Land. It is particularly fitting for me to welcome you because of my former association with that Committee.

If I may be allowed the luxury of singling out two or three people, I would like particularly to welcome Angus Hills and Stan Rowe, whose reputations we all know. Some of the early site work in Canada was carried out at Petawawa. Carl Heimberger did vegetative site types here. I recall meeting Angus Hills and George Brown in 1949 when they were doing initial work for the Hills classification between Petawawa and Ackray. Thus, it is an appropriate place for our meeting.

The meeting has been called, as I understand it, to establish a committee, if that is deemed to be a need for Canada. It has been called also to establish a Committee structure, meeting schedules, reporting relationships and finalized terms of reference. In addition, I understand that you will be assessing biophysical projects carried out during the last five years.

I have no particular hang-ups about how the committee might be operated, about who might chair it - that is federal, provincial or university - nor about what the terms of reference might be. Whatever the final structure, whatever the final arrangement, the Lands Directorate is prepared to provide a secretariat for the Committee.

Some of you will recall, that the Biophysical Classification Sub-Committee was established under the National Committee on Forest Land. We financed the incremental costs of biophysical pilot studies in Canada. If my memory is correct, these were in Nova Scotia, Quebec, Alberta, British Columbia and Manitoba. From those five studies and from the exchange of ideas in the Sub-Committee, chaired by Doug Lacate, a hierarchical structure for biophysical studies was developed and published. That publication, however brief, has provided

ALLOCUTION D'OUVERTURE

R.J. McCormack
Directeur Général
Direction Générale des Terres
Ministère de l'Environnement
Ottawa, Ontario

Il me fait plaisir de souhaiter la bienvenue à de vieux amis. Beaucoup d'entre vous avez été associés au Comité national des terres forestières, dont j'ai moi-même fait partie.

Permettez-moi, si vous le voulez bien, de souligner la présence de deux personnes que vous connaissez tous, Angus Hills et Stan Rowe. C'est à Petawawa qu'ont eu lieu certains des premiers travaux de classification au Canada. C'est en effet ici que M. Carl Heimberger a réalisé la classification des types de végétation. Et je me rappelle avoir rencontré Angus Hills et George Brown, en 1949, alors qu'ils accomplissaient le travail préliminaire pour la classification de Hills, entre Petawawa et Ackray. L'endroit se prête donc fort bien à la tenue de notre réunion.

On a convoqué la réunion, à ce qu'il me semble, dans le but de mettre sur pied un comité, si c'est jugé nécessaire, ainsi que pour élaborer la structure de ce comité, le calendrier des réunions, les différentes responsabilités et les attributions finales. Je crois en outre que vous évaluerez les projets biophysiques entrepris au cours des cinq dernières années.

Je n'ai aucune idée préconçue sur le fonctionnement éventuel du comité, ni sur la personne qui pourrait le présider, que ce soit un représentant du gouvernement fédéral, d'un gouvernement provincial ou d'un université, ni sur les attributions qu' on pourrait lui donner. Néanmoins, quelles qu'en soient la structure et l'organisation finales, la Direction générale des terres est prête à lui fournir un secrétariat.

Certains d'entre vous se souviendront que c'est sous l'égide du Comité national des terres forestières que le sous-comité de la classification biophysique a vu le jour. Nous avons financé les études pilotes biophysiques au Canada. Si ma mémoire m'est fidèle, il y en avait en Nouvelle-Ecosse, au Québec, en Alberta, en Colombie-Britannique et au Manitoba. On a pu, grâce à ces cinq études et à l'échange d'idées au sein du sous-comité présidé par Doug Lacate, élaborer et formuler une structure hiérarchisée

us with guidelines within which most of the biophysical studies have been carried out. Admittedly, there have been many variations; again this does not disturb me because in a country with such variable topography and physiography there will be a need for flexibility. In any case, it was only intended to be a first approximation.

It is appropriate for us to ask ourselves why we need another committee, particularly when we disbanded the National Committee on Forest Land. It is worth noting that after the cancellation of that Committee, we received a number of letters from a wide variety of people, expressing regret that there was no longer a vehicle for national coordination or a national forum for the exchange of views. We stuck to our decision at that time, largely because the purpose for which the NCFL had been formed - that is as an advisory body for the Canada Land Inventory - was no longer valid. We felt then that if another program was started, any committee which was required would be for a different purpose and may well require a different structure.

Both the Winnipeg and Toronto workshops on biophysical classification, three and two years ago respectively, again identified a need for some coordination mechanism. Several federal departments have ongoing biophysical programs and there is a need for cross-communication, even within the federal bureaucracy. After much discussion, after pressure from some of the provinces, we've decided to provide the opportunity for a National Committee, whatever it may finally be called. I believe that the name is open to question also.

The Lands Directorate invited representatives from the Departments of Indian and Northern Affairs, Agriculture, and Energy, Mines and Resources to participate in the formulation of possible terms of reference. The representatives were Roy Strang, Pete Clarke and Bob Fulton. The proposed terms of reference were sent to all provinces and federal departments with a vested interest. In almost all cases the responses were favourable and I encouraged Jean Thie to go ahead with the initial meeting.

I would like to reiterate that the terms of reference and the organization as proposed, are not engraved in stone. The meeting should decide whether there should be a committee, if so, what its structure and terms of reference should be; in other words it is up to you to make the final decision.

I have no strong feelings whether or not there

pour les études biophysiques. Le document en question a fourni, même s'il était bref, des directives qui ont servi à la réalisation de la plupart des études biophysiques. Je dois admettre qu'il y a eu beaucoup de différences d'application, mais cela ne me dérange pas du tout car, dans un pays comme le nôtre ayant une topographie et une physiographie aussi variées, il faut beaucoup de souplesse. De toute façon, ce document n'était destiné qu'à une première approximation.

Il serait bon de nous demander pourquoi nous avons besoin d'un autre comité, surtout que nous avons dissous le Comité national des terres forestières. J'en profite pour signaler qu'une foule de gens nous ont écrit après la disparition de ce Comité pour nous dire qu'ils déploraient l'absence d'un outil national de coordination ou d'un lieu d'échange d'idées au niveau national. Nous nous en sommes tenus à notre décision à l'époque, surtout parce que le but pour lequel le Comité avait été créé, c'est-à-dire, servir d'organisme de consultation pour l'Inventaire des terres du Canada, ne valait plus. Nous avons alors jugé que si on lançait un autre programme, le groupe éventuellement nécessaire aurait un but différent et pourrait bien avoir besoin d'une structure différente aussi.

Les ateliers sur la classification biophysique tenus à Toronto et à Winnipeg il y a deux et trois ans respectivement, ont à nouveau mis en lumière le besoin d'avoir un mécanisme de coordination. Plusieurs ministères fédéraux ont des programmes biophysiques en cours et ils ont besoin d'un organisme pour communiquer entre eux, même au sein de la bureaucratie fédérale. Ainsi, après en avoir longuement discuté et après avoir examiné les demandes de certaines provinces, nous avons décidé de donner l'occasion de créer un nouveau comité national. Quant à son nom, je crois que nous pourrons tenter de le trouver nous-mêmes.

La Direction générale des terres a invité des représentants des ministères des Affaires indiennes et du Nord, de l'Agriculture et de l'Energie, des Mines et des Ressources à participer à la formulation des attributions possibles. Ces représentants étaient MM Roy Strang, Pete Clarke et Bob Fulton. On a envoyé les attributions proposées à toutes les provinces et à tous les ministères fédéraux ayant un intérêt dans l'entreprise. Or, comme dans la plupart des cas les réponses étaient favorables, j'ai encouragé Jean Thie à préparer la première réunion.

J'aimerais répéter que les attributions et l'organisation proposées ne sont pas définitives. C'est à l'assemblée de décider s'il doit y avoir

should be a committee. Certainly the National Committee on Forest Land, which I chaired for many years and on which all of the provinces, the universities, and the interested federal departments were represented, was a very useful vehicle. It was completely unstructured; I don't recall ever having to put a question to a formal vote. It was particularly useful for people in land classification, and I suggest that this Committee may well achieve the same objective.

My own view is that the most useful function may well be as a forum for the exchange of technical information, and the diccussion of mutual problems.

I participated in the Canada Land Inventory for twelve years -- from its beginnings to maturity. I am fully aware that uniformity in Canada is neither desirable nor necessary. I think though, we can use a common approach in biophysical classification.

Finally, Mr. Chairman, I would like to wish the meeting every success, again express pleasure at meeting a number of old friends, and thank you for the opportunity of addressing the meeting.

R.J. McCormack

un comité et, si oui, de ses attributions et de sa structure. En d'autres termes, la décision est entre vos mains.

Je n'ai personnellement aucune préférence particulière quant à savoir si oui ou non on doit créer un comité. Bien sûr, le Comité national des terres forestières que j'ai présidé pendant de nombreuses années et où toutes les provinces, les universités et les ministères fédéraux intéressés étaient représentés, était assurément un outil utile. Pourtant, il manquait totalement de structure; je ne me rappelle pas avoir soumis une question à un vote officiel. Il servait surtout aux gens oeuvrant dans le domaine de la classification du territoire et je suggère que le nouveau comité vise le même but.

La fonction la plus utile du nouveau comité serait, d'après moi, de servir de tribune pour l'échange d'information technique et de discussion des problèmes communs.

J'ai participé pendant douze ans à l'Inventaire des terres du Canada, soit du début jusqu'à ce qu'il atteigne sa maturité et j'ai pleinement conscience que l'uniformité n'est ni souhaitable, ni nécessaire au Canada. Je crois tout de même que nous pouvons avoir une approche commune à l'égard de la classification biophysique.

Finalement, Monsieur le Président, je souhaite beaucoup de succès à la réunion, où j'ai le plaisir de rencontrer beaucoup de vieux amis et je vous remercie de m'avoir donné l'occassion de m'adresser à l'assemblée.

R.J. McCormack

SUMMARY OF BUSINESS SESSIONS

FIRST BUSINESS SESSION — DISCUSSION ON THE OBJECTIVES AND TERMS OF REFERENCE OF THE CANADA COMMITTEE ON ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION (CCELC)

Prior to and during these meetings, the group was called the National Committee on Biophysical Classification (NCBC). The name was changed to its present form during the last day of meetings at Petawawa.

The first morning was devoted to a general discussion of the needs, objectives, activities, membership and organization of the proposed committee. A first set of objectives was distributed to each participant prior to the meeting. In anticipation of probable comments, members of the Lands Directorate also prepared an alternative objective.

Proposed Objectives

1. *To coordinate the continued development of a Canadian Biophysical Classification System.*

2. *To provide national technical coordination and stimulate operational cooperation of biophysical-type surveys.*

3. *To make recommendations and provide advice to federal and provincial government agencies and private industry as to the technical feasibility, methodology benefits and costs of biophysical-type surveys for resource planning and management purposes.*

Alternative Objective

To promote the continued development and use of a biophysical approach to land classification:

- through technical information exchange and through problem-oriented working groups, subcommittees and workshops; and

- through recommendations and advice to governmental and private agencies as to the technical feasibility, methodology, benefits and cost of biophysical-type surveys for resource planning and management purposes.

During the ensuing discussion, several topics were discussed at length, including:

i) that there is a desire for a national, coordinated approach to ecological land classification which would coordinate and promote the use of ecological inventories while still permitting regional variation in details of classification;

ii) that a national approach to ecological land classification, and interprovincial communication in this subject, would be best achieved through a strong national committee with specialized working groups;

iii) that one of the most important concerns of an ecological classification committee be to promote the use of land inventory data, be it through user participation, user education, workshops, symposia, or whatever, and that some statement of cost/benefit be made available;

iv) that there is a perceived need to add socioeconomic data to ecological inventories. On this point there was no consensus on how or whether this might or should be achieved, simply that the question is worthy of further examination. Some advantages and disadvantages are: recognition of native rights and customs, settlement suitability assessment, the unstable nature of socioeconomic data with respect to biophysical-type data and the possible infringement on policy in areas of provincial jurisdiction; and

v) that ecological inventory programs must recognize the current speed of resource developments, and the planners need for timely information.

The meeting then adjourned for coffee, during which the chairman invited several participants to meet with him to reformulate a new set of objectives, based on the foregoing discussion. These participants were: J. Maxwell (federal), G. Roberts and A. Borys (provincial), and S. Rowe (independent). This group proposed the following objective:

To encourage the continued development of and to promote the application of a uniform ecological (biophysical) approach to land classification for resource planning, management and environmental impact assessment purposes.

This objective is to be achieved through:

i) *technical information exchange* and organization of problem-oriented working groups and workshops;

ii) encouragement and wide *distribution of information* methodology and applications of ecological (biophysical) surveys;

iii) the initiation of *dialogue* with the general public, users and potential users on the presentation and application of ecological information; and

iv) *recommendations and advice* to governmental and private agencies on the application, feasibility, methodology, benefits and costs of ecological- (biophysical-) type surveys.

This objective was later accepted by the general meeting, which also discussed and agreed to the following organization of the Committee:

i) that the membership of the CCELC (national body) be composed of one representative for each province, one for each of the key federal agencies, and by invitation, selected individuals from universities, provincial and federal specialists, and project leaders in the fields of ecological land classification;

ii) that for the first two years, the chairman of the CCELC will be provided by the Lands Directorate, and thereafter will be named by the Committee. The Lands Directorate, Environment Canada, Ottawa, will provide a permanent secretariat for the CCELC; and

iii) that the technical work of the CCELC on the further development of Ecological Land Classification be carried out by means of Working Groups. These will be established to provide solutions to scientific and technical problems as identified by the CCELC.

The meeting was then adjourned for lunch.

WORKSHOP SESSIONS

Four Workshops were established, with the following discussion items and membership:

Workshop A - Biophysical classification: philosophy, definitions and methodology.

*J.S. Rowe	W.D. Holland
S.C. Zoltai	B.F. Findlay
M. Jurdant	E.B. Wiken
D.S. Lacate	P. Gimbarzevsky
A.N. Boissonneau	C. Tarnocai
G.F. Mills	

Workshop B - Applications and user relations.

*A.E. Borys	B.B. Delaney
P. Rennick	E.M. MacAulay
J.S. Clark	M. Barnett
G.A. Yarranton	H.E.R. Gavin
G. Roberts	

Workshop C - Activities of CCELC for 1976/77.

*M.E. Walmsley	A.A. Buys
R. Schmidt	J. Dumanski
C. Kitchen	R.C. Ellis
E.T. Oswald	T.W. Pierce
R.J. Fulton	J. Thie
G.H. Watson	K.J.S. Beanlands

Workshop D - Land/water integration.

*R.E. Bailey	J.P. Ducruc
R.P. Bukata	G.A. Hills
G. McCullough	R.A. Hale
N. Lopoukhine	D.M. Welch

*Goup Leader

Each of these Workshops produced a set of recommendations which, along with recommendations from several individuals, were discussed in the second business session of the meeting.

SECOND BUSINESS SESSION — DISCUSSION ON CCELC WORKING GROUPS

At this session, a large number of recommendations were discussed. These recommendations were those of the four workshops, of three individuals (Zoltai, Holland and Delaney), and from the Saskatchewan provincial report by Roberts. Following a lengthy discussion during which some recommendations were rejected and others modified, it was agreed that the CCELC should establish five Working Groups, namely a Methodology and Philosophy Working Group, a Data Systems Working Group, a Wetland Classification Working Group, and a Land/Water Integration Working Group.

Listed below are the various recommendations agreed upon by the meeting. They have been rearranged according to appropriate Working Groups. The originating Workshop or individual is in brackets after each suggestion.

Methodology and Philosophy Working Group

1) A Working Group should be established with the task of formulating a statement of the rationale of biophysical classification. The statement should consider whether a new set of Guidelines is needed, what are the concepts and aims of the biophysical approach, and who are the various user groups meant to be served by such an approach and classification. (Methodology)

2) The Methodology/Philosophy Working Group should recognize and investigate the problem of the distinction between classification units and mapping units. Current examples of maps could be solicited from project leaders, and combined to present a commentary on this problem at the next meeting of the CCELC. (Methodology)

3) A biophysical classification system should place primary emphasis on physical aspects of the landscape, and then add on biological and chemical characteristics, as these tend to be variables dependent upon the former. (Activities)

4) The CCELC should investigate methods of obtaining extra input from vegetation scientists, in particular by aiming their efforts toward a unified framework for vegetation classification in Canada. (Holland)

5) Efforts should be made to develop climatic data input into biophysical land classification methodology in order to assist in differentiation of the 'Vegetation-Soil District' level of mapping. (Holland)

6) The concept of 'Vegetation-Soil District' should be further developed and adopted for trial. (Holland)

7) The CCELC should develop more rigorous terms, definitions, taxonomic criteria and a hierarchical classification structure throughout the entire biophysical system. (Holland)

8) The CCELC recommends that the Lands Directorate undertake the preparation of a Glossary of Terms that are specific to biophysical surveys, rather than being terminology of other disciplines. Each term should have a preferred definition followed by synonyms. French language terms should be included. (Methodology)

Applications Working Group

1) The CCELC should establish a working group responsible for achieving the objective of the CCELC relating to applications and use of biophysical information. (Applications; Holland)

2) The Applications Working Group should identify the users and potential users. Probable users include government personnel involved with economic development, resource management, environmental assessment and contingency planning, private industries such as mining, forestry, pipelines, hydro, chemicals and so on, communities active in economic development or concerned with preserving their way of life, consultants, etc. (Applications)

3) There is a need to make biophysical information readily understood and useable by a wide variety of users and potential users. (Applications)

4) The CCELC should prepare a proper and understandable definition of biophysical surveys. (Activities)

5) The CCELC should prepare a manual that explains what biophysical information is. This should be a single manual for all disciplines, to ensure integration of information. However, discipline-oriented appendices would likely be necessary and better received by professionals in certain disciplines. (Applications)

6) Efforts should be made towards upgrading of user skills in the understanding of inventory methodology, resource analysis and interpretative results. This could be achieved by the development and sale of a training manual. (Holland)

7) The CCELC should ensure that students at educational institutions, and entering disciplines where they will be expected to use biophysical information as a tool, are taught the skills of its use. (Applications)

8) The CCELC should initiate user dialogue; this would be most effective in small groups for informal discussion. (Applications)

9) User information packages should be directed at the management and planning level as well as at the operations level. (Applications)

10) The CCELC should hold symposia at different jurisdictional levels for the dissemination of information. Funding may be required for this. (Applications)

11) The CCELC should prepare 'canned' information packages explaining biophysical information. These would be useful for audiences larger than symposia, and also where there is a large turnover of staff in user agencies. (Applications)

12) The CCELC should consider having consultative expertise, available in each jurisdiction, who could be called upon to offer interpretations as and when required. (Applications)

13) The CCELC must make sure that biophysical information is not gathered for the sake of inventory, but that it responds to specific needs and that it is used, rather than becoming simply a library of information. (Applications)

14) The CCELC should ensure that biophysical information is used correctly, and not misused as is some CLI data. (Applications)

15) The CCELC should ensure that biophysical information is presented to communities as soon as it is ready and in a manner that they can understand. (Applications)

16) The CCELC should consider the question of whether biophysical information will become a tool in the process of change, for example, in northern communities, and will the communities have any control over the change. Community awareness should have high priority in development processes. (Applications)

17) The Lands Directorate of DOE, DREE and the Canadian Council on Rural Development should jointly sponsor or undertake research to identify a role for biophysical inventories and resource planning in the development process and identify the mechanisms required for a biophysical program consistent with locally based development. (Roberts)

18) Under the advice of the CCELC, the Lands Directorate should undertake research on the costs and benefits of biophysical inventories. (Roberts)

19) A CCELC Working Group should be formed to investigate the applications of biophysical information, past, present and future, with special emphasis on the benefits and usefulness accrued. (Activities)

20) The CCELC should provide coordination to ensure that duplication in the acquisition of resource information does not occur. This coordination should be by way of information exchange, and not by imposition upon provincial projects. (Applications)

21) The CCELC should encourage biophysical team members to develop user contacts and to maintain some involvement with site-specific problems and studies as a self-training tool. (Holland)

22) The CCELC should establish research requirements in order of priority, and methods of funding should be investigated. (Holland)

23) Methods of providing publication assistance for biophysical projects should be examined by the CCELC. (Holland)

24) The CCELC should encourage dialogue with wildlife scientists and recreation scientists with respect to the utility of biophysical information. (Activities)

Data Systems Working Group

1) The CCELC should form a subcommittee on the aspects of data collection, storage, manipulation, retrieval and presentation with respect to biophysical data.

2) The parameters required for a biophysical survey should be defined in specific terms. (Activities)

3) Exploration should be made whereby basic data-gathering for vegetation and soils be made more intensive in order to identify and explain ecologically significant relationships that may be used to verify and strengthen interpretations. (Holland)

Wetland Working Group

1) The Wetland Working Group merits continued support in order to complete its tasks. Such a group should be adopted and sponsored as a Working Group by the CCELC. (Activities; Zoltai; Methodology)

2) The tasks of a Wetland Working Group should include the finalization of the Wetland Classification system and the promotion of its use throughout Canada. (Zoltai)

3) The Wetlands Working Group should organize and implement multidisciplinary pilot projects of wetland classification in different parts of the country. (Zoltai)

4) The Working Group should define and refine the *Wetland Regions of Canada* as a spatial framework for regional wetland studies. (Zoltai)

5) The Working Group should initiate and maintain a registry of wetland types, and prepare the publication of this information as needed. (Zoltai)

Land/Water Integration Working Group

1) It is recommended that a Land/Water Integration Working Group be established to develop coastal and inland water classification and subsequently to investigate their compatibility and integration with land classifications. (Land/Water)

2) The Working Group should advise on the feasibility and necessity of having a biophysical classification scheme that will compatibly incorporate terrain and water. (Land/Water)

3) The CCELC should support a working group on Coastal Zone Ecosystem Classification, including components of marine wildlife and of recreation. (Activities; Land/Water)

4) The CCELC should support a working group on Aquatic Ecosystems Classification. This Group should investigate the integration of aquatic ecosystems with terrestrial components. (Activities; Land/Water)

5) At least one member of the Working Group should be familiar with existing biophysical philosophy. (Land/Water)

After adjournment for coffee, the meeting reassembled to discuss various other business items.

Name of the Committee

After lengthy debate, the meeting approved that the name of the committee become the *Canada Committee on Ecological (Biophysical) Land Classification.*

Chairmanship

Jean Thie of the Lands Directorate, DOE, was approved as Chairman for the first two years.

Next Meeting

Following several suggestions, particularly from the Applications and the Methodology Workshops, it was agreed that the next CCELC meeting be at Kamloops, B.C. sometime during 1977. The consensus was that CCELC meetings should be held in different places.

Urban Workshop

There was agreement that a two- to three-day Workshop be held on Urban Biophysical Mapping, but that there was as yet no need for a CCELC Working Group on this subject.

The meeting was then declared closed, after which, all partook of an extremely pleasant stroll through the sylvan glades of Petawawa.

LIST OF PARTICIPANTS

Bailey, R.E.
Nova Scotia Department of Environment
Office of the Deputy Minister
Box 2107
Halifax, Nova Scotia
Tel: 424-5833

Barnett, M.
Terrain Sciences Division
Geological Survey of Canada
Energy, Mines and Resources
601 Booth Street
Ottawa, Ontario K1A 0E8
Tel: 994-5802

Beanlands, K.J.S.
Lands Branch
Department of Forestry & Agriculture
Confederation Building
St. John's, Newfoundland
Tel: 722-0711 Ext. 339

Boissoneau, A.N.
Ontario Centre for Remote Sensing
Ministry of Natural Resources
801 Bay Street
4th Floor
Toronto, Ontario
Tel: 965-8411

Borys, A.E.
Senior Land Use Planner
Planning Branch
Dept. of Renewable Resources
and Transportation
1495 James Street
Winnipeg, Manitoba
Tel: 786-9214

Bukata, R.P.
Remote Sensing Section
Applied Research Division
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario L7R 4A6
Tel: 637-4670

Buys, A.A.
Canadian Forestry Service
Environment Canada
396 Cooper Street
Majestic Bldg.
Ottawa, Ontario
Tel:

Clark, J.S.
Soil Research Institute
Agriculture Canada
K.W. Neatby Bldg.
Ottawa, Ontario K1A 0C6
Tel: 994-9650

Delaney, B.
Director of Inventory
Department of Forestry & Agriculture
Building 810 - Pleasantville
St. John's, Newfoundland
Tel: 737-3753

Ducruc, J.P.
Direction régionale des Terres
Environnement Canada
1080 Route du Vallon
C.P. 2800
St.-Foy, Québec G1V 4C7
Tel: 694-3965

Dumanski, J.
Soil Research Institute
Agriculture Canada
K.W. Neatby Bldg.
Ottawa, Ontario
K1A 0C6
Tel: 994-9657

Ellis, R.C.
Regional Director - Ontario Region
Lands Directorate
Environment Canada
867 Lakeshore Road
P.O. Box 5050
Burlington, Ontario L7R 4A6
Tel: 164-4253

Findlay, B.F.
Applications & Consultation Division
Atmospheric Environment Service
Environment Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Tel: 667-4625

Fulton, R.J.
Terrain Sciences Division
Energy, Mines & Resources
601 Booth Street
Ottawa, Ontario K1A 0G1
Tel: 994-5093

Gavin. H.C.R.
Manitoba District Manager
Environmental Protection Service
Environment Canada
800 - 275 Portage Avenue
Winnipeg, Manitoba R3B 2B3
Tel: 985-2961

Gimbarzevsky, P.
Forest Management Institute
Environment Canada
2nd Floor - Majestic Bldg.
396 Cooper Street
Ottawa, Ontario
Tel: 996-8793

Hale, R.A.
Inland Waters Directorate
Environment Canada
1st Floor, Motherwell Bldg.
1901 Victoria Avenue
Regina, Saskatchewan S4P 0K6
Tel:

Hills, G.A.
91 John Street
Thornhill, Ontario L3T 1Y3
Tel: 889-2284

Holland, W.D.
Canadian Forestry Service
Northern Forest Research Centre
Environment Canada
5320-122 Street
Edmonton, Alberta T6H 3S5
Tel: 435-7210

Jurdant, M.
Direction régionale des Terres
Environnement Canada
1080 Route du Vallon
C.P. 2800
St.-Foy, Québec G1V 4C7
Tel: 694-3965

Kitchen, C.
Ecoplans Ltd.
279 Weber St. N.
Waterloo, Ontario N2J 3H9
Tel: 579-5266

Lacate, D.S.
Regional Director
Lands Directorate - Pacific Region
Environment Canada
1001 W. Pender Street
Room 904
Vancouver, B.C. V6E 2M7
Tel: 544-3161

Lopoukhine, N.
Lands Directorate - Atlantic Region
Environment Canada
P.O. Box 365
Halifax, Nova Scotia B3J 2P8
Tel: 426-4196

MacAulay, E.
Nova Scotia Department of Lands & Forests
Truro, Nova Scotia B3J 2T9
Tel: 895-1591

Maxwell, J.W.
Director, Policy and Program Development Branch
Lands Directorate
Environment Canada
20th Floor, Place Vincent Massey
Ottawa, Ontario K1A 0H3
Tel: 997-4149

McCormack, R.J.
Director General
Lands Directorate
Environment Canada
20th Floor, Place Vincent Massey
Ottawa, Ontario K1A 0H3
Tel: 997-1246

McCullough, G.
Freshwater Institute
Fisheries & Marine Service
Environment Canada
501 University Crescent
Winnipeg, Manitoba R3T 2N6
Tel: 269-7379

Mills, G.F.
Project Leader NRIP
Canada-Manitoba Soil Survey
Department of Soil Science
University of Manitoba
Winnipeg, Manitoba
Tel: 474-8153

Netterville, J.
Terrain Sciences Division
Geological Survey of Canada
Energy, Mines & Resources
601 Booth Street
Ottawa, Ontario K1A 0E8
Tel: 994-5802

Oswald, E.
Pacific Forest Research Centre
Environment Canada
506 West Burnside Road
Victoria, British Columbia
Tel: 388-3811

Pierce, T.W.
Lands Directorate
Environment Canada
20th Floor, Place Vincent Massey
Ottawa, Ontario K1A 0H3
Tel: 997-2320

Rennick, P.
Land Use Assignment Section
Alberta Department of Natural Resources
Natural Resources Bldg.
Edmonton, Alberta
Tel: 427-7474

Roberts, G.
Department of Northern Saskatchewan
Box 5000
La Ronge, Saskatchewan
Tel: 425-2033

Rowe, J.S.
Department of Plant Ecology
University of Saskatchewan
Saskatoon, Saskatchewan
Tel: 373-0910

Schmidt, R.
Interdisciplinary Systems (IDS)
528 St. James Street
Winnipeg, Manitoba
Tel: 775-0418

Tarnocai, C.
Pedologist
Canada-Manitoba Soil Survey
Department of Soil Science
University of Manitoba
Winnipeg, Manitoba
Tel: 474-8153

Thie, J.
Lands Directorate
Environment Canada
20th Floor, Place Vincent Massey
Ottawa, Ontario K1A 0H3
Tel: 997-2320

Vass, S.
Department of Environment
P.O. Box 2000
Charlottetown, P.E.I. C1A 7N8
Tel: 892-3561

Walmsley, M.
Environment and Land Use Committee
Secretariat
Resource Analysis Unit
Parliament Buildings
Victoria, B.C. V8V 1X4
Tel: 387-6378

Watson, G.H.
Canadian Wildlife Service
Environment Canada
16th Floor, Place Vincent Massey
Hull, Quebec K1A 0H3
Tel: 997-1840

Welch, D.M.
Lands Directorate
Environment Canada
20th Floor, Place Vincent Massey
Ottawa, Ontario K1A 0H3
Tel: 997-2320

Wiken, E.B.
Lands Directorate
Environment Canada
20th Floor, Place Vincent Massey
Ottawa, Ontario K1A 0H3
Tel: 997-2320

Yarranton, G.A.
Environmental Studies Section
Water, Lands, Forest & Environmental Branch
Indian and Northern Affairs
Centennial Tower
400 Laurier Avenue West
Ottawa, Ontario K1A 0H4
Tel: 992-4067

Zoltai, S.C.
Canadian Forestry Service
Environment Canada
Northern Forest Research Centre
5320-122 Street
Edmonton, Alberta T6H 3S5
Tel: 435-7210

PRESENT STATUS OF ECOLOGICAL LAND CLASSIFICATION IN CANADA

SITUATION ACTUELLE DE LA CLASSIFICATION ÉCOLOGIQUE DU TERRITOIRE AU CANADA

BIOPHYSICAL LAND CLASSIFICATION IN BRITISH COLUMBIA: THE PHILOSOPHY, TECHNIQUES, AND APPLICATION

M.E. Walmsley
Terrain Systems Analysis/Interpretation Division
Environment and Land Use Committee SECRETARIAT
Victoria, British Columbia

ABSTRACT

The Biophysical System used in British Columbia to describe and define the chemical, biological and physical attributes of the landscape is discussed. The logic inherent in the system is described by discussing the philosophy of land classification. This is furthered by illustrating the techniques used and some example applications of the data base. All of this is used to point out the utility of the biophysical system in providing base data from which renewable resource capability maps can be drawn as well as information by which land resource managers can recommend alternative management practices which will avoid environmental deterioration.

RÉSUMÉ

Le système biophysique utilisé en Colombie-Britannique pour décrire et déterminer les attributs chimiques, biologiques et physiques du paysage est étudié. La logique du système est décrite par l'analyse de la philosophie de la classification du territoire, puis complétée par l'exposé des techniques utilisées et par des exemples d'application de la base de données. L'objet de cette démarche est de souligner l'utilité du système pour l'obtention de données de base permettant de tracer des cartes des ressources renouvelables et d'acquérir des renseignements à l'aide desquels les gestionnaires de ressources du terrain peuvent recommander des méthodes d'aménagement non destructrices de l'environnement.

INTRODUCTION

In British Columbia, the application of the biophysical land classification system rests with the Environment and Land Use Committee (ELUC) Secretariat and more specifically, its Resource Analysis Unit although other agencies do apply the same concept. This role has been fulfilled by the Secretariat since its inception in 1974 and carried on through the termination of the Canada Land Inventory (CLI) program in 1975.

This paper will briefly outline the structure of the ELUC Secretariat and discuss the philosophy held in British Columbia with regard to ecological land classification. Some examples will be given for illustration.

THE WORKING STRUCTURE

The ELUC Secretariat is made up of three main units (Figure 1) which reflect the manner in which the problems of resource use, environmental management and resource allocation are handled. Generally, the Special Projects Unit and the Resource Planning Unit have similar mandates, specifically those of problem formulation, identification of alternatives and the assessment of the consequences associated with each alternative. In fulfilling these roles, the Resource Planning Unit tends to deal with regional resource management problems while the Special Projects Unit considers more site-specific problems, focusing on individual classes of resource use conflict.

Resource inventories and data interpretations are a prerequisite to any type of planning in the resource management field. This role is fulfilled by the Resource Analysis Unit, which is responsible for the application and dissemination of biophysical data bases in the Province. Initially, the Resource Analysis Unit was made up of personnel from the British Columbia Land Inventory, formerly attached to the Department of Agriculture. This, however, has expanded to provide not only the resource inventory function, but also the data base interpretations required by planners for sound management and administration of the particular resources as well as the support services (laboratory, computing, library, etc.) required for the inventory and interpretive phases. These three roles are illustrated in Figure 1 and are covered respectively by the Resource Inventory Division, Analysis/Interpretation Division and the Data Services Division.

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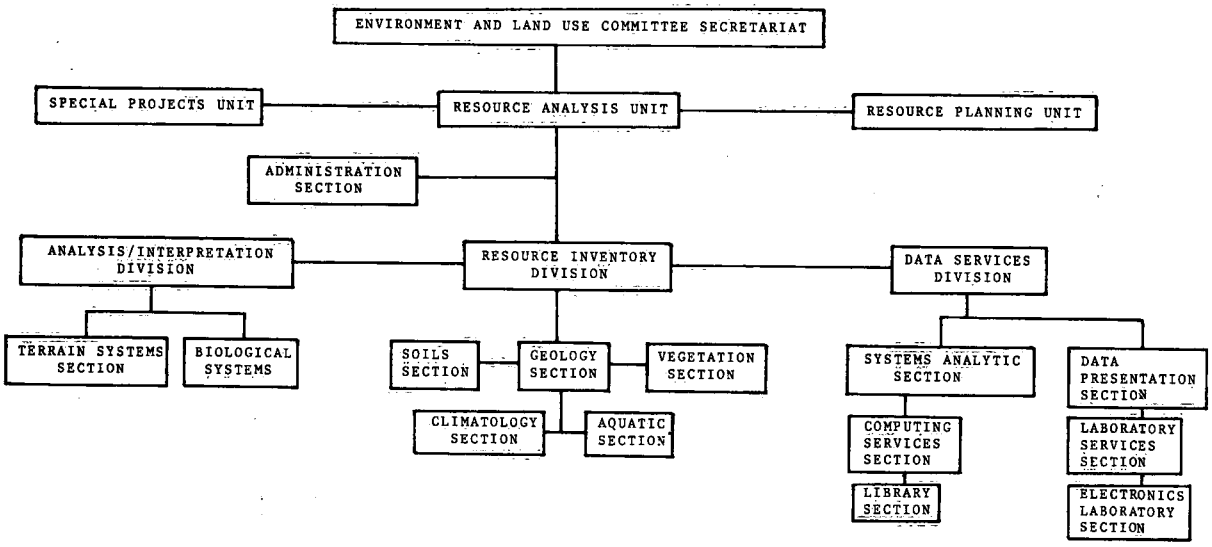
Figure 1: The overall structure of the Environment and Land Use Committee (ELUC) Secretariat



The identification of the biological and physical characteristics of the landscape provides the basis for determining the inherent capability of the land to support a particular land use. Land capability determination then is an important product of the Resource Analysis Unit's work, since through this process, limitations can be immediately identified, providing an invaluable tool for integrated land use management.

PHILOSOPHY

Many people look upon land classification as a magical process, one that combines all information about soils, climate, topography, markets, demand functions, laws and even the goals, skills and intellectual capabilities of people into a solution of land use problems (Conklin, H.E.). Slowly, we are becoming aware that this is not true, that land classification can take any form we specify. Classification systems are simply contrivances of man, structured to suit his need, reflecting the development of the particular science at that point in time. Since needs change and science progresses, classification systems must reflect these changes to continue to satisfy the objectives set out for their development. If this does not happen, the science within which the classification system is used will stagnate.

Clearly, classification is the placing together of individuals into groups which are mutually exclusive. It follows then that a classification system provides for placing each individual in *a* group or class so that no individual can fit into more than one class. These classes or groups are defined in terms of some attributes of the individual for which values can be established. Prior to setting up the limits of the classes, it is necessary to provide a description or inventory of the individuals. Since we are constantly faced with the fact that we cannot measure or describe everything about an individual, it is necessary to decide, usually before the inventory takes place, what attributes are important. The fact that we are dealing with natural systems makes this task all the more arduous, since there are a multitude of variables with respect to these individuals which could be chosen to set up the system.

When considering this problem, it becomes readily apparent that a paradox exists which is perhaps one of the greatest hurdles to overcome when dealing with ecosystems. Since we are primarily interested in the performance of land, our system should reflect function, but due to practical considerations, this is not feasible due to time constraints and problems of comprehension. Hence, we fall back on morphological characteristics (appearance, shape) since they are more easily ascertained. These morphological characteristics are then used as indicators of performance characteristics (function). Herein lies the nemesis of the land classifier and the place where the most effort must be placed in terms of research to determine the relationships. Without an understanding of such complex relationships, the classification system is but a hollow shell of little real use to anyone. For example, what does a change from weak subangular blocky structure to one of strong angular blocky mean in assessing the performance of the land?

In any system of land classification, we choose specific variables at each level of generalization and define class limits or ranges which best suit our purpose. Specifically then, the problem is one of choosing the *right* variables and class ranges to suit our needs, since the individual is lost within the class. Those characteristics which are not chosen to differentiate among classes are covered up due to their apparent irrelevancy.

The particular classification scheme used by the survey teams of the ELUC Secretariat and other government agencies (i.e. biophysical) is not a land classification system *per se*. Rather, it is simply a pragmatic mechanism designed to bring together ecological information in a form which facilitates communication and hence simplifies the arduous task of understanding the vast amount of information collected by the various resource disciplines, while still maintaining a degree of scientific credibility.

OBJECTIVES, SYSTEMS AND METHODS

The objectives behind the biophysical classification scheme used in British Columbia are neither complex nor difficult to understand. These are listed as follows, being fully cognizant of the possibility of making motherhood statements:

1. To differentiate and classify ecologically significant segements of the land and water surface, rapidly and at a small scale (Lacate, 1974).

2. To identify opportunities and limitations for particular types or combinations of land use, and hence provide a management tool for resource planners.

3. To relate management practice to land productivity in a quantitative and qualitative manner so that management alternatives can be identified.

The biophysical system at present provides the opportunity for terrestrial and aquatic classification systems to come together. Those schemes are:

1. *Physiographic Subdivisions* of British Columbia as defined by Holland (1964), following some modifications.

2. *Vegetation Zonation* as defined by van Barneveld (pers. comm.).

3. *The Terrain Classification System* as defined by the ELUC Secretariat, Geology Section and Terrain Systems Section (1976a).

4. *Bedrock Geology Subdivisions* as defined by particular mappers for the area of concern.

5. *The Aquatic Classification System* as defined by the ELUC Secretariat, Aquatic Section and Biological Section (1976b).

6. *The System of Soil Classification for Canada* as defined by the Canada Soil Survey Committee (1974).

7. *Climatic Parameters* as required and defined by the ELUC Secretariat, Climatology Section (1976).

It is felt that the objectives as outlined are met by the *Biophysical System* through the use of both a pragmatic and conceptual overlay technique, the conceptual part being facilitated by integrated survey teams composed of various resource disciplines exchanging ideas and concepts during and following the inventory phase. The pragmatic part is simply the overlaying of one map on another, so that map units used to define one type of broad map unit can be used in defining another more detailed map unit.

Physiography

The technique for applying the biophysical system starts with the broad scale zonation schemes and subsequently works down to the more detailed levels of land classification. On the regional level of classification, the *physiographic subdivisions* (Holland, 1964) of the province are used to provide the initial stratification. These various subdivisions are outlined in Figure 2. This subdivision of the Province provides units of the landscape which are alike topographically and within which the genesis of the landforms are understood. Within each Physiographic Subdivision, there are similarities of the landforms resulting from:

1. Similar processes of erosion and deposition.

2. Similarities of bedrock response to erosion.

3. Similarities of orogenic history.

In this respect, these subdivisions are similar to the *Land Region* (Lacate, 1969), being mapped at a scale of approximately 1:2,000,000.

Vegetation

In order to reflect the overall biological characteristics of the environment, it is necessary to apply a classification of the dominant climatic climax vegetation zones as they occur

Figure 2: Physiographic subdivisions of British Columbia (Holland, 1964)

CANADIAN CORDILLERA

WESTERN SYSTEM	OUTER MOUNTAIN AREA	St. Elias Mountains		Fairweather Ranges Icefield Ranges Alsek Ranges Duke Depression
		Insular Mountains	Queen Charlotte Mountains	Skidegate Plateau Queen Charlotte Ranges
			Vancouver Island Mountains	Vancouver Island Ranges Alberni Basin Estevan Coastal Plain
	COASTAL TROUGH	Hecate Depression	Queen Charlotte Lowland	Argonaut Plain
			Nahwitti Lowland	Suquash Basin
			Hecate Lowland	Milbanke Strandflat
		Georgia Depression	Georgia Lowland	Fraser Lowland
			Nanaimo Lowland	
	COAST MOUNTAIN AREA	Coast Mountains	Boundary Ranges Kitimat Ranges	
			Pacific Ranges	Chilcotin Ranges
		Cascade Mountains	Skagit Range Hozameen Range Okanagan Range	
INTERIOR SYSTEM	NORTHERN PLATEAU AND MOUNTAIN AREA	Yukon Plateau	Tagish Highland Teslin Plateau Nisutlin Plateau	
		Liard Plain		
	CENTRAL PLATEAU AND MOUNTAIN AREA	Stikine Plateau	Tahltan Highland Taku Plateau	
			Kawdy Plateau	Atsutla Range
			Nahlin Plateau Tanzilla Plateau Klastline Plateau Spatsizi Plateau	
		Skeena Mountains	Klappan Range Tatlatui Range Eaglenest Range Sicintine Range Slamgeesh Range etc.	
		Nass Basin		
		Hazelton Mountains	Nass Ranges Kispiox Range Bulkley Ranges Tahtsa Ranges	
		Cassiar Mountains	Dease Plateau Stikine Ranges Kechika Ranges Sifton Ranges	
		Omineca Mountains	Swannell Ranges Finlay Ranges Hogem Ranges	
	ROCKY MOUNTAIN TRENCH			
	SOUTHERN PLATEAU AND MOUNTAIN AREA	Interior Plateau	Fraser Basin	Nechako Plain
			Nechako Plateau	McGregor Plateau
			Fraser Plateau Thompson Plateau Quesnel Highland Shuswap Highland Okanagan Highland	
		Columbia Mountains	Selkirk Mountains Cariboo Mountains Purcell Mountains Monashee Mountains	
EASTERN SYSTEM	MACKENZIE MOUNTAIN AREA	Liard Plateau		
	ROCKY MOUNTAIN AREA	Rocky Mountains	Border Ranges	Galton Range Macdonald Range Clark Range Flathead Basin
			Continental Ranges	Front Ranges Kootenay Ranges Park Ranges
			Hart Ranges	Misinchinka Ranges
			Muskwa Ranges	Rabbit Plateau
		Rocky Mountain Foothills		

INTERIOR PLAINS

Alberta Plateau	Fort Nelson Lowland

in the province. Such a system is that defined by van Barneveld which defines specific *Forest Zones*, which for practical purposes can be considered equivalent to the *Biogeoclimate zones* of Krajina (1965). To illustrate this concept, a copy of the biogeoclimatic zones of the province is presented in Figure 3.

Vegetation characteristics are considered important in ecological land classification as a result of the following points (Cotic, van Barneveld and Sprout, 1974):

1. Vegetation is a natural resource by its own right.

2. Vegetation is an indicator of the state of other ecological factors such as climate and soils. Since it is these factors which determine the nature and quality of the natural resources, it is necessary to understand the vegetative resource to enable proper land management to occur.

3. Vegetation is an important variable in the formation of soil. As stated by Jenny (1941)and Major (1951), the genesis of soil follows the following factorial equation:

$$s = f(c, g, r, o, t)$$

s = soil
c = climate
g = geologic parent material
r = relief or topography
o = organic (vegetation)
t = time

As a consequence of this, vegetation must be taken into account when studying or interpreting a soil. The parameters considered important in

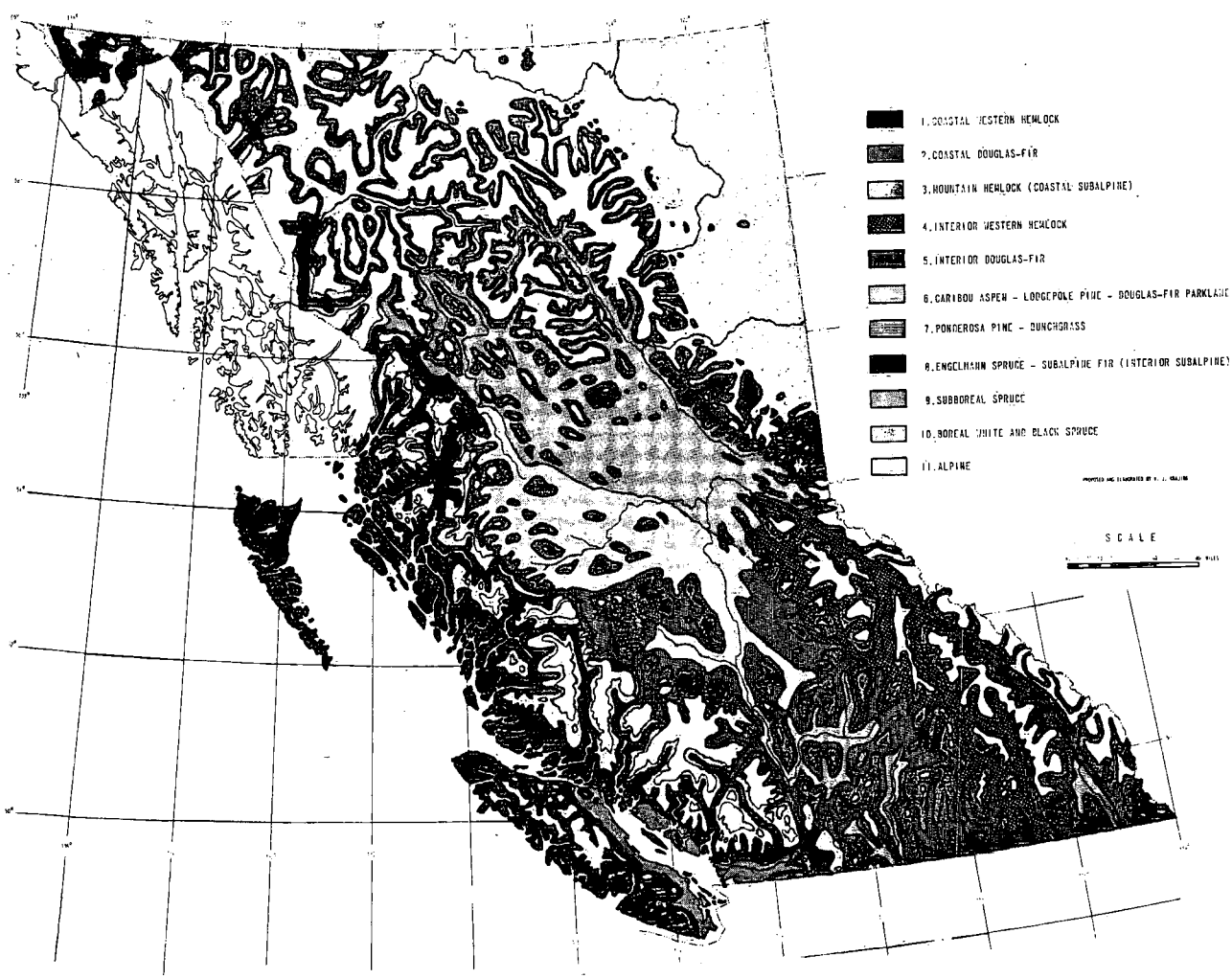


Figure 3: Biogeoclimatic zones of British Columbia

the forest zonation scheme are quality (species composition, structure, age), quantity, and dynamics (secondary succession sequences and their ultimate climaxes, which reflect the potential of the resource).

To illustrate how this forest zonation system functions, Figure 4 provides a comparison of the forest zones and subzones described in the West Kootenays and the East Kootenays, showing the approximate elevation at which each zone and subzone occur. Forest zones reflect differences mainly in macroclimate. These zones may be subdivided into subzones either due to differences in possible successional trends (e.g. Douglas fir with and without Ponderosa pine) or on the basis of gross differences in growth form and type of forest (e.g. forested subzone and krummholz subzone).

Figure 5 illustrates the legend used on the forest zonation maps for the northwestern part of the province (NTS 93L/14). This will provide some insight into the type of mapping program currently undertaken by the vegetation group. Mapping is currently undertaken at a scale of 1:50,000.

At the local level of integration, map information is gathered on surficial geology, pedology and bedrock geology to provide a further subdivision of the regional units. This level of ecosystem generalization most closely approximates the *Land System* described by Lacate (1964) and Christian (1958) and forms the working level for ecosystem mapping in the province.

Surficial and Bedrock Geology

Surficial geology, the study of landforms and related deposits, is examined by applying the *Terrain Classification System* (ELUC Secretariat,

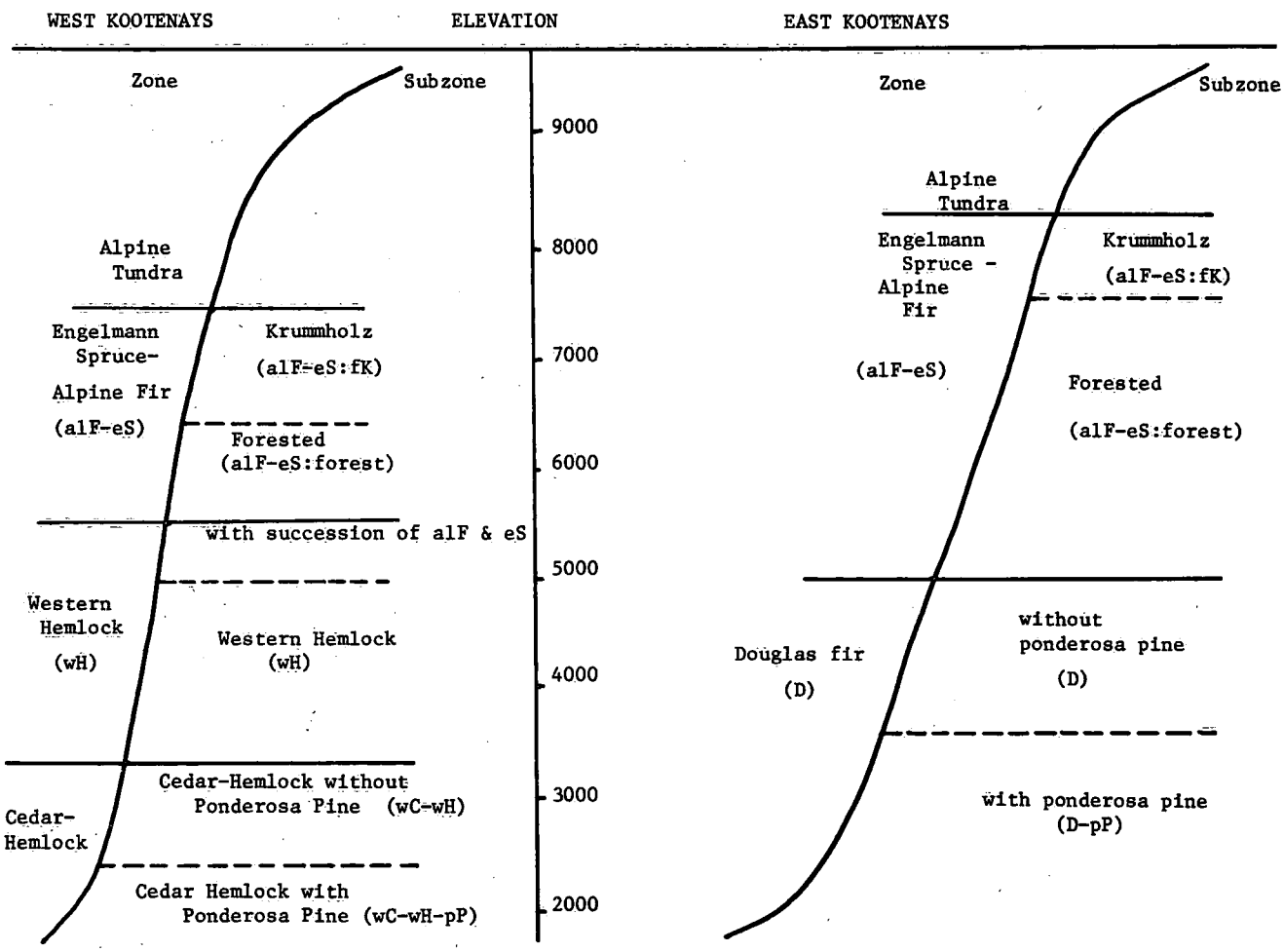


Figure 4: Comparison of forest zones in the West and East Kootenays

Figure 5: Forest zonation legend (van Barneveld, 1976)

Macrophysiognomy

	deciduous	coniferous	mixed
forested dense	dfd	cfd	mfd
forested open	dfo	cfo	mfo
forested parkland	dfp	cfp	mfp

b bog open
bt bog treed
cf cultivated fields
fk forested krummholz
ps pioneer shrub
s savannah
ta alpine tundra
R rock
rl recently logged

Species

sAl Sitka Alder
wB White Birch
wC Western Red Cedar
D Douglas Fir
alF Alpine Fir
wH Western Hemlock
wL Western Larch
lP Lodgepole Pine
pP Ponderosa Pine - Yellow Pine
wP White Pine
tA Trembling Aspen
bCo Black Cottonwood
eS Engelmann Spruce
wS White Spruce
W Willow

Ecological state

DC disclimax
MCC mature climatic climax
MEC mature edaphic climax
} > 60 yrs.
MS maturing seral approx. 60 - 140 yrs.
PS pioneer seral
YCC young climatic climax
YEC young edaphic climax
YS young seral
} < 60 yrs.
OS over-mature seral > 140 yrs.

Zonal colour code

Interior western hemlock - western red cedar zone
- Seral pP subzone
- Seral eS-alF subzone
- Subzone lacking seral pP, eS or alF

Interior Douglas fir zone
- Seral pP subzone
- Subzone lacking seral pP

Subalpine alpine fir - Engelmann spruce zone
- Forested subzone - lacking seral D
- Krummholz subzone
- Seral D subzone - adjacent to Int. D zone

Alpine tundra zone

Map symbols

Zonal Boundary
Subzonal Boundary
L. Lake
Hook joining similar units
Vegetation plot location
72-501
Present condition units

Survey reliability

B.C.F.S. forest cover maps:
Arrowhead & Salmon Arm P.S.Y.U.s - 1962
Shuswap P.S.Y.U. - 1963
Okanagan P.S.Y.U. - 1964
Niskonlith P.S.Y.U. - 1965
Edgewood P.S.Y.U. - 1967
Barton Hill P.S.Y.U. - 1970
Eagle P.S.Y.U. - 1971
Spallumcheen P.S.Y.U. - 1972
T.F.L. forest cover maps:
T.F.L. 9, 16 & 32 - Crown Zellerbach - 1973-1975
T.F.L. 23 - Canadian Cellulose Company Ltd. - 1975
T.F.L. 33 - Federated Co-operatives Ltd. - 1975
B.C.F.S. Individual sample volume statements - 562
B.C.D.A. Vegetation survey - 1973 - N.T.S. 82 L - 288 plots & soil survey - 1971-1973 - N.T.S. 82 L
C.L.I. Forest inventory - 1971-1972 - 134 plots
Aerial photographs - 80 chain - 1970

Compiled by Vegetation Section, Resource Analysis Unit, E.L.U.C. Secretariat - Kelowna, B.C.. March 1976.

1976a). This system provides for the mapping of landforms and geomorphic processes which have modified and are still modifying the landforms (Alley, 1976). The system is divided basically into two sections:

1. *Consolidated Materials* (pre-Quaternary materials - mostly bedrock).

2. *Unconsolidated Materials* (Quaternary mantle overlying the bedrock).

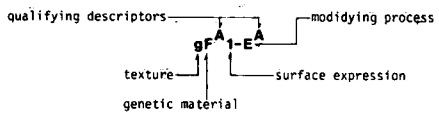
The unconsolidated component provides for the definition of a terrain unit according to the *genetic material*. As modifiers or descriptors, information can be supplied for things such as *texture, surface expression, process modifiers* and *genetic qualifiers*. To satisfy the geologic history component and engineering requirements of the system, *stratigraphic relationships* can be shown. *On-site symbols* are employed to show the exact location of some specific terrain features. Since the scale of application is approximately 1:50,000, many parts of the landscape cannot be shown as simple individual genetic materials. In this event, *composite units* are employed, which group terrain elements.

Figure 6 presents an example of a terrain legend and letter notation as devised by Ryder (1976). This legend will explain the terminology used above and will illustrate the simplicity and

Figure 6: Legend - surficial geology

Explanation of Letter Notation

A combination of letters is used to designate each map unit. The relative position of letters within the symbol indicates the characteristic that they represent.



Units consisting of two or more types of terrain are designated by two or more groups of letters separated by dots and slashes:-

eg. **gFt/dCf** (See Composite Units below)

Material underlying the surface unit is shown by a symbol that is written beneath the surface unit symbol and separated from it by a horizontal line:-

eg. $\frac{\text{sEv}}{\text{gFt}}$

Genetic Materials

letter symbol	name (process status*)	
A	anthropogenic (A)	man-made or -modified materials including those associated with mineral exploitation and waste disposal.
C	colluvial (A)	products of mass wastage; includes rubbly bedrock-derived material and material derived from unconsolidated Quaternary sediments; includes earthflow, mudflow and landslide deposits and talus material. - generally consists of massive to moderately well-stratified sediments with a great range of particle sizes.
E	eolian (A)	materials transported and deposited by wind; includes dunes, loess and sheets of sand and silt. - generally consists of medium to fine sand and coarse silt that is well sorted and poorly compacted.
F	fluvial (I)	material transported and deposited by streams and rivers; alluvial materials. - generally consists of moderately to well-bedded and moderately to well-sorted gravels and/or silt.
F^G	fluvio-glacial (I)	fluvial materials that were deposited either in contact with or directly in front of glacier ice. - generally consists of non-bedded to poorly-bedded and non-sorted to poorly-sorted gravels with minor amounts of sand; evidence of collapse associated with melting ice (slump structures, kettles, irregular topography) is commonly present; includes kames, kame terraces, eskers and pitted outwash.
I	ice (A)	permanent snow and ice; glaciers.
L	lacustrine (I)	sediments that have accumulated in lakes. - generally consists of stratified and sorted sand, silt and clay, and moderately to well-sorted, rounded gravels that are the products of lakeshore wave action.
L^G	glacio-lacustrine (I)	lacustrine materials that were deposited in contact with, or directly from melting glacier ice. - typically consists of stratified silt and sand with slump and settling structures and with scattered (ice-rafted) stones; surface is irregular and/or kettled.
M	morainal (I)	material deposited directly by glaciers; till. - generally consists of compact, non-sorted and non-stratified material that contains a wide range of particle sizes and a matrix of silt or clay.
O	organic (A)	material resulting from the accumulation and decay of vegetative matter. - generally consists of peat, unstratified and locally containing minor amounts of marl and inorganic detritus.
O^B	organic (bog) (A)	peat material consisting of undecomposed to moderately decomposed sphagnum mosses; water-table is generally high; dominant vegetation is black spruce, feathermosses, sphagnum spp. and ledum spp.
O^F	organic (fen) (A)	peat material consisting of well to moderately decomposed sedges (carex spp.); watertable is commonly at the surface; vegetation dominantly consists of sedges, grasses and reeds with some shrub cover.
O^S	organic (swamp) (A)	peat material consisting of decomposed sedge or feathermoss species; water-table is generally at or above the surface; vegetation is most commonly a tree cover of cedar and spruce.
R	bedrock (I)	outcrops and rock covered by less than 10 cms of unconsolidated material.
U	undifferentiated (I)	used where more than three types of genetic material occur in close proximity and cannot be separated at the scale of mapping.

* See Qualifying Descriptors below for definition of Process Status

Modifying Processes

letter symbol	name (process status*)	description
A	avalanched (A)	slopes modified by frequent snow avalanches and by the deposition of rock debris transported by snow avalanches.
C	cryoturbated (A)	unconsolidated sediments or colluvium modified by frost heaving and churning; includes patterned ground.
D	deflated (A)	areas modified due to the removal of sand and finer particles by wind action.
E	channelled (I)	surfaces crossed by channels formed by running water; includes channels of braided streams, meander scars, and scroll patterns; channels are broad, shallow, and generally not incised.
E^G	channelled by glacial melt-water (I)	surfaces crossed by glacial meltwater channels; channels on former outwash plains are generally broad and shallow; other meltwater channels are typically narrow, flat-floored, steep-sided troughs
F	failing (A)	slopes where slow downslope movement of masses of unconsolidated material or bedrock is occurring; slopes may be crossed by tension fractures, slump scarps, or show other evidence of slow failure; also includes slopes where relatively rapid soil creep is occurring.
G	frost shattered (A)	rock surfaces covered with angular fragments derived *in situ* by frost shattering.
H	kettled (I)	surfaces marked by depressions formed due to melting of ice blocks in fluvioglacial, glacio-lacustrine or morainal sediments.
K	karst (A)	bedrock (chiefly limestone) modified by solution resulting in surface features such as sinkholes and limestone pavement, and subsurface caverns and underground drainage.
N	nivated (A)	surface modified by shallow depressions that result from frost action, meltwater erosion and mass wasting around and under snow patches.
P	piping (A)	surface modified by small, steep-sided depressions, commonly aligned along routes of subsurface drainage; results from collapse of underground conduits formed by removal of particulate matter; ("pseudokarst").
S	soliflucted (A)	surface modified by the slow downslope movement of saturated overburden across a frozen or otherwise impermeable substrate.
V	gullied (A)	surface crossed by deep, steep-sided ravines that are parallel or subparallel and result from fluvial erosion.

* See Qualifying Descriptors below for definition of Process Status

Composite Units

Composite units are employed where two or three types of terrain are intermixed or occupy such small areas that they cannot be designated as separate units at the scale of mapping. Symbols (defined below) are used to indicate the relative amounts of each terrain type, and the components are always written in decreasing order of importance.

. the components on either side of this symbol are approximately equal

/ the component in front of the symbol is more extensive than the one that follows

// the component in front of the symbol is considerably more extensive than the one that follows

eg. Mb//R — Mb is considerably more extensive than R

Mb//R.Cv — Mb is considerably more extensive than R; R and Cv are of roughly equal extent

Mb/R//Cv — R is less extensive than Mb; Cv is considerably less than R

Figure 6: Legend - surficial geology (continued)

Surface Expression

letter symbol	name	description
a	apron	a relatively gently sloping surface that is at the foot of a steeper slope and underlain by material derived from that steeper slope.
b	blanket	a mantle of unconsolidated material which has no constructional form of its own, but derives its general surface expression from the topography of the unit which it overlies; it masks minor topographic irregularities in the underlying unit and is more than 1 m thick. - if the underlying unit consists of unconsolidated materials, it is shown in the unit symbol; if no underlying unit is shown, it may be assumed to be bedrock.
f	fan	a surface that is the sector of a cone.
h	hummocky	steep-sided hillocks and hollows that are rounded or irregular in plan; slopes of 15 to 35° predominate on unconsolidated materials, and slopes of 15 to 90° predominate on bedrock; local relief is greater than 1 m.
l	level	a flat or gently inclined (less than 5°) surface with uniform slope and local relief of less than 1 m.
m	rolling	elongate or linear, parallel or subparallel hills or ridges with slopes generally less than 15° and local relief of more than 1 m.
r	ridged	elongate or linear, parallel or subparallel hills or ridges with slopes predominantly between 15 and 35° on unconsolidated materials and between 15 and 90° on bedrock.
s	steep	steeply inclined erosional slopes (scarps) with gradients commonly greater than 35° on unconsolidated materials and greater than 35° on bedrock.
t	terraced	step-like topography; includes both scarp face and the horizontal or gently inclined surface above it.
u	undulating	low hills and depressions with slopes generally less than 15° and rounded or irregular in plan; local relief greater than 1 m.
v	veneer	a mantle of unconsolidated materials which has no constructional form of its own, but derives its surface expression from the topography of the underlying unit; it reflects minor irregularities of the underlying surface, is generally between 10 cms and 1 m in thickness, and outcrops of the underlying unit are common. - if the underlying material is unconsolidated, it is included in the unit symbol; if no underlying unit is indicated, it is assumed to be bedrock.

Texture

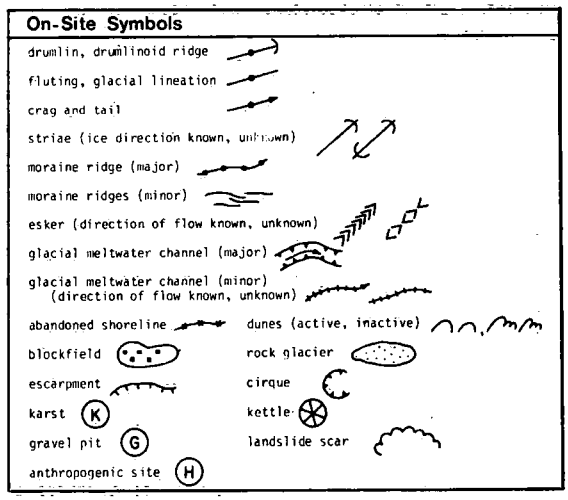
letter symbol	name	particle size (mm.)	other characteristics
b	bouldery	256	rounded & subrounded particles
g	gravelly	>2-256	rounded & subrounded particles (includes interstitial sand)
s	sandy	0.625-2	
ȿ	silty	0.0039-0.0625	
c	clayey	<0.0039	
d	diamicton		heterogeneous mixture of particles of any size, roundness or angularity in silt and clay matrix
r	rubbly	2-256	angular and subangular particles with finer interstitial material
a	blocky	>256	angular and subangular particles

Notes:- (1) The absence of a textural term from a unit symbol indicates that texture of the material was not observed in the field and cannot be reliably interpreted from air photos. The reader is referred to the general textural descriptions under the heading Genetic Materials (below).
(2) Where two textural terms are used together, they are written in order of increasing importance. eg. ȿs is silty sand, sg is sandy gravel.
(3) A diamicton texture is always implied in the case of morainal (M) materials. Any textural term written in the symbol merely modifies this basic texture. eg. ȿM indicates till consisting of silty diamicton, not silt alone.

Qualifying Descriptors

letter symbol	name	description
G	glacial	- used to qualify non-glacial genetic materials or process modifiers where there is evidence that glacier ice affected the mode of deposition of materials or the mode of operation of a process. (See F^G, L^G and E^G above).
B, F, S	bog, fen, swamp	- used where possible to supply additional information about units of organic material. (See O^B, O^F and O^S above).
A, I	active, inactive (process status descriptors)	- used to qualify genetic materials and modifying processes with regard to their current state of activity. Active: there is evidence that a modifying process is either operating continuously or is of a recurrent nature at the present time; there is evidence that the process of formation of a genetic material is operative at the present time. Inactive: there is no evidence to suggest that a modifying process is continuing or recurrent; the process of formation of a genetic material has ceased. A process status descriptor is designated for each genetic material and for each modifying process on the basis of their most common state of activity at the present time. (See process status column in Genetic Materials and Modifying Processes above). Process status descriptors are shown in unit symbols on the map only where the current state of activity is contrary to the designated state.

On-Site Symbols



Mapped by:

Fieldwork Completed:

Date of Photography:

Drafted by:

Date:

versatility of the system.

Bedrock information (e.g. chemistry, texture) forms a part of the biophysical system either by the use of existing bedrock geology maps or the application of a bedrock classification scheme designed for field description. The bedrock classification scheme presently used is given in Figure 7.

CONSOLIDATED MATERIALS

INTRUSIVE & PLUTONIC	
Acid	IA
granite	IA01
granodiorite	IA02
pegmatite	IA03
aplite	IA04
quartzorthoclase porphyry	IA05
quartzplagioclase "	IA06
Intermediate	II
syenite	II07
diorite	II08
Basic	IB
dolerite	IB09
gabbro	IB10
Ultrabasic	IU
peridotite	IU11

EXTRUSIVE	
Acid	EA
rhyolite	EA12
dacite	EA13
Intermediate	EI
trachyte	EI14
andesite	EI15
Basic	EB
basalt	EB16
Fragmental	EF
tuff	EF17
breccia	EF18
ash	EF19
cinders	EF20

METAMORPHIC

Grade	and/or	Grainsize	
Low grade	ML	Fine grained	MF
slate	ML21	slate	MF21
phyllite	ML22	phyllite	MF22
greenschists	ML23	hornfels	MF30
Medium grade	MM	Medium grained	MG
biotite schists	MM24	schists	MG31
garnet schists	MM25	amphibolite	MG32
kyanite schists	MM26	granofel	MG33
High grade	HM	quartzite	MG34
sillimaniteschist	HM27	Coarse grained	MC
gneiss	HM28	gneiss	MC28
migmatite	HM29	amphibolite	MC32
		granofels	MC33
		quartzite	MC34
		marble	MC35

SEDIMENTARY

Fine grained	SF
siltstone	SF36
mudstone	SF37
shale	SF38
chert	SF39
Medium grained	SM
sandstone	SM40
greywacke	SM41
arkose	SM42
calcarenite	SM43
quartzite	SM34
Coarse grained	SC
breccia	SC18
conglomerate	SC44
Carbonaceous	CA
lignites	CA45
coal	CA52
Calcareous	CL
limestone	CL46
dolomite	CL47
marl	CL48
travertine	CL49
Silicified	SI
quartzite	SI34
Evaporite	EV
gypsum	EV50
halite	EV51

CONSOLIDATED MATERIAL STRUCTURE

Bedding:	
flat	BE 1
gentle dip	BE 2
moderate dip	BE 3
steep dip	BE 4
Simple fold:	
anticline	SF 1
syncline	SF 2
Foliation:	
horizontal	FO 1
inclined	FO 2
vertical	FO 3
Joint:	
inclined	JO 1
vertical	JO 2
horizontal	JO 3
Lineament:	LI
Fault:	
defined	FA 1
approximate	FA 2
Massive:	MA

Figure 7: Consolidated materials classification scheme, ELUC Secretariat, 1976.

Aquatic Systems

Although not yet specifically a part of the Biophysical type in terms of terrestrial mapping, the *Aquatic Classification System* as described by Chamberlin *et al.* (1976) provides a physical and biological description of aquatic systems in British Columbia. The common approach between the terrestrial and aquatic systems is the treatment of the domains in a relatively holistic manner, encompassing all the different landscapes which occur within its intended area of application. Like other resource inventory schemes, the Aquatic System defines a relatively homogeneous unit (stream reach unit) and the properties of that unit are measured. The working scale for application of the system as part of the reconnaissance inventory is 1:50,000.

Figure 8 indicates the various categories of information available following the inventory. The broad categories, more fully expressed by the legend, are:

1. Physical channel and bank characteristics.
2. Substrate type.
3. Aquatic and land vegetation.
4. Fish species present and their life history.
5. Hydrology.

These data then serve as the basis for a multitude of resource evaluation interpretations when required. A computer storage system for non-mapped stream system data is being developed. Access will be by watershed systems.

Soil

Pedological characteristics of the various landscapes defined by the physiographic, geological (surficial and bedrock) and vegetation systems, are measured and defined. Soils are described and classified according to the *System of Soil Classification for Canada* (Can. Soil Surv. Comm., 1974). As a consequence, the soil mapping provides the concept of the *map individual* for ecological classification. This is a direct result of the functional relationship expressed earlier, showing that soil is the integration of all these environmental characteristics. The study of soil is one key to understanding the complex environmental relationships.

Soil mapping in British Columbia at the reconnaissance level (1:50,000) employs the soil association as the map unit. Through the recognition in the field of *polypedons*, members of the soil association are described. Here a soil association is meant to mean a natural

Figure 8: Aquatics biophysical legend

Scale 1:50,000

REACH SYMBOLS

GENERAL: FISH SPECIES / CHANNEL | SUBSTRATE

Fish Species

1. Sport and Commercial abbreviations

Symbol	Species	Symbol	Species
Ch	Chinook salmon	LT	Lake trout
Co	Coho salmon	GB	German Brown trout
Cm	Chum salmon	MW	Mountain Whitefish
Pk	Pink salmon	LW	Lake Whitefish
Sk	Sockeye salmon	Gr	Grayling
Ko	Kokanee salmon	LMB	Largemouth bass
Rb	Rainbow trout	SMB	Smallmouth bass
St	Steelhead trout	NP	Northern pike
Ct	Cutthroat trout (Coastal)	WP	Walleye pike (Pickerel)
		YP	Yellow perch
YCt	Yellowstone Cutthroat trout	Sg	Sturgeon
		Bb	Ling (Burbot)
EB	Eastern Brook trout	Cp	Carp
DV	Dolly Varden Char		

2. OS - indicates known but non-sport or non-commercial species, data bank must be consulted for complete species list.
3. Sp - indicates fish observed but not indentified.
4. Ø - indicates fish not detected at time and place of sampling.
5. Absence of any fish species symbol indicates that no sampling information was available.
6. (Co) - indicates probable but unconfirmed presence.
7. Skt - indicates reach used by species for migration only, no resident population.
8. Note: no specific symbol exists for a barren stream. When such a condition is suspected, it may be indicated by (Ø) which is an inference that if sampling took place, fish would not be detected.

Channel

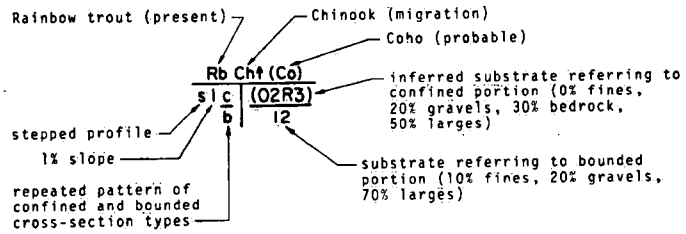
1. Longitudional Profile:
   - s - stepped — repetitious sequence of slopes or forms
   - r - regular — homogeneous or continuous profile
2. Slope: % (elevation gain/reach length)
   - > 3% measured to nearest percent
   - < 3% measured to nearest tenth percent
3. Cross-section
   - c - confined — (channel is entrenched or lateral movement is controlled by banks)
   - b - bounded — (channel movement is limited by valley walls near the edge of the floodplain)
   - u - unconfined — (channel is not bounded by valley wall and much lateral movement or flooding is possible at high flows)

Substrate Materials

Fines, gravels and bedrock are listed in sequence to nearest 10%, expressed as an integer. Larges are inferred. (see example)

1. fines - materials in 0-2 mm size class
   gravels - materials in 2-100 mm size class
   larges - materials greater than 100 mm in size
2. Bedrock percentage indicated by Rn, where integer n represents percentage. R without integer implies 0-10%.
3. F, G, L or R used alone indicates 90-100% of a reach is in one category size, fines, gravels, larges or rock respectively.

Example



Note: 1) where the channel or substrate component is man-made, the symbol is underlined.

2) where channel or substrate data has not been verified the symbol is placed in parentheses

HEADWATER CLASSES

1. Slope
   - I > 5%
   - II < 5%
2. Cross-section
   - c: confined
   - u- unconfined
3. Wetland Class
   - m - marsh
   - b - bog
   - f - fen
   - s - swamp
   - p - pond

eg. Ic(b) - a steeply sloping confined channel, probably through an alpine bog.

Note: slope and cross-section may be used alone.

LAKES

General: Fish Species | T.D.S. / Max. depth | Littoral area

1. Fish species: same as streams
2. T.D.S.: total dissolved solids, if available
3. Maximum depth: measured to nearest meter.
4. Littoral area: measurement or visual estimate of % of total area < 6m. When estimate is made, parenthesis will be used.

SITE SPECIFIC STREAM SYMBOLS

- 3R — An obstruction 3 m high of the following types: R (Rock), L (Logs), B (Blocks), D (Man-made), Bd (Beaver dam), θ (Culvert), F (type unknown)
- 5R50 — A chute or cascade 5 m high and 50 m long of the above types
- C — A chute or cascade with details unknown
- Bd — A sequence of beaver dams
- Ch — Clear evidence (eg: persistent redds or observed spawning adults) of spawning by the indicated species.
- A zone of flood and side channels
- A persistent debris accumulation
- A culvert
- A bridge. (Chan = a channelized channel.)
- 2 — A site (point) number with biophysical data available
- 4 — A water quality sampling site number
- 7 — A water quantity sampling site number
- R3 — A reach boundary. R3 indicates beginning of 3rd reach.
- 20R — A reach boundary which is an obstruction. The obstruction height is not to be included in either adjacent reach for the purposes of reach slope calculation.
- A major bank or valley side wall slump zone.
- An alluvial sink hole without surface effluent
- K — A karst pothole
- Persistent snow or ice
- Major watershed boundary
- Sub-watershed boundary
- Minor watershed boundary

23.0400.020.010 indicates watershed system code number

Definitions and methods are available from Resource Analysis Unit, ELUC Secretariat. Mapping and drafting services provided by RAU, _____. Date of fieldwork _____.

Figure 9: Example computer output from soil data file

SOIL: BLIZZARD UNIT TYPE: ASSOCIATION

DATE OF SURVEY: 26 09 70 SURVEYOR: JRJ KELOWNA. SOILS DIV.: BCDA.

LOCATION		CLASSIFICATION		SLOPE	
LATITUDE (N)	49 02 30	MINI HUMO-FERRIC PODZOL		%	65
LONGITUDE (W)	116 56 00			TYPE	SIMPLE
PRECISION (SEC)	15	STATUS: MODAL SOIL (NO DEVIATION)		CLASS	H
ELEVATION (FT)	5000			ASPECT (DEG)	270
AIR PHOTOGRAPH	BC5348 112			PROFILE SITE	TOE
CLIMATE REF.	CRESTON			LENGTH (YDS)	500
RELEVANCE	POOR				

PARENT MATERIAL & LANDFORM

TEXTURAL MODIFIER	SILTY
UNCONSOLIDATED COMPONENT	COLLUVIAL
LANDFORM	VENEER
UNCONSOLIDATED COMPONENT	BEDROCK
LANDFORM	STEEP SLOPE

STONINESS	MODERATELY	FLOOD HAZARD	NO HAZARD	DRAINAGE	MODERATELY WELL
ROOTING DEPTH	31 IN.	SEEPAGE	ABSENT		

HORIZON	THICKNESS DEPTH (IN)	HORIZON BOUNDARY	COLOUR D=DRY M=MOIST		TEXTURE	STRUCTURE 1
L-H	-1- 0	ABRUPT				
B FH	0- 7	CLEAR	7.5 YR 3/2	(M)	LOAM	WEAK SUBANGULAR BLOCKY
B F	7-16	CLEAR	7.5 YR 4/4	(M)	LOAM	WEAK SUBANGULAR BLOCKY
BC	16-26	GRADUAL	10 YR 5/6	(M)	FINE SANDY LOAM	SINGLE GRAIN
CB G	26-31	ABRUPT	10 YR 5/6	(M)	FINE SANDY LOAM	SINGLE GRAIN
R	31-					PLATY

HORIZON	CONSISTENCE	ROOTS 1
L-H		ABUNDANT
B FH	FRIABLE	ABUNDANT
B F	FRIABLE	ABUNDANT
BC	FRIABLE	ABUNDANT
CB G	FRIABLE	PLENTIFUL
R	EXTREMELY HARD	VERY FEW

CHEMICAL TABLES

HORIZON	PH1 SAMPLE STATE	PH1 METHOD	PH1 VALUE	PH2 SAMPLE STATE	PH2 METHOD	PH2 VALUE	ORGANIC CARBON	PYROPHOSPHATE EXT. CARBON %	NITROGEN %
L-H	2	2	4.7	2	4	4.4	27.90		.98
B FH	2	1	4.7	2	4	4.4	4.26	2.52	.21
B F	2	1	5.3	2	4	4.9	1.94	1.07	.09
BC	2	1	5.3	2	4	5.1	.52		.04
CB G	2	1	5.4	2	4	5.1			
R	2	1	6.5	2	4	6.1			

HORIZON	EXCHANGEABLE CATIONS CA	MG	NA	K	C.E.C. DETERMINED	EXTRACTABLE FE METHOD	RESULT	METHOD	RESULT	EXTRACTABLE AL METHOD	RESULT
L-H											
B FH	.41	.12	.04	.29	22.8	1	1.1	3	.6	1	1.7
B F	.31	0.00	.06	.17	12.9	1	.8	3	.1	1	1.5
BC	.30	0.00	.01	.07	5.7			3	.0		
CB G	.51	.07	.02	.06	5.0			3	.1		
R											

HORIZON	METHOD	RESULT	P1 PPM.	P2 PPM.	S PPM.
L-H			28.2	37.4	53.7
B FH	3	1.0	12.9	29.0	16.0
B F	3	.4	5.5	17.8	19.1
BC	3	.2	20.5	57.5	28.6
CB G	3	.2	35.7	57.6	13.4
R				15.4	

grouping of soil associates based on similarities in climate or physiographic factors and soil parent materials (Agriculture Canada, 1976). The member of the soil association following manipulation according to the other disciplines mentioned, is the *Biophysical type*, recognized in the inventory system. The difference between a soil association as defined by the Canada Soil Survey Committee (CSSC) and the biophysical type is recognized, but confusion still exists since the same geographic names are used for both. This is as yet unresolved.

Discussion

As a result of the vast amount of data being collected, computer storage/retrieval systems have been implemented for pedological, vegetation, climatic and aquatic information. In a brief and cursory manner, it is worth noting that the systems will allow not only quick, accurate data retrieval and hence remove the need to have the often mundane tables of physical/chemical/climatic data, but also the ability to manipulate the data and hence ask specific questions of the data, to provide some specific interpretation. Figure 9 displays a portion of output from the soil data file, to illustrate the basic data stored.

In order to illustrate the application of the *Biophysical System*, the legend for the biophysical map of a section of the West Kootenays is given in Figure 10. This legend illustrates the succession from physiographic region, to vegetation zone, to parent material (bedrock and surficial geology) and finally to soil association member of biophysical type. Figure 11 schematically illustrates this concept by showing the flow of information and some of the possible interpretations from the data base.

Due to scale limitations and landscape complexity, it is not always possible to map each of these biophysical types individually. To alleviate the confusion which may result as a consequence of this, each type is described as much as possible through the combination of an extended legend, cross-sectional diagrams and land resource reports. Figure 12 provides an example of a typical cross-sectional diagram, illustrating the breakdown of the landscape into the various soil association members.

This approach to land classification in British Columbia provides an integration of the functional elements of the ecosystems and presents this in a format which is simple and practical in terms of providing data for identifying resource opportunities and constraints and hence facilitate scientific land use planning. In this manner, the objectives as outlined earlier are met.

APPLICATION

Although it is not possible to illustrate every application of the biophysical system, suffice it is to say that the biophysical map unit forms the basis for resource analysis including land capability, and land use planning as well as management. As a consequence of its systematic structure, it also provides the physical, chemical and biological data bases which may be inherent in any of its parts. For example, any application requiring only surficial geological data will only require that map and set of data. This is easily retrievable due to the structure of the system.

The following discussion is directed toward pointing out some of the more important examples of application through a brief discussion of the methods and in some cases by illustration. Appendix 1 contains a set of maps which illustrate those particular parts of the province where information is available on particular resource themes. The examples shown are not exhaustive and reference should be made to the Catalogue of Maps and Publications (ELUC Secretariat, 1976c).

Land Capability

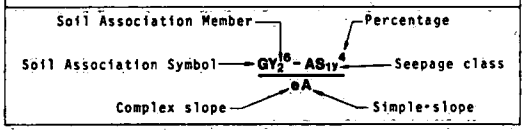
The term 'land capability' refers to the inherent, natural opportunities afforded by renewable resources prior to planning and management. The interpretive systems first described and applied under the CLI System have in some cases been modified to suit particular characteristics in British Columbia, but are still part of the 'routine' set of interpretations made from biophysical data.

Land capability for forestry (Kowall, 1971) and soil capability for agriculture (Runka, 1971) are more or less unchanged from those methods of application defined by the CLI. The climate capability for agriculture is presently being revised by the Resource Analysis Unit, and although it will follow the same rationale, some of the technical ways in which data are interpreted will change.

The land capability for wildlife (ungulates) is also under revision. Although it is as yet not finalized, some inventory projects have applied the methods of classification in use. Figure 13 illustrates a portion of the legend from an ungulate capability map for elk in the northwestern part of the Province. Maps were also drawn for moose and goat. This legend points out the biophysical features considered in this interpretation.

Figure 10: Condensed soil legend for the Cranbrook P.S.Y.U. (Map sheets 82G and J)

Example of Symboling System



Biophysical Soil Association

Map Symbol	Soil Name	Modal Soil Dev't	Generalized Landform	Vegetation Zone
AS	Avis	ODB	gF	wC-wH
AZ	Abruzzi	OGL	ǵL *	D
BB	Brennan	ODB	rCv	alF-eS(D)
BC	Beatrice	OHFP	rCv	alF-eS
BF	Big Fish	OEB	rCv*	D
BH	Buhl	OHFP	rCv	alF-eS
BK	Bohan	OHFP	rCv	alF-eS(D)
BN	Burton	ODB	rCv	wC-wH
BO	Bonner	OHFP	rCv	alF-eS
BP	Bunyon	OHFP	rCv	alF-eS
BS	Badshot	ODB	rCv*	alF-eS(D)
CA	Conrad	OHFP	rC	alF-eS
CB	Coubrey	ODB	rC	alF-eS(D)
CD	Cedrus	OEB	rC*	D(pP)
CE	Cayuse	ODB	rC	wC-wH
CF	Clifty	OHFP	rC	alF-eS
CG	Cummings	ODB	rC	D
CH	Champion	OHFP	rC	alF-eS
CHN	Chauncy	BrGL	rC*	alF-es(D)
CJ	Cornwell	BrGL	rC*	D
CL	Calamity	OHFP	rC	alF-eS(D)
CLD	Cold Creek	ODB	rC	D
CM	Columbia	OHFP	rC*	alF-eS
CP	Cooper	OHFP	rC	alF-es(D)
CR	Cervil	OEB	rC*	D
CW	Couldron	ODB	rC*	alF-eS(D)
E	Elko	OEB	sFv* / gF	D(pP)
F	Flagstone	OEB	sF *	D(pP)
FF	Fenwick	CuR	sFl*	D
FH	Flathead	CuR	gFl	alF-es(D)
FK	Font	GlCuR	gFl	alF-eS
FL	Flatbow	BrGL	ǵM*	D
FR	Fletcher	ODB	gFf	wC-wH
FS	Fort Steele	CuR	gFl*	D(pP)
FT	Fruitvale	OHFP	gFf	alF-eS(D)
FU	Fourpoints	CuR	gFl*	alF-eS(D)
FV	Festubert	GlCuR	gFl*	alF-eS
FX	Fisher	OEB	gF	D(pP)
FY	Forsyth	CuR	gFl	D
GB	Gagnebin	ODB	gF*	alF-eS(D)
GC	Grace	ODB	gF	D
GL	Gold	OHFP	gF	alF-eS
GN	Glen Cairn	ODB	gF	D
GT	Galton	OHFP	gF	alF-eS(D)
GY	Glenlily	ODB	gF	wC-wH
H	Hyak	ODBC	sFv / gF	D(pP)
K	Kinbasket	OGL	ǵM*	D(pP)
KA	Kaslo	OHFP	gF	alF-eS(D)
KE	Keen	OEB	gF*	D
KG	Kingcome	OHFP	gF*	alF-eS
KO	Kokum	OEB	sFl	D(pP)
KR	Kinert	ODB	gF	wC-wH
KY	Kayook	OEB	sEv* / gF	D(pP)
L	Lakit	OEB	sFv / gFl	D(pP)
LI	Linten	OHFP	ǵL*	alF-eS
LN	Lancaster	BrGL	ǵL*	alF-eS(D)
LY	Lawley	BrGL	ǵL	wC-wH
M	Mayook	OEB	ǵL*	D(pP)
MC	Marconi	OHFP	ǵM*	alF-eS
MD	Marmalade	OEB	ǵM*	D
MF	Mansfield	ODB	sM	D
MI	Moyie	BrGL	ǵM	alF-eS(D)
MM	Mount Mike	BrGL	ǵM*	alF-eS(D)
MN	Minton	OHFP	sM	alF-eS
MS	Malpass	BrGL	ǵM	D
MX	McKay	PGL	ǵM*	alF-eS
MU	Maiyuk	ODB	sM	alF-eS(D)
O	Oldtown	OEB	sF	D(pP)
OD	Odlum	TyH	O	alF-eS
OL	Olivia	TyH	O	D(pP)
ON	O'Neill	TyH	O	alF-eS(D)
OS	Olson	TyH	O	D
P	Plumbob	ODBC	ǵM*	D(pP)
RA	Radium	SHFP	rCv*	at-alF-eS(K)
RB	Rock Bluff	OEB	rCv*	D(pP)
RD	Rabbit	BrGL	rCv*	D
RL	Rossland	SHFP	rCv	at-alF-es(K)
RP	Round Prairie	ODB	rCv	D
RT	Ruault	OHFP	rCv*	alF-eS
RX	Rosen	BrGL	rCv*	alF-eS(D)
RY	Ryan	ODB	rCv	D
S	Salishan	CuR	ǵFl*	D(pP)
SA	Saha	ODBC	gF*	D(pP)
SH	Swehaw	OHFP	sM	alf-eS
SL	Sentinel	OHFP	sM	alF-eS(D)
SM	Spillimacheen	OEB	ǵM*	alF-eS(D)
SN	Sandon	OHFP	ǵM	alF-eS
SS	Sheilds	LuHFP	ǵM	alF-eS(D)
SY	Skelly	BrGL	ǵM	wC-wH
WY	Wycliffe	OEB	ǵM*	D(pP)
YK	Yahk	OR	rCa*	at-alF-eS(D)
YR	Ymir	OR	rCa	at-wH(wC)

Soils Nomenclature

ODBC	Orthic dark brown chernozem
OEB	Orthic eutric brunisol
ODB	Orthic dystric brunisol
DDB	Degraded dystric brunisol
OHFP	Orthic humo-ferric podzol
SHFP	Sombric humo-ferric podzol
LuHFP	Luvisolic humo-ferric podzol
OGL	Orthic gray luvisol
BrGL	Brunisolic gray luvisol
PGL	Podzolic gray luvisol
CuR	Cumulic regosol
GlCuR	Gleyed cumilic regosol
OR	Orthic regosol
TyH	Typic humisol

Landform Nomenclature

Texture ← sFl* → Surface Expression

ǵ - silty
s - sandy
g - gravelly
r - rubbly

Genetic Materials
M - moraine (till)
C - colluvial
F - fluvial
E - aeolian
L - lacustrine
O - organic
* - calcareous genetic materials

v - veneer (<1m. deep)
l - level (<5° slope)
f - fan
a - apron

Vegetation Zonation

D(pP)	Ponderosa pine subzone of the Douglas fir zone
D	Douglas fir zone
alF-eS(D)	Douglas fir subzone of the subalpine fir-Engelmann spruce zone
alF-es	Subalpine fir-Engelmann spruce zone
alF-eS(K)	Krummholz subzone of the subalpine fir-Engelmann spruce zone
at	Alpine tundra
wC-wH	Western red cedar - western hemlock zone

Numbering System for Biophysical Soil Associations

i.e. the XX association

XX_1	modal (typical) soil
XX_2	modal soil major - drier soil minor
XX_3	modal soil major - wetter soil minor
XX_4	modal soil major - different soil development minor
XX_5	modal soil major - lithic soil minor
XX_6	lithic soil major - modal soil minor
XX_7	modal soil major - regosol (talus) soil minor
XX_8	modal soil major - avalanche chute soil minor
XX_{9-12}	used for units with modal and other minor types of soil

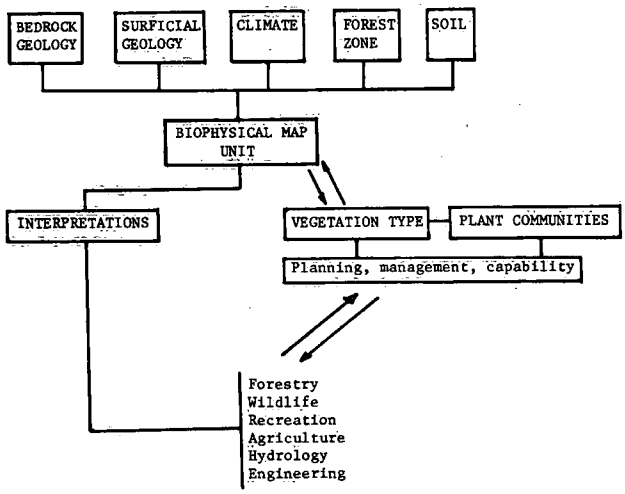
Topographic Classes

Simple Topography		Complex Topography		Slope
Single Slopes (regular surface)		Complex Slopes (irregular surface)		%
A	depressional to level	a	nearly level	0-0.5
B	very gently sloping	b	gentle undulating	0.5-2
C	gently sloping	c	undulating	2-5
D	moderately sloping	d	gently rolling	5-9
E	strongly sloping	e	moderately rolling	9-15
F	steeply sloping	f	strongly rolling	15-30
G	very steeply sloping	g	hilly	30-60
H	extremely steeply sloping	h	very hilly	>60

Seepage Modifiers

v	a minor part of the soil unit is transmitting telluric seepage water (ie. mid to lower slopes with some moister areas).
w	a major part of the soil unit is transmitting and receiving telluric seepage water (ie. lower slopes with most areas moister than the modal soil).
x	a major part of the unit is receiving and collecting telluric seepage water and shows some evidence of gleying (ie. a gleyed podzol at the toe of a slope).
y	a minor part(s) of the unit is collecting stagnant water and has gleysolic soils (ie. the wet depressions on a glacial-fluvial plain).

Figure 11: Parameters inherent in the definition of the Biophysical Map Unit



The recreation capability system (Block, 1975) has been revised from the original CLI method. Specifically, this system provides for physically separating (2 maps) the assessment of the inherent limitations of the land and water for outdoor recreation and the classification of the land and water for outdoor recreation values (recreation features and attractions). The CLI System did not have this ability. As a result, this new system allows for considerable flexibility in application and scale. Figure 14 contains a portion of the legend from a recreation capability and recreation features map and illustrates those biophysical characteristics considered.

Engineering

Engineering-related interpretations of biophysical data are mainly related to the surficial geology and soils data bases and climate information. Commonly, those interpretations are expressed as degrees of limitation or suitability for a particular engineering use. Data that are used for these interpretations are a combination of laboratory analyses and estimated properties. An example of the estimated properties considered is presented in Table 1 (Cotic, van Barneveld and Sprout, 1974). Interpretations made using this and other data for the same soil report area are shown in Table 2.

By providing tables such as these in the land resource report, a person using the information can readily apply the interpretations directly to the soil map. In this way, the number of maps can be kept to a minimum and the engineering information can be directly used in planning and management.

Silviculture (Timber Management)

Silvicultural interpretations are commonly of two types. One set that addresses those features which directly affect timber management and another set which indicates the effect on soils and other resources of timber harvesting

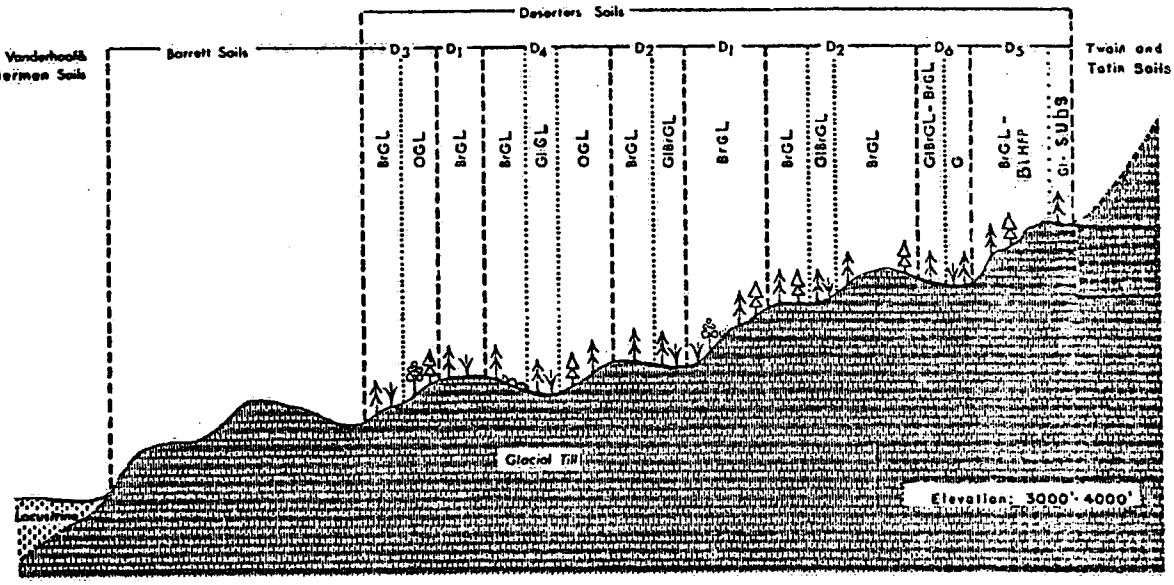


Figure 12: Typical cross-sectional diagram used in land resource reports to describe soil association members and vegetation (Cotic et al. *1974)*

Figure 13: One type of legend presently in use for ungulate capability mapping. (Luckhurst, 1975)

Biophysical capabilities for wildlife - elk

DESCRIPTIVE LEGEND

On this reconnaissance map, the land is divided into units on a biophysical basis which takes into account geology, landform, relief, soils and vegetation. The biophysical framework is the same as that used for capability inventories of forestry, agriculture, native forage and recreation in the map area. Base data maps of soils, landforms, vegetation and climate as well as biophysical capability maps for forestry, recreation and agriculture are available from the Resource Analysis Unit, E.L.U.C. Secretariat, Victoria.

CAPABILITY CLASSIFICATIONS

Capability ratings are established on the ability of the land to meet the total needs of the wildlife species over the long term. In terms of food and cover needs, the ratings are based on the optimum vegetational stage (successional stage) that can be maintained assuming good management practices that do not degrade the environment or land base. The application of management prescriptions are limited to the following non-intensive practices:

1) Prescribed burning or grazing.
2) Prescribed logging or occasional slashing.
3) Protection from fire or any land-use practice that would reduce the productivity of the land for the wildlife species.

When assigning capability ratings, map units are evaluated on the basis of their position in the ecosystem as a whole and not in isolation.

Capability ratings reflect only biological and physical parameters of the environment and do not take into account human elements such as social or economic parameters.
Capability ratings assigned do not reflect present land use, ownership, lack of access, distance from cities, or amount of hunting pressure.

Carrying capacity estimates based on the number of animals which can be supported annually on a sustained basis are assigned to each capability class as a measure of productivity.

CLASS 1 LANDS IN THIS CLASS HAVE THE LEAST LIMITATION TO THE PRODUCTION OF ELK.

They can provide a wide variety and abundance of food plants and other necessary habitat elements. These very high capability lands can support an estimated 26 to 51 elk per square mile annually.

When required, this class may be subdivided on the basis of productivity into Class 1a (26 to 34 elk per square mile per year), Class 1b (34 to 43 elk per square mile per year) or Class 1c (43 to 51 elk per square mile per year) etc. using an increment equivalent to 25% of the upper figure for Class 1a.

CLASS 2 LANDS IN THIS CLASS HAVE SLIGHT LIMITATIONS TO THE PRODUCTION OF ELK.

Capability on these lands is high, but less than Class 1. These lands can support an estimated 17 to 26 elk per square mile annually.

CLASS 3 LANDS IN THIS CLASS HAVE MODERATE LIMITATIONS TO THE PRODUCTION OF ELK.

Capability on these lands is moderate to moderately high and they can support an estimated 9 to 17 elk per square mile annually.

CLASS 4 LANDS IN THIS CLASS HAVE MODERATELY SEVERE LIMITATIONS TO THE PRODUCTION OF ELK.

Capability on these lands is moderate to moderately low and they can support an estimated 2 to 9 elk per square mile annually.

CLASS 5 LANDS IN THIS CLASS HAVE SEVERE LIMITATIONS TO THE PRODUCTION OF ELK.

Capability on these lands is very low and it is estimated they can support less than 2 elk per square mile annually.

CLASS 6 LANDS IN THIS CLASS HAVE LIMITATIONS SO SEVERE THAT THERE IS NO PRODUCTION OF ELK.

L.C.: low capability - this designation applies to extensive areas which are low or lacking in habitat potential for a species and are therefore excluded from classification. It is also applied to lands on which man's activities have more or less permanently obscured or eliminated the habitat potential for a species.

SUBCLASSES

The most significant environmental factors limiting the production of the species and thus determining the capability class, are indicated on the map by subclasses. In most cases, the limitations do not affect the animals themselves, but rather the ability of the land to meet the needs of the species in terms of food, cover, and other requirements. For convenience, the subclasses are placed in three main categories: those relating to climate; those relating to the inherent characteristics of the land and those relating to the vegetative cover which, although reflecting characteristics of the land and/or climate, are not adequately covered or explained by limiting subclasses in these categories.

LIMITATIONS OF CLIMATE

SUBCLASS A: aridity - Drought or aridity that adversely affects the habitat.

SUBCLASS C: climate - A combination of climatic factors acting to reduce favourable habitat and the production and survival of the ungulate species.

SUBCLASS Q: snow depth - Excessive snow depth that reduces the mobility of the ungulate species or the availability of food plants.

SUBCLASS U: exposure - Exposure to extreme climatic factors such as extreme or drying winds that adversely affect the species or its habitat.

LIMITATIONS OF THE LAND

SUBCLASS E: erodability - Maintenance of optimum vegetation for food and cover restricted at assumed management level due to susceptability to soil erosion ranging from sheet erosion through minor gullying.

SUBCLASS F: fertility - Lack of available nutrients in the soil for optimum plant growth.

SUBCLASS G: landform - Poor distribution of interspersion of landforms necessary for optimum habitat.

SUBCLASS I: inundation - Excessive water level fluctuation or tidal action that adversely affects the habitat or survival of the species.

SUBCLASS M: soil moisture - Poor soil moisture, either excessive of deficient.

SUBCLASS N: soil chemistry - Excessive salinity, lack of essential trace elements or abundance of toxic elements in the soil.

SUBCLASS R: soil depth - Restriction of the rooting zone by bedrock or other impervious layers.

SUBCLASS S: soil sensitivity - Maintenance of optimum vegetation restricted at assumed management level due to susceptibility to loss of soil nutrients through leaching.

SUBCLASS T: adverse topography - Either steepness or flatness of the land.

SUBCLASS W: mass wasting - Extensive erosion processes, active or potential, as in talus slope or slope failure situations.

LIMITATIONS OF VEGETATION

SUBCLASS D: dense regeneration - Maintenance of optimum vegetation for food and cover restricted at assumed management level by susceptibility to dense regeneration of vegetation.

SUBCLASS V: rapid seral succession - Maintenance of optimum vegetation for food and cover restricted at assumed management level by rapid seral succession. Maintenance of a more favourable condition is either beyond assumed management levels or would result in impairment of the land base over time at assumed management levels.

SPECIAL CLASS INDICATORS

The following are used to denote known habitat elements considered critical to the distribution or abundance of the species.

Seasonal concentration areas are shown by the following symbols:

W: areas of winter concentrations
Sp: areas of spring concentration
S: areas of summer concentration
F: areas of fall concentration

L: denotes mineral licks used by the species

denotes an important movement corridor for the species.

CONVENTIONS

Large arabic numerals denote capability class.

Small lower case letters placed after capability class 1 denote a subdivision of that class.

Large upper case letters placed after the capability class indicate the special class indicator.

Small arabic numerals placed after class numeral, class subdivision letter or special class symbol indicate the approximate proportion (in tenths) of the complex that is represented by that class. The dominant class appears first in the symbol.

Small upper case letters placed after class numeral, class subdivision letter or special class indicator denotes the subclass.

For a more detailed description of the classification system the reader should refer to the manual of Biophysical Capability Classification for Wildlife (Ungulates) in British Columbia. This manual presently at print will be available from the Resource Analysis Unit, E.L.U.C. Secretariat, Victoria, B.C.

EXAMPLES

An area of class 5 land with snow depth, dense regeneration and landform limitations is shown thus:

5^{Q}_{DG}

A class 1a fall concentration area with limitations due to snow depth is shown thus:

$1aF^{Q}$

An area of which 70% is class 5 with limitations due to exposed bedrock and snow depth and 30% is class 3 wintering area with limitations due to snow depths and exposure to extreme winds is shown thus:

$5^{7}_{RQ}\text{-}3W^{3}_{QU}$

activities. Examples of these two groups, illustrating the use of biophysical information in timber management, include:

1. Interpretations which directly affect timber management:

a) windthrow hazard
b) susceptibility to brush revegetation
c) susceptibility to alder revegetation
d) potential for natural regeneration
e) limits of regeneration
f) recommended tree planting species

Figure 14a: Outdoor recreation features inventory

Recreation features are considered to be aspects of land and water units providing opportunity for recreation. In an inventory program, they represent the major natural and cultural features of the land for recreation, and indicate the types of recreation activities which might occur on a unit.

Symbolization

Each recreation features unit may have up to five seperate types of symbols:-

(1) Feature Symbol - a capitalized letter indicating the general recreation feature identified analogous with CLI recreation feature category.

(2) Feature Modified (Optional) - a lower case letter may accompany the feature symbol to give a more specific definition of the recreation feature.

(3) Sub-Feature Category - a numeral immediately following the feature symbol or feature modifier to provide more detailed information on the recreation feature.

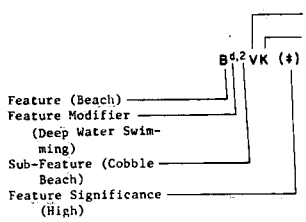
(4) Feature Significance - each unit will be given one of five symbols indicating feature significance.

(5) Feature Annotation (Optional) - a feature or set of features on a given unit may be accompanied by a numerical annotation indicating that additional information concerning the recreation feature(s) is on file. Annotations will be recorded on the basis of 1:250,000 NTS map sheets.

Examples:

Single Feature E^2 ⓪ - a unit of unique vegetation of very high significance

Multiple Feature



A unit with a cobble beach fronting water with opportunities for deep water swimming accompanied by significant viewing opportunities and capability for organized camping.

Feature Significance

Five classes or categories of feature significance are defined. Quality is the primary basis for assessing feature significance. This is related primarily to a feature's "attractivity" or ability to hold people's interest. Any one feature should be ranked on the basis of that kind of feature only. For example, the "best" wildlife features should rank as high in feature significance as the best "beaches".

⓪ Very High Feature Significance

Units in this class have a very high ability to attract recreational use. Features in this category would be of national significance.

(*) High Feature Significance

Units in this class have a high ability to attract recreational use. Features in this category would be of provincial significance.

(+) Moderate Feature Significance

Units in this class have a moderate ability to attract reacreation use. Features in this category would be of regional significance.

(-) Low Feature Significance

Units in this class have a low ability to attract recreational use. Features in this category have a natural attractivity that is common throughout the map area.

(=) Very Low Feature Significance

Units in this class have a very low ability to attract recreational use. There are no features in this category which stand out. They may, however, be some attraction for specialized recreational activities or they may merely provide open space.

BIOTIC FEATURES	Aquatic biotic features	A1	Angling
		A2	Aquatic habitat
		A3	Fish run observation
		A4	Aquatic foods
	Vegetation	E1	Zonal vegetation
		E2	Unique vegetation
		E3	Edible plants
	Wildlife	W1	Upland birds
		W2	Water birds
		W3	Small mammals
		W4	Large mammals
		W5	Unique wildlife
PHYSICAL GEOGRAPHIC FEATURES	Hydrologic	D	Hydrologic feature
	Waterfalls	F1	Site-specific waterfall
		F2	Waterfall landscape
		Fv	Waterfall viewing
	Glacier & Snowfield	G1	Glacier interpretation
		G2	Snowfield
	Springs	T1	Warm springs
		T2	Cold springs
		Tz	Developed hotsprings
		Tr	Spring mineral deposit
	Landforms	L	Landform feature
	Rock Formation	R1	Rock formation
		R2	Mineral Deposit
		R3	Fossils
		R4	Rock climbing
	Landscape Features	M	Small surface waters
		Q	Topographic patterns
		Q1	Hiking
		V	Viewing
POPULAR WATER-ORIENTATED FEATURES	Beaches	B1	Sand beach
		B2	Cobble beach
		B3	Rock beach
		B4	Fine-textured beach
		Bf	Family bathing
		Bd	Deep water swimming
		Bn	Non-swimming
	Canoeing	C1	Canoeing - open boats
		C2	Specialist boating
	Harbour/moorage	U	Harbour/moorage potential
		Uz	Harbour/moorage facility
	Boating	Y1	Family boating
		Y2	Deep water boating
		Y3	Sailing
WINTER SPORTS FEATURES		S1	Cross-country winter sports
		S2	Ice surface features
		S3	Downhill skiing
	Native/Indian	Ha1	Archaeologic site
		Ha2	Pictograph/petroglyph
		Ha3	Legend sites
	European	Hb1	Historic sites
		Hb2	Monuments
		Hb3	Historic routes
	Cultural	P	Vacant urban land
		P1	Cultural site
		P2	Pastoral landscape
	Man-made	Z	Man-made feature
DEVELOPMENT SITE POTENTIAL		K	Potential camping, etc.
MISCELLANEOUS FEATURES		X	Miscellaneous features
		8	Built-up (urban) areas

2. Those features which directly affect soils and other natural resources induced by timber harvesting:

a) type of damage expected during and subsequent to timber harvesting operations
b) recommended slash disposal methods
c) considerations for management practices.

Environmental Impact Analysis

The use of natural resource data such as those provided by the biophysical system in assessing environmental impacts is well documented by many studies across Canada. One example of direct use of this data base in British Columbia is the Guidelines for Coal Development (ELUC Secretariat, 1976d). Implicit in these guidelines during the initial assessment of possible

Figure 14b: Inventory of the physical carrying capacity for outdoor recreation

Physical carrying capacity may be defined as the inherent ability of the landscape to sustain recreational use. Various environmental factors set limits beyond which no major increases in recreational use can occur. If an increase in the use does occur beyond these limits, excessive damages to the physical environment may result.

The designation of carrying capacity units is based mainly on soils, landform and vegetation information. Climate, wildlife and hydrologic data have been used when available.

These carrying capacity maps apply mainly to spring, summer and fall recreational use. The full amount of information necessary to produce a winter recreation carrying capacity inventory was not available.

CARRYING CAPACITY CLASSIFICATION

The carrying capacity classes represent the relative quantity of recreational use that can be sustained per unit area of land per year. No attempt at present has been made to relate actual numbers of users to the individual classes. This is due to a current lack of useful research information on this subject.

Class 1 carrying capacity indicates that a high amount or intensive type of recreational use can be sustained. The other three classes with their increasing number and/or severity of limitations reflect a decreasing ability to sustain intensive use.

Lower carrying capacity classes will permit extensive use activities within certain landscapes.

Carrying capacity classes are based only on biological and physical parameters of the environment, and do not reflect social or economic features. They do not reflect present land use ownership, lack of access, or distance from cities. (Note: present land use is reflected in the man-made limitation as described in the carrying capacity legend).

No management inputs have been assumed in the designation of these classes. The limitations expressed may be interpreted to reflect the problems that may be expected in the event of recreational use facility development.

CLASS 1 VERY HIGH

These units have a high physical carrying capacity for recreation, and are capable of supporting a wide variety of activities. They have slight to no limitations, and will suffer little or no damage under "normal" recreational use.

Some of the activities which may occur include organized camping and cottaging. The soils of these units are moderate to coarse textured, very stable, and moderately well to well drained. They have relatively flat topography.

CLASS 2 HIGH

These units have a moderate carrying capacity for recreational use and are capable of supporting a fairly wide variety of activities. However, due to minor limitations, they will require a higher amount of management input than the very high (Class 1) carrying capacity areas for similar intensity of use. Some of the limitations which may occur within this class include gentle slopes, stoniness, and fine textured soils.

CLASS 3 MODERATE

These units have a moderate carrying capacity for recreational use. As a result, they are not suited to intensive recreational activities (e.g. organized camping, cottaging). They are capable of supporting most extensive recreational activities (e.g. hiking, bird watching, wilderness camping). Some of the limitations which may occur within this class are severe stoniness, shallow soil and moderate slopes.

CLASS 4 LOW

These units have a low carrying capacity for recreational use. They are not capable of supporting intensive use and extensive use should be very limited. Some of these limitations which may occur within this class include steep slopes (26 - 35°), sensitive vegetation, and actively eroding soils.

CLASS 5 VERY LOW

These units have a very low carrying capacity. They have very severe limitations in supporting any amount of recreational use. These units are best avoided where possible. Some of the limitations which may occur within this class include very steep slopes (> 35°), actively failing slopes, and very sensitive vegetation.

LIMITATIONS - PHYSICAL CARRYING CAPACITY FOR RECREATION

LIMITATIONS	TYPE	SYMBOL
Soil	Soil erosion (sheet, rill, creep)	S^e
	Compaction	S^k
	Septic tank limitations (this is additional information and is used in higher capability area in which intensive facility development may be expected)	S^l
	Organic Soils	S^o
	Soil texture: stoniness	S^p
	: fine textured	S^f
	Shallow soils (impervious horizons, often associated with minor bedrock outcrops)	S^s
	Unspecified soils factor/factors	S^u
	Soil drainage: poor drainage	S^w
	: poor drainage (receiving position)	S^{wr}
	: excess drainage	S^m
Landform	mass-wasting: avalanching	L^a
	: failing slope	L^f
	: talus	L^t
	erosion	L^g
	periglacial erosion (nivation, solifluction, congeliturbation)	L^p
Bedrock		R
Topographic	steep bluff (cliff) - (river bank)	T^b
	steep slope	T^s
	variable topography (undulating, hummocky, rolling)	T^u
Vegetation	density (undergrowth density, canopy density)	V^d
	nuisance/hazard species	V^n
	vulnerability (sensitivity)	V^v
Climate	aridity	C^a
	permanent ice or snowfield	C^s
	other (fog, exposure)	C
Hydrologic	physical limitations: steep offshore	H^s
	: hazardous currents	H^c
	: cutbank erosion	H^e
	: inadequate water depth	H^f
	: high summer water - no foreshore	H^n
	: flooding	H^i
	biological nuisance (aquatic weeds, leeches)	H^b
	pollution (industrial waste, sewage effluent, logging debris)	H^p
Faunal	conflict (waterfowl nesting area; migration route)	V^c
	hazard (grizzly area; rattlesnake area)	V^h
	nuisance/pest (mosquito, blackflies)	V^n
Man-made	railway or highway obstruction (ie. beach areas) This applies only to Class 1 or 2 areas in which the feature value as well as the carrying capacity is decreased by the occurrence of the obstruction.	Z
Miscellaneous		X

MAPPING PERCENTAGES

50 - 50
60 / 40
80 // 20
90 : 10

impacts, is a *documentation of the major biophysical changes created by the development.* Once past this stage, more detailed biophysical information is required from a management, mitigation, and monitoring point of view. Other examples include the use of the biophysical data base for assessing forest harvesting related impacts. One such type is what is termed *Environmental Protection Areas.* This is an attempt to outline broad areas where there are potential environmental impacts relating to recreation, wildlife, fisheries, soils and management. Another is the *Folio System* which is a program administered by the B.C. Forest Service, requiring the forest company to provide a documentation of the possible environmental

Table 1: Estimated soil properties significant to engineering (after Cotic et al.*, 1974)*

Soil Association	Parent Material	Depth in Ft. to Bedrock	Depth in Ft. to Water Table	Depth From Surface	Classification: Texture Range	Classification: Unified	Classification: AASHO	Percentage Passing Sieve: 3/8"	No. 4 4.7mm	No.10 2.0mm	No.40 0.42mm	No. 200 0.074mm	Liquid Limit	Pl. Index	Permeability
Alix - AX	Gravelly outwash		>10	8" +	sg-stg	GP, GW	A-1	45-55	40-50	30-40	0-5		NP*	NP	Very rapid
Babine - BE	Shallow lacustrine		>10	0-30" 30" +	sic-c l-cl	ML or CL CM or GC	A-7 A-2 to A-6	60-80	50-70	45-65	35-55	100 20-45	35-50 NP	10-25 NP	Slow Slow
Barrett - BA	Basal till		>10	12" +	gl-gcl	GM or GC	A-2 to A-6	60-80	50-70	45-65	35-55	20-45	NP-40	NP-20	Slow
Berman - BN	Lacustrine silts		>10	0 +	sil	ML	A-4					100	30-40	5-15	Moderate
Cluculz - CZ	Shallow over rock	<5			gsl, gl								NP	NP	Rapid to mod-
Cobb - CB	Ablation till		>5	0 +	gsl, gls, gl	GM	A-2	65-90	60-80	65-75	40-60	10-30	NP	NP	Moderate
Colony - CY	Recent beach		2-5	0 +	s, ls, cos, g	SP	A-1	100	95-100	75-95	40-60	0-5	NP	NP	Rapid
Crystal - CR	Ablation till		>5	0 +	gsl, gls, gl	GM	A-2	65-90	60-80	65-75	40-60	10-30	NP	NP	Moderate
Dahl - DL	Shallow over rock	<5			gsl, gls								NP	NP	Rapid to mod-
Decker - DR	Shallow over rock	<5			gsl, gls								NP	NP	Rapid to mod-
Deserters - D	Basal till	>5	>10	12" +	gl, gcl	GM or GC	A-2 to A-6	60-85	50-80	45-70	35-55	20-45	NP-40	NP-20	Slow

* NP - non-plastic

impacts which may result from forest harvesting in a particular watershed. Applications of this clearly point out the role and value of biophysical information in making natural resource management assessments.

CONCLUSION

Although there is still much to learn in terms of providing a data base for land planning and management, the system as outlined functions, at the moment, satisfactorily in British Columbia. It must be realized that the biophysical system is not a finite entity but provides the means by which its application can change not only in time but also geographically depending on the important attributes of the landscape considered.

At present, the Resource Analysis Unit is devel-

Soil Assoc. and Symbol	Degree and Kind of Limitation for - Septic and Absorption Fields	Shallow Excavations	Dwellings with Basements	Local Roads and Streets	Soil Features Affecting: Reservoir Area	Embankments
Alix - AX	Slight	Severe; sidewall instability	Slight	Slight	Very rapid permeability	High permeability, low compressibility
Babine - BE	Severe; slow permeability	Moderate to severe, difficult to work	Moderate; moderate, shrink-swell; moderate to high frost action in underlying till	Moderate to severe; moderate to high frost action, moderate shrink-swell, slope	Slope, deep water table	Medium to low shear strength, fair stability
Barrett - BA	Severe; slow permeability	Moderate to severe; difficult to work, slope	Moderate; Moderate shrink-swell, moderate to high frost action	Moderate to severe; moderate to high frost action, moderate shrink-swell, slope	Slope, deep water table, slow permeability	Medium to high shear strength, fair stability
Berman - BN	Moderate to severe; moderate to moderately slow permeability	Slight	Moderate to severe; high frost action	Severe; high susceptibility to frost action, high erodibility	Moderate permeability	Moderate permeability fair stability
Cluculz - CZ	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Severe; slope, shallow over rock	Shallow over rock, stones, slope	Shallow over rock, stones, slope
Cobb - CB	Moderate; permeability, slope	Moderate to severe; slope, stones, side-wall instability	Moderate to severe; slope, stones	Moderate; slope, stones in places organics (swamps)	Moderate permeability, stones. Compact till 5 to 10 feet from surface	Medium permeability and internal erosion good stability
Colony - CY	Slight to moderate; water table	Severe; sidewall instability, water table	Moderate; seasonal water table	Slight; (moderate to severe close to lakeshore)	Rapid permeability, high water table	Medium shear strength, high permeability
Crystal - CR	Moderate; permeability, slope	Moderate to severe; slope, stones, side-wall instability	Moderate to severe; slope, stones	Moderate; slopes, stones, in places organics (swamps)	Moderate permeability, stones. Compact till 5 to 10 feet from surface	Medium permeability and internal erosion, good stability
Dahl - DL	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Severe; shallowness over rock slope	Shallow over rock, stones, slope	Shallow over rock, stones, slope
Decker - DR	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Severe; shallowness over rock, slope	Shallow over rock, stones, slope	Shallow over rock, stones, slope
Deserters - D	Severe; slow permeability, slope	Moderate to severe; difficult to work, slope	Moderate; moderate shrink-swell, moderate to high frost action	Moderate to severe; moderate to high frost action, moderate shrink-swell, slope	Slope, slow permeability	Medium to high shear strength, fair stability

Table 2: Engineering interpretations (from Cotic et al.*, 1974)*

oping methods such as Climate Suitability for Recreation, Climate and Terrain Suitability for Urban Development, Climate and Terrain Suitability for Logging, etc. These approaches, when developed with the users involved, such as logging companies, consulting firms, etc., will be a valuable tool in resource planning.

ACKNOWLEDGEMENTS

Sincere appreciation is exteneded to the following members of the Resource Analysis Unit who have provided much of the required criticism for the paper: Dr. N. Alley, Dr. A.N. Boydell, Mr. T. Vold, Mr. W.C. Yeomans, Mr. W. A. Benson, Mr. T.W. Chamberlin, Dr. D.E. Howes and Mr. P.N. Sprout. I would especially like to thank Ms. F. Tait for typing the manuscript.

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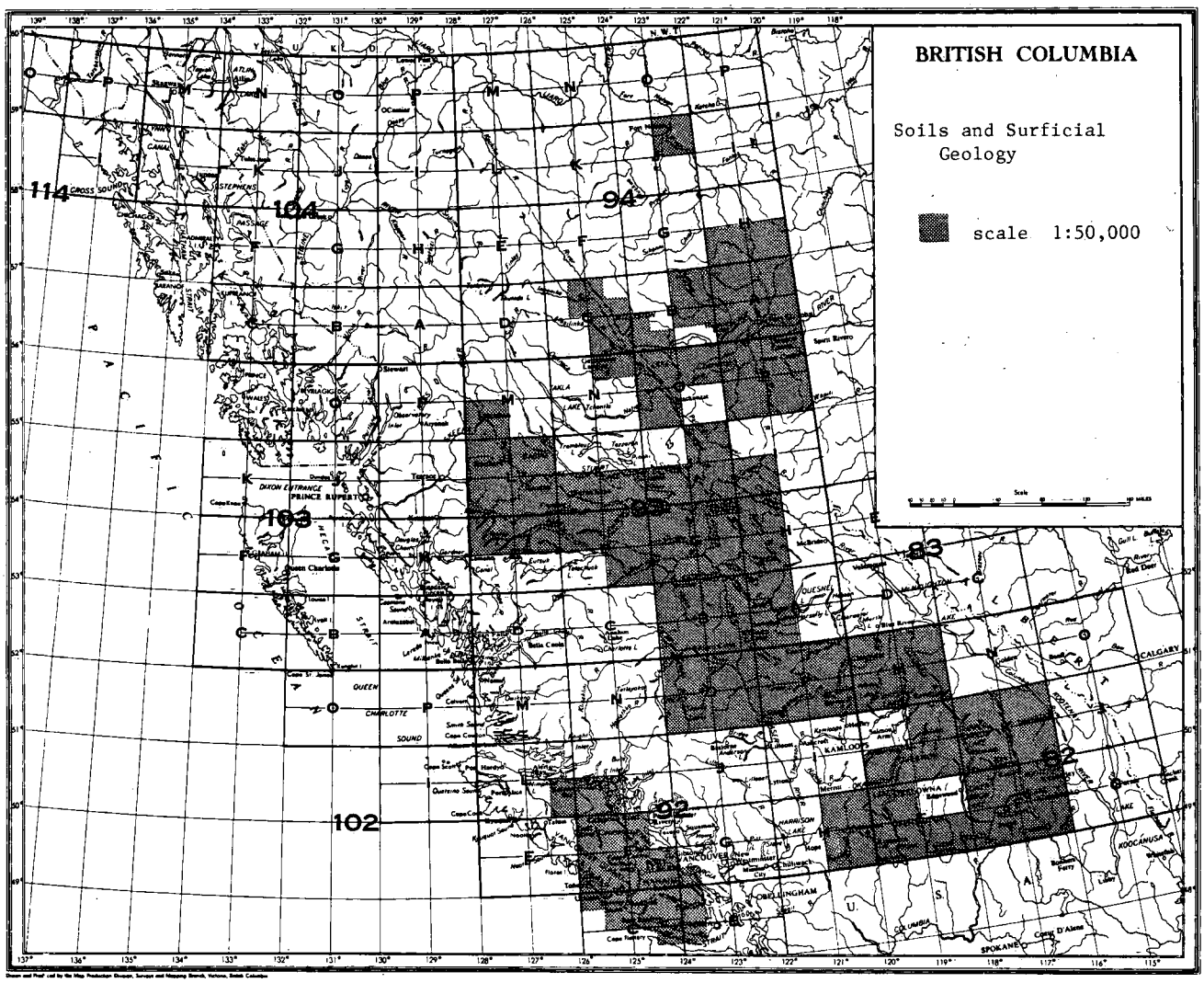
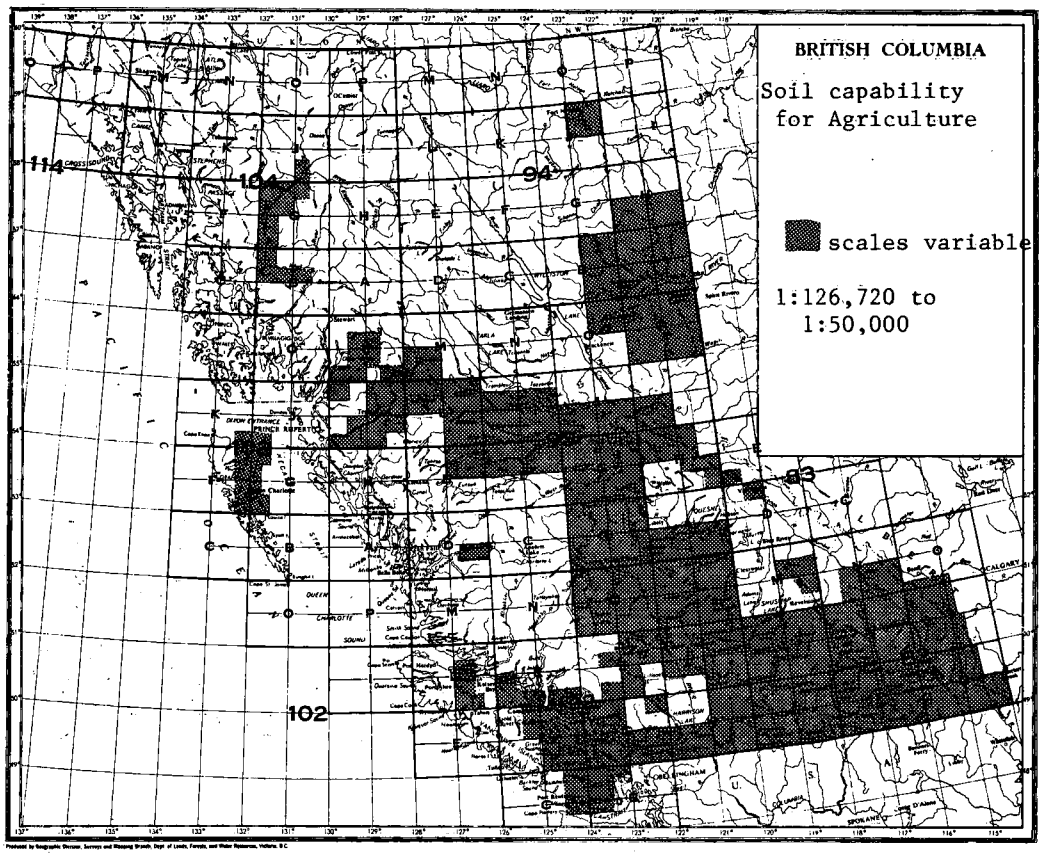
APPENDICES: Examples of the areas inventoried for various data themes and interpretations

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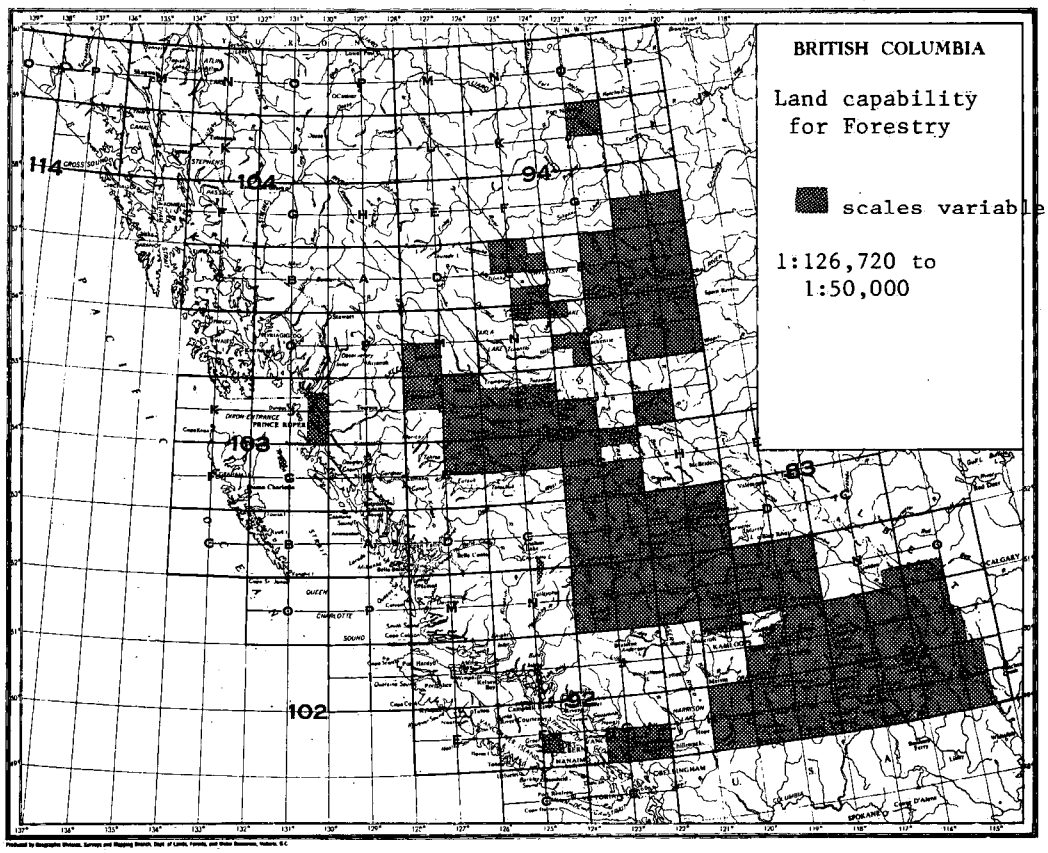
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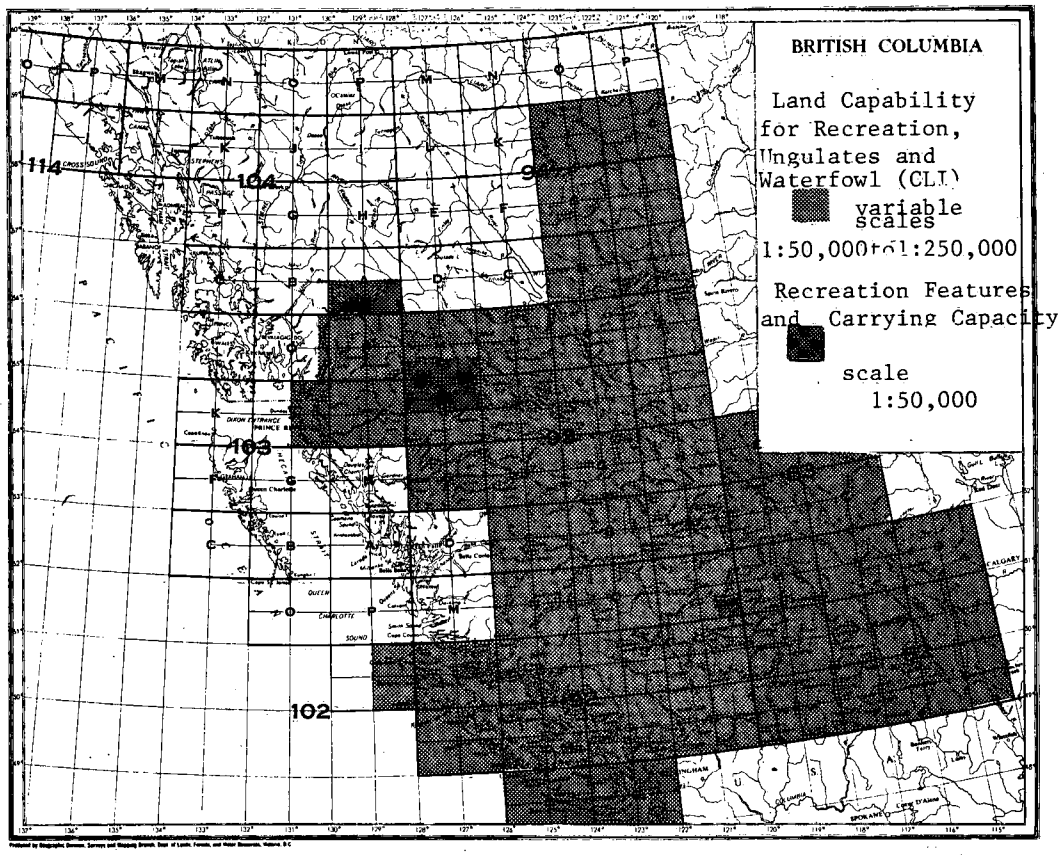
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Land Capability for Recreation, Ungulates and Waterfowl (CLI)
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Recreation Features and Carrying Capacity
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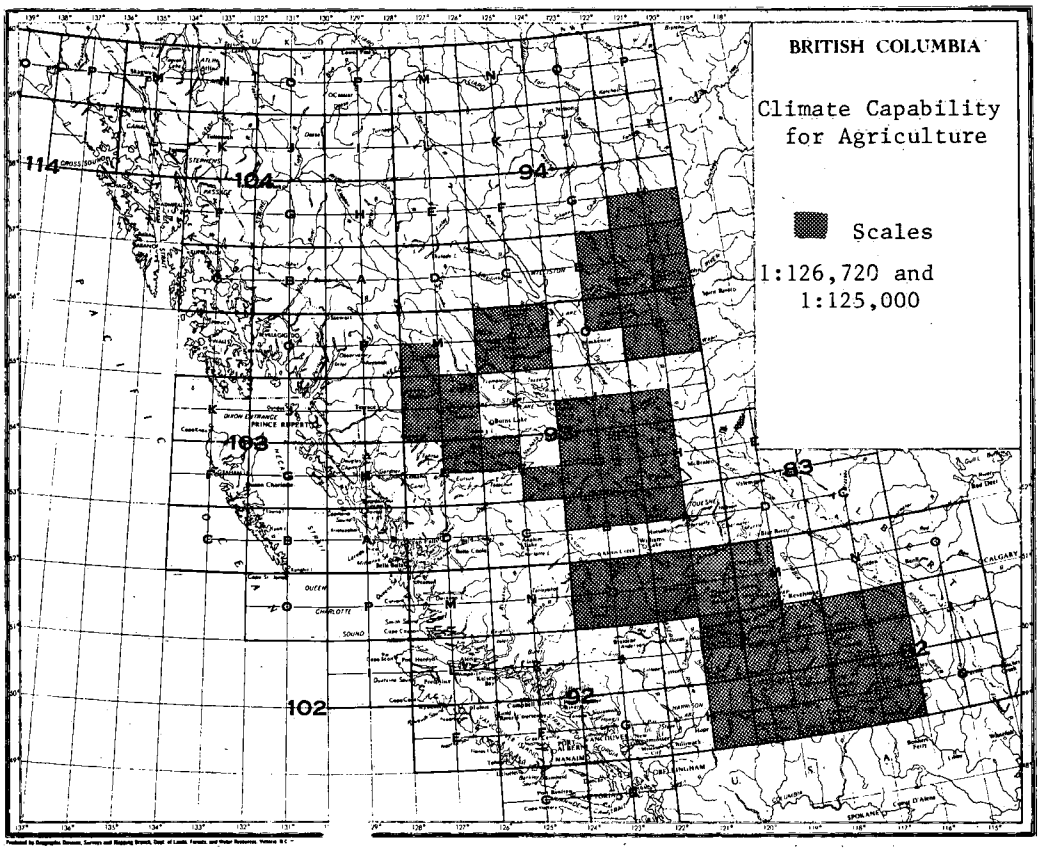
CALGARY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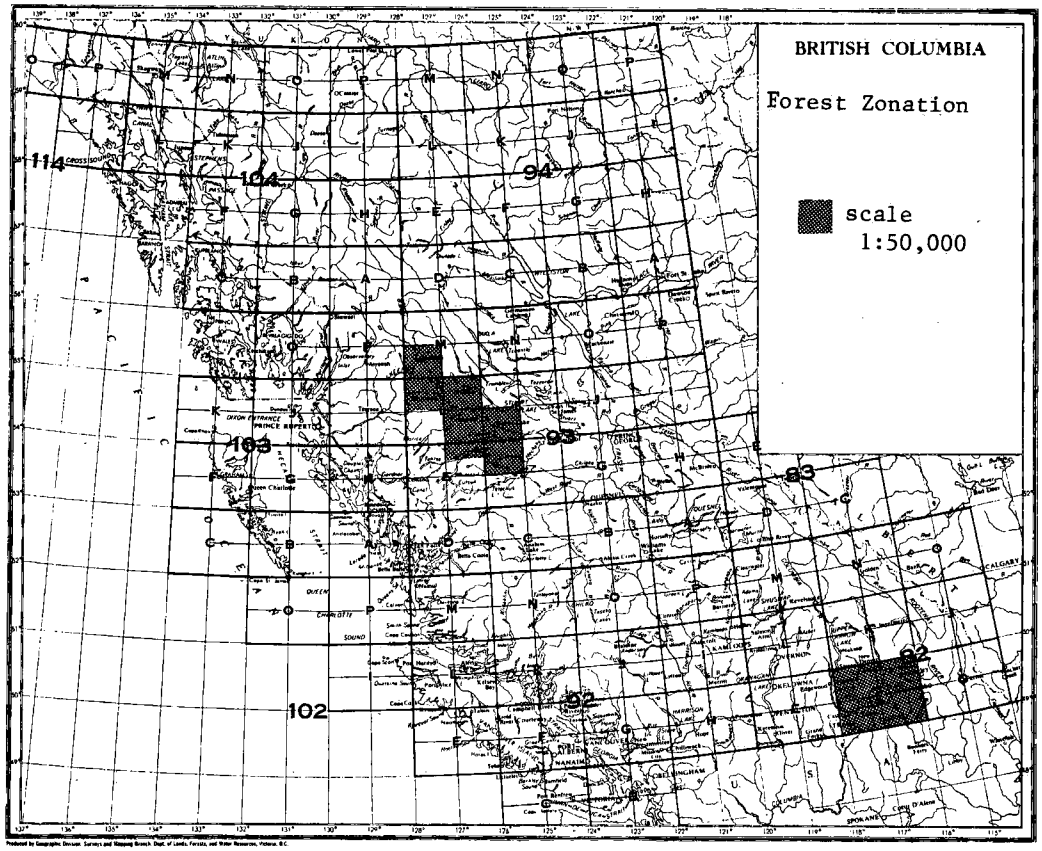
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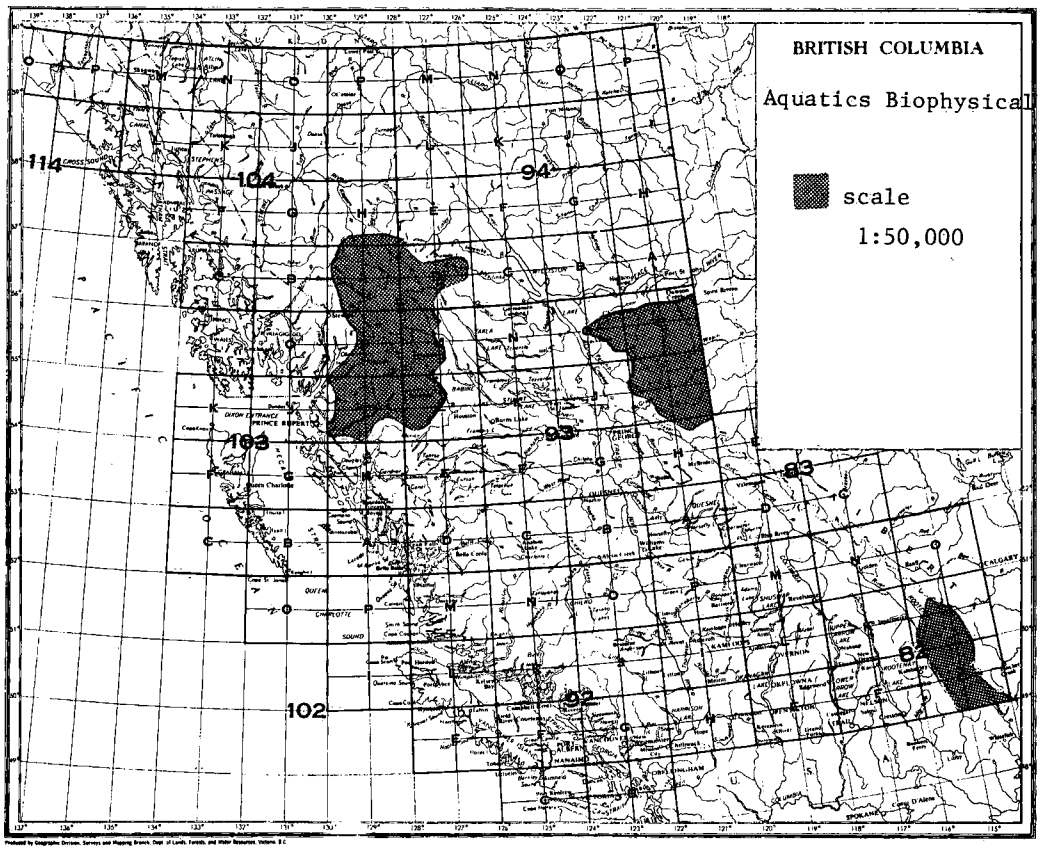
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A SUMMARY OF BIOPHYSICAL INVENTORIES, PROPOSALS AND RESEARCH NEEDS FOR SASKATCHEWAN

G. Roberts
Planning and Research Secretariat
Department of Northern Saskatchewan
La Ronge, Saskatchewan

INTRODUCTION

There have been no major integrated biophysical or resource inventory programs in Saskatchewan since the completion of the Canada Land Inventory and Pilot Land Use Study. Resource inventories have been completed in specific areas for environmental impact assessments (eg. Churchill River Study, Cluff Lake uranium development, Elizabeth Falls hydro-electric development etc.) and work is underway on an inventory of wildlife habitat in the southern portion of the province.

This paper briefly describes the wildlife habitat inventory program, outlines a proposal of the Department of Northern Saskatchewan (DNS) for biophysical work, and identifies some general concerns and research topics regarding biophysical inventories.

SASKATCHEWAN WILDLIFE HABITAT INVENTORY

A four-phase mapping program of wildlife habitat in the southern portion of the province is being undertaken by the Wildlife Research Unit of the Department of Tourism and Renewable Resources. The work was initiated in 1975, under the supervision of Syd Barber.

The inventory methodology involves the preparation of four overlay maps inventoried and produced on the standard 1:250,000 National Topographic Series Maps. The program has a three year life expectancy at an annual cost of $50,000. It is estimated that six map sheets will be completed each year.

One of the key maps of the overlay series is biophysical in nature. A classification system of twelve land types has been devised on the basis of soil classifications. These land types are used to determine potential habitat types.

A second overlay map identifies the percentage of land in native grasses and a third identifies land tenure.

These maps together provide the basis for the fourth overlay which, through interpretation of the preceeding maps, identifies critical wildlife habitat.

This map series is of a single purpose design that appears, with proper interpretation, to meet the objective of identifying habitat critical to the protection of specific categories of wildlife.

In the portion of the province dominated by agricultural activities it may be a powerful tool in the development of resource allocation policies and management strategies for the protection of wildlife. Nevertheless, the inventory lacks the scope of an integrated biophysical survey; it cannot be interpreted by a wide variety of disciplines and used as a basis for integrated resource planning.

BIOPHYSICAL INVENTORIES AND THE DEPARTMENT OF NORTHERN SASKATCHEWAN

The Department of Northern Saskatchewan is the single agency responsible for the delivery of a majority of programs in the northern portion of the province. The provision of basic services - from health care and education to economic and resource development - falls within its mandate. Given the need for delivery of basic services in the north, land use planning and biophysical inventories have not been seen as high priorities in the initial years of the Department. Nevertheless, the importance of general resource planning is now recognized and a proposal for a lands section within the Department has been made. It is hoped that this work may be initiated in the near future.

Within the lands section there will be a small biophysical inventory group. The coordinator of the biophysical inventory will work closely with the planners and resource managers in the lands section and other agencies during the design of the inventory system to ensure its usefulness and *interpretability* for a number

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

of disciplines.

The data collection process will remain independent of the planning process (and the planner's bias of interpretation); nevertheless, the system itself will be open to modification on the basis of the usefulness of the information to planners and resource managers. It is in the development of this system that the DNS hopes that the Canada Committee on Ecological (Bio-physical) Land Classification (CCELC) will be of some assistance.

RESEARCH REQUIREMENTS

Several questions that require research are identified below. The first group, related to the economics of biophysical inventories, are questions we often hear and expect from Treasury Board and their analysts. The second group are related more generally to the concept of development in the *mid-north* and the role of biophysical inventories and resource planning within the development process.

1. What are the costs and benefits associated with biophysical inventories?

If the province of Saskatchewan is to undertake a biophysical inventory, what can we except it to cost and more importantly what benefits can we expect? Will the process of decision making be less costly than at present?

A research strategy to answer these questions should include the following components:

(a) Identify the process of resource planning and environmental impact assessment and document the associated costs if biophysical information is not available. This information should be compiled for each of the following development categories:

- transportation,
- mineral exploration and development,
- recreation and tourism,
- fisheries,
- forestry,
- wildlife management,
- community planning, and
- power developments and transmission corridors.

(b) Identify the change in process of resource planning and environmental impact assessment if biophysical information is available and document the cost savings/increases associated with having this information available.

(c) Is it possible to measure the quality of decisions and identify how the quality is affected by having biophysical information available?

(d) If the benefits outweigh the costs, what training programs are required to enable the various disciplines, (e.g. transportation engineers, wildlife managers, etc.) to make effective use of the biophysical information?

2. An assumption that appears to be a part of the rationale for a biophysical inventory is that better resource information will lead to better resource allocation and management decisions. Further, it is assumed that resource allocation and management problems are ultimately technical (i.e. soluble within a scientific framework).

In Northern Saskatchewan there is a concern that biophysical resource inventories and integrated resource planning, while they appear to be part of a rational process to better manage our environment, tend to reduce problems of values and perceptions to an oversimplified technical level.

An example of this process in operation was identified in Bodley (1975). In the Chittagong Hills, Bangladesh, an eleven-man research team prepared a master plan for the integrated development of the area. While this process (described by Webb, 1966) used sophisticated inventory and planning techniques that appear valid to us, the process ignored the conflict between the traditional economic system of the tribal groups of the area and the national economic system. This example brings to question the nature of the relations between *values*, *technical information*, and *decision making*. Furthermore, the question of whose objectives are being served (i.e. local, regional, provincial, etc.) by the process of information collection and planning is raised.

The Canadian Council on Rural Development (CCRD) recently prepared a paper on development in the mid-north (CCRD, 1976) that identifies a *locally based development strategy*. This concept can be used as a framework for the evaluation of the relations of biophysical inventories, values, and decision making in the developmental context of the mid-north. The objective of this work should be to identify a role for biophysical inventories and resource planning in the development process and identify a process for undertaking a biophysical program that is consistent with locally based development.

It is suggested that the Lands Directorate of

Environment Canada, under the CCELC, undertake a research program to fill the informational voids identified under 1. above.

In the second area of concern, the CCELC should collaborate with the Lands Directorate, the Department of Regional Economic Expansion (DREE), and the Canadian Council on Rural Development to undertake the required research.

SUMMARY

1. No major integrated biophysical or resource inventory programs have been undertaken in Saskatchewan since the Canada Land Inventory or Pilot Land Use Study.

2. A wildlife habitat inventory program that has a biophysical component is being completed for the southern portion of the province by the Wildlife Research Unit of the Department of Tourism and Renewable Resources.

3. The Department of Northern Saskatchewan is intending to establish a lands section that would have a biophysical inventory unit.

4. It is suggested that:

(a) The Lands Directorate of Environment Canada, under the advice of the CCELC, undertake research on the costs and benefits of biophysical inventories.

(b) The Lands Directorate, DREE, and the Canadian Council on Rural Development jointly sponsor or undertake research to identify a role for biophysical inventories and resource planning in the development process and identify the mechanisms required for a biophysical program consistent with locally based development.

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PRESENT STATUS OF BIOPHYSICAL ACTIVITIES IN MANITOBA

A.E. Borys
Manitoba Department of Renewable Resources and Transportation Services
Winnipeg, Manitoba

ABSTRACT

Manitoba initiated a biophysical program for the mid-north portion of the province in 1974. To-date, fieldwork for six and one-half 1:250,000 map sheets has been completed, and two and one-half map sheets are planned for 1976. The program operates on an annual budget of $140,000 with a staff of six plus office technical support. The program is planned to continue at this rate until all of Manitoba where communities exist is mapped.

RÉSUMÉ

Le Manitoba a lancé un programme de classification biophysique pour la région septentrionale moyenne de la province en 1974. Jusqu'ici, les travaux sur le terrain pour six cartes topographiques et demie (1:250,000) sont terminés et deux cartes et demie sont prévues pour 1976. Le programme dispose d'un budget annuel de $140,000 et occupe six personnes, en plus de personnel de soutien technique. Il se poursuivra au même rythme jusqu'à ce que l'ensemble de la partie du Manitoba qui présente des communautés ait été portée sur cartes.

The geography of Manitoba is such that the major land-based activities occur in the southwestern quarter of the province, and it was this portion of Manitoba that was surveyed under the Canada Land Inventory. Resource and base line information in the North remains sporadic, nonexistent, inconsistent in methodology, etc. With the provincial government's firm commitment to increased development of the North for direct benefit to the people of the many dispersed communities in these regions, it became evident that some systematic approach to acquiring base line and resource information had to be initiated.

In 1974, a biophysical land classification program was initiated. The intent was to develop a program specific to identified Manitoba needs, and to map all of Northern Manitoba on a reconnaissance basis (i.e. at the land systems level). The total area represents approximately thirty-one 1:250,000 map sheets. During 1974-75, the program was developed and fieldwork was completed for two 1:250,000 map sheet areas. This was followed by four and one-quarter map sheets in 1975-76 and will be followed by approximately two and one-half map sheets this year, making a total of roughly nine map sheets. Specifics and methodology will be discussed by Gordon Mills, project leader of the biophysical team. It is planned that the operation will continue at approximately the same rate until, if not all of Northern Manitoba is mapped, at least the mid-north will be completed (i.e. that area in which communities are located).

The above survey is the only one currently under way. However, various groups have shown considerable interest and it is conceivable that small isolated areas in the south may be mapped (e.g. Parks Branch is interested in carrying out a biophysical classification in some of its parks). The program is being carried out by the Department of Renewable Resources and Transportation Services (RRTS). However, the team itself is composed jointly of staff from RRTS and the Soil Survey Unit which is associated with the Soil Science Department at the University of Manitoba. RRTS has placed on the program two professionals and one technician. Soil Survey has contributed the equivalent of two professionals, one technician, and technical assistance as required for soil analysis, drafting, etc. The joint effort appears to be working well and has created an excellent liaison between the University and the government department. Private activity is currently limited. However, a local consulting firm is in the process of establishing expertise in this area and is actively seeking contracts.

The Manitoba project is modest financially, with a current budget of $140,000 plus soil survey input of approximately $75,000. This will not likely be increased substantially. However, a strategy for greater economic development as relating to northern communities is being

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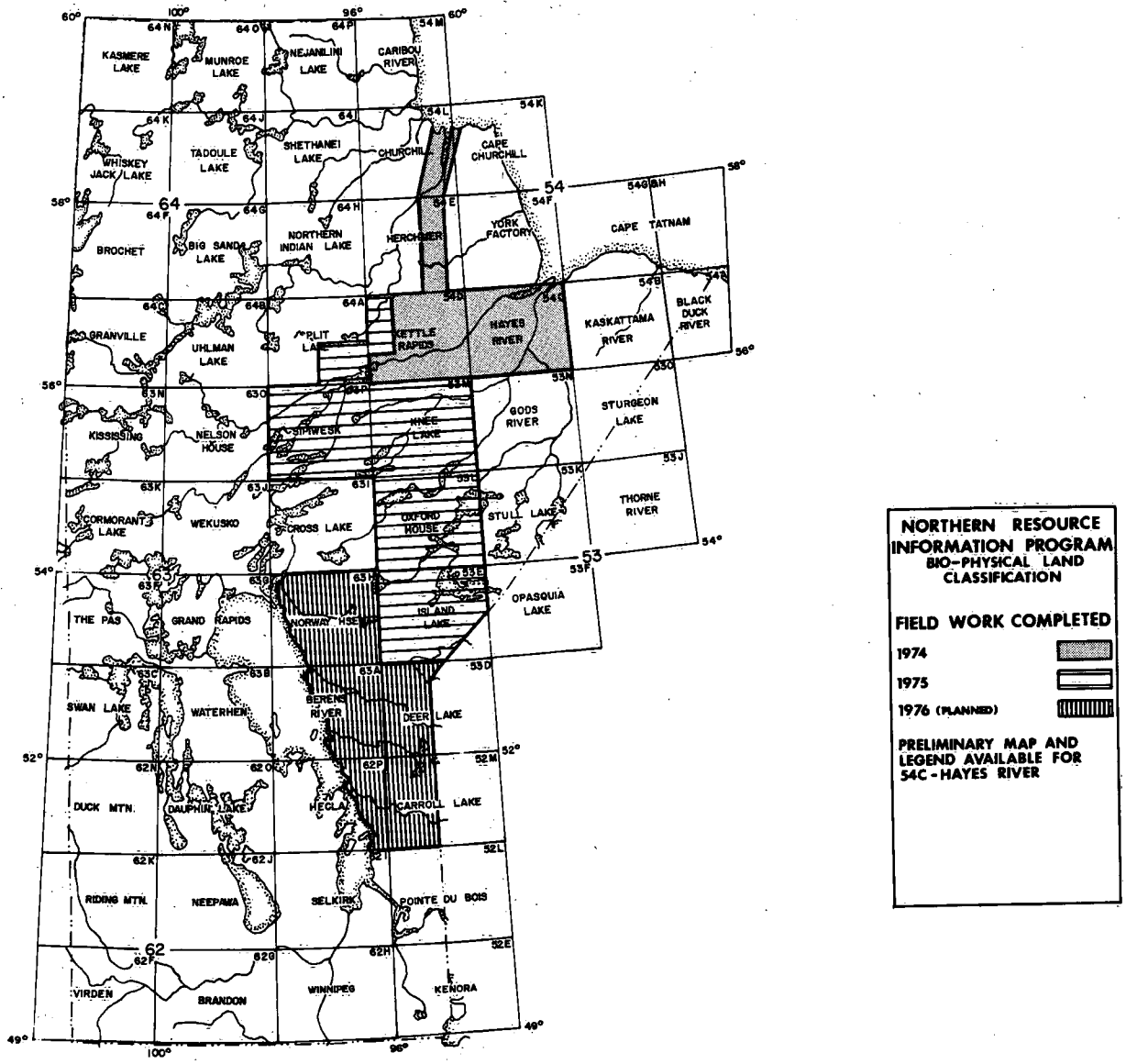


developed by the province and demands may be made for a survey at the land type level. However, such a survey would be confined to areas selected on the basis of the reconnaissance survey.

Attached to the biophysical team last year, RRTS provided a wildlife biologist. His task was to make the biophysical information more usable and more readily interpretable by wildlife people. A preliminary report was produced, primarily as it related to the Hayes River map sheet. Critical evaluation of the report revealed that the work done by the biologist was useful but, invariably, more information was requested, information that could not be provided within the existing budget. Currently the wildlife component is being dropped and replacement of staff will consist of expertise in the biophysical area.

One major concern that Manitoba has relates to the lack of a classification for water bodies. Initially the program was quite ambitious and it was hoped that a reconnaissance water classification would be developed concurrently with the land classification. However, this did not materialize although basic water information was collected during the first two field seasons. Unless there is renewed demand for such a classification and increased budget it is unlikely this component will be developed and carried out under the present program. At this stage it is not possible to assess the usefulness of the maps for environmental impact assessment, planning, etc. Only one map has thus far been published. Much interest in the program has been shown and numerous requests for the map have been made, but direct feedback from users has not occurred.

RESEARCH AND SURVEYS FOR BIOPHYSICAL MAPPING IN ONTARIO

A.N. Boissonneau
Ontario Centre for Remote Sensing
Ministry of Natural Resources
Toronto, Ontario

ABSTRACT

The biophysical mapping programs which have been undertaken in Ontario are described. The research being conducted to evolve suitable biophysical classifications for purposes of wildlife habitat studies, wetland classification and environmental impact studies are described. This research also entails the evolution of the most appropriate methods of applying these classifications. Finally, the prospects for future biophysical projects in Ontario are discussed.

RÉSUMÉ

Le présent document décrit les programmes de production de cartes biophysiques de l'Ontario. Il expose en outre les recherches entreprises pour déterminer les classifications biophysiques appropriées aux études de l'habitat faunique, les classifications des terres humides et les études des incidences environnementales. Ces recherches portent aussi sur l'élaboration des méthodes les mieux désignées pour la mise en application de ces classifications. Enfin, l'auteur analyse les projets de classification biophysique à venir.

SURVEYS

The 1:250,000-scale of mapping in the Ontario system of land classification and land use capability evaluation was applied to an area of approximately 216,000 mi^2. This program was undertaken after the Canada Land Inventory (CLI) program in Ontario had been completed, and was essentially finished by April 1974. The agreement between CLI and Ontario permitted the latter to collect sufficient field data during the CLI field program to permit a later mapping of land units and a description of their dominant physiographic site components. Consequently, for the CLI area in Ontario, the time required and the cost to the province for land classification mapping and land use capability evaluations for forestry and recreation were minimal, since only office work and cartography were involved. For the map sheets outside the CLI area, Ontario bore the full cost for field and office work and cartography.

The reasons for undertaking this project were:

1. Although a basic land classification framework underlies the CLI maps, the CLI program presented only land use capability maps for agriculture, forestry, recreation and wildlife. Thus, the Ontario Land Inventory (OLI) program was designed to present this land classification framework for the CLI area so that a much broader spectrum of users could be provided with land classification data which they could use for any purpose which involved an understanding of inherent land qualities.

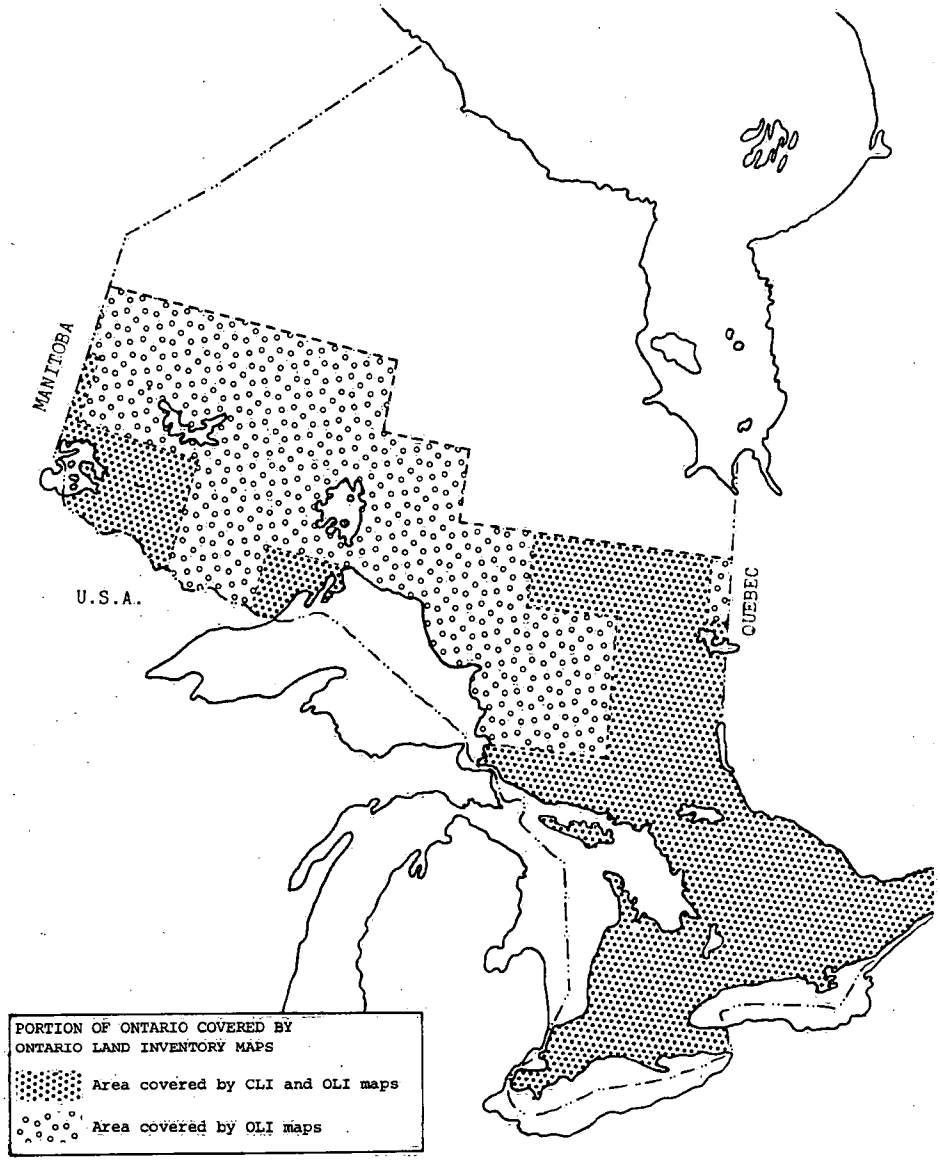
2. The CLI area in Ontario was confined to agricultural and fringe agricultural areas. The OLI program was designed to expand this coverage to include the commercial forest area of Ontario.

3. The Canada-wide capability gradients of the CLI did not provide much scope for rating the land use capabilities of boreal regions, since all lands in these regions were crowded into four of five classes (4 to 7, or 5 to 7) of the national capability gradients. Consequently, for the OLI program, regional land use capability gradients were used in which sites with the best level of production observed within a region were assigned to Class A and sites with the poorest level of production within a region were assigned to Class G. Then bench mark sites were established for the intervening five classes between A and G.

4. Rather than use the CLI overall rating of intensity of use of lands for all recreational activities, the OLI program was designed to provide specific rating for each of a wide range of recreational activities.

5. Rather than use single ratings for ungulates and waterfowl, the OLI program was designed

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.



to provide ratings for individual wildlife species, and to indicate the degree of effort required to realize these potential ratings, making allowances for the present vegetation cover. Land units were delineated which were of a suitable size for representation on 1:250,000-scale maps and which contained a destinctive pattern of physiographic sites, which differed from the pattern of adjacent land units. The land units were defined on the basis of three physiographic feature classes - macro-relief, texture of parent soil materials and depth of soil over bedrock.

Each OLI land classification map was supplemented by a book containing tabular listings of the dominant physiographic site types within each map unit and indicating the estimated percentage of the land unit which each physiographic site type occupies. Consequently, although such important limitations to crop production as soil moisture and mineral composition of parent soil material could not be mapped at 1:250,000-scale of mapping, the area distribution, within land units, of sites which are a combination of texture and mineral composition of parent soil materials, depth of soil and soil moisture regime, have been noted in the tabular summaries.

Having a list of the dominant physiographic site types of each land unit and an estimate of the

proportion area and land use capability ratings for these site types, it was a simple matter to combine these values to obtain an overall rating of timber use capability using a three-component expression of capability, where the first class occupies about 50% of the area of the unit, the second class 30% and the third class 20%.

Land use capability evaluation for recreation and wildlife has been completed for the project area using a 1:50,000-scale of mapping.

An ingenious method of cartographic production was used for the OLI land classification and timber use capability evaluations. The method was evolved to obtain attractive maps, of an acceptable level of accuracy, at a minimal cost. Supplies of topographic maps were obtained from the appropriate federal government agency at no cost to the OLI. Land classification and timber use capability data were overprinted on these maps, and hence no paper costs were involved in the map production. The overprinting was achieved by scribing the lines and symbols for the land classification and timber use capability maps on scribe coats. The scribe coats were then fitted with devices so that they would align with the boundaries of the average copy of the appropriate map sheet. The scribe coats were then mounted on the printing press so that lines and symbols would be overprinted on the front of the map and the legend would be printed in the blank portion of the bottom of the back of the map. It was found that the dimensions of the copies of each map sheet were sufficiently similar to permit a precise registration of lines.

The cost of the project averaged $\$4.55/mi^2$. The time required for the project was about 4½ years, or 80 man-years of professional staff and assistants, or 150 man-years of professional and support staff. These figures are necessarily only approximations, because for much of the time, OLI and CLI programs ran concurrently, and separate records were not kept of the time spent on each project during this interval.

RESEARCH

A contribution of the Ontario work group of the wetland subcommittee, National Committee on Forest Land, published a hierarchical classification framework for the wetlands of Ontario, and illustrated the use of the framework by proposing a set of wetland types for the Northern Clay Section of NE Ontario (Jeglum *et al.*, 1974). One of the objectives of this classification was to provide a set of wetland types, particularly at the higher levels of the classification, which could be recognized on remotely sensed imagery.

Consequently, as a first step to testing the adequacy of this classification, a study area, comprising a group of five large bogs, was selected to investigate if the bog types of the classification could be readily identified on LANDSAT imagery and on conventional, black and white, 1:16,000-scale, air photos. The study area is located 75 km NW of Timmins, Ontario, which is in the southern part of the Northern Clay Section.

It was found that when a helicopter was available for one day to collect ecological data from 14 field stations, bog types could be mapped with confidence on the 1:16,000-scale air photos at all levels down to a dominance type, or complex of dominance types. The dominance type is the penultimate level of detail of the classification hierarchy. It was also found that large-scale densitometric analysis (Approximately 1:10,000-scale) of LANDSAT imagery could be used, in most cases, to identify bog types to the same level of accuracy as the interpretation of types on the 1:16,000-scale air photos. In a few cases, however, types which were distinguished on the 1:16,000-scale air photos were combined in the densitometric analysis. This study has been published in the Proceedings of the Third Canadian Symposium on Remote Sensing (Boissoneau and Jeglum, 1975).

A paper investigating the possibilities of interpreting the whole spectrum of wetland types of the Northern Clay Section is in its final stages of preparation. It will provide photo interpreters with keys and tables summarizing the features which can be used to identify the wetland types of the Northern Clay Section on black and white air photos of 1:16,000-scale, and on normal colour and false-colour infrared supplementary aerial photography. In addition, it will provide stereograms illustrating the appearance of wetland types on air photos, and the nature of the transitional areas between wetland types.

The Fish and Wildlife Research Branch of the Ontario Ministry of Natural Resources have been studying movements of moose in the Ear Falls area of NW Ontario. They approached the Ontario Centre for Remote Sensing (OCRS) about the possibility of using LANDSAT imagery to identify broad ecosystems types which would be useful in explaining movements of moose and their concentration in certain areas. Preliminary work in the Ear Falls area has indicated that densitometric analysis of LANDSAT images can provide a useful level of habitat types for studies of this type. A more intensive investigation on this method of delineating

habitat types is being made on Sibley Penninsula, in the Thunder Bay area of NW Ontario. It is the objective of the OCRS to present the results of these studies at the Fourth Canadian Symposium on Remote Sensing to be held in the Spring of 1977.

BASELINE STUDIES FOR ENVIRONMENTAL IMPACT ASSESSMENTS

Jeglum (1975) has provided an illustration of the usefulness of wetland types for analysis of the impact of a highway in blocking a peatland drainageway. Knowing the positions of the wetland types within the soil moisture-aeration gradient, it was possible to postulate the original condition of the wetland vegetation of the drainageway, and to postulate the succession of wetland types which was caused by the damming. These postulations were confirmed in the record of wetland types preserved on air photos, which cover a 23-year time-span. In 1947 (nine years after the road was built), the driest wetland types - black spruce swamp and black spruce-forested bog - occupied most of the drainageway, upstream and downstream of the highway. Photos taken in 1959 and 1970 show the progressive replacement of these swamp and treed-bog types downstream from the road with wetter sedge bog, low-shrub bog and fen types.

A federal-provincial cooperative program has been initiated in the Hudson Bay Lowlands to provide baseline ecological studies for future assessments of the impact of developments. Federal participants include the Canadian Forestry Service, the Canadian Wildlife Service, the Process Research Division of the Canada Centre for Inland Waters, and the Inland Waters Directorate. Provincial participation includes the Fish and Wildlife Research Branch, the Moosonee District, and the OCRS, all within the Ontario Ministry of Natural Resources.

In the initial year of the program (1976-77), it is planned to study the ecosystems of four reference areas in the James Bay area, and to extrapolate these findings to a broader area using remote-sensing data. One reference area is located in the environs of Kinoje Lake, which is about 90 km west and north of Moosonee. The other three reference areas are located along the coast of James Bay. Insofar as biophysical classification is concerned, the pertinent term of reference of this committee is to *develop a hierarchical biophysical classification system appropriate to the Hudson Bay Lowlands that will facilitate subsequent mapping of the area, if or when it is deemed necessary.*

The Ministry of Natural Resources has undertaken Canada Goose nesting studies in the Kinoje Lake area. These studies have shown that the area provides good nesting sites for this species, but prime nesting sites are associated with specific wetland types. A preliminary map of the wetlands has been produced by the OCRS using the field data of the Fish and Wildlife Research Branch and interpretation of 1:32,000-scale, black and white air photos.

Within the next month, a plan of groundtruth studies for the Kinoje Lake area will be established, and this plan will be implemented by helicopter traverses during the period 28 July to 30 July, 1976.

Large scale densitometric analyses have been made for Ship Sands Island, North Point and Long Ridge Point in the James Bay coastal area. Groundtruth of several replications of each densitometric class will be collected for each reference area.

On the basis of the field data for the four reference areas, and on the basis of the extrapolation of this field data to the entire reference areas using 1:32,000-scale air photos, complexes of the wetland types of these reference areas will be extrapolated to a broader regional area, using various scales of densitometric analysis of LANDSAT imagery. The purpose of this exercise will be to select the scale of densitometric analysis which will provide wetland types that are the best compromise between the level of detail required by wildlife biologists and engineers concerned with local areas, and the level of detail which is required to make the production of synoptic maps of the large area of wetlands in the Hudson Bay Lowlands rapid and inexpensive.

BIOPHYSICAL CLASSIFICATION FOR LAND USE PLANNING

The Ontario Ministry of Natural Resources is engaged in a program to provide strategic land use plans (the SLUP program). The objectives of this program are:

1. To document the broad land, vegetation, social and economic features which are pertinent to land use planning.

2. To propose provincial land use policies for the planning regions.

3. To evolve land use plans for the regions.

Public participation is involved at all three phases to assure that the program is not developed *in vacuo*.

A senior administrator of the SLUP program reports that the program could not have been

executed without OLI data, since no SLUP plan for a region is accepted unless it includes an analysis of the land inventory data. He stated that it was apparent that planners who had worked on the OLI staff had the proper perspective for regional planning, whereas planners who did not have land inventory experience invariably got bogged down in details of soil or forest inventory, or some other part of the background material for planning.

It is anticipated that the SLUP for Northwestern Ontario will be published in the fall of 1976. It will provide a model for the SLUP plans of the other regions of the province, and will probably provide an impetus to their completion.

PROSPECTS FOR BIOPHYSICAL CLASSIFICATION PROGRAMS IN ONTARIO

The prospects of initiating new biophysical mapping programs in the future are, in my opinion, epitomized by the word *bleak*. Perhaps I should emphasize at this point that a prognostication must necessarily be a matter of personal opinion. The OLI will be disbanded in April 1978. It was hoped that the OLI could make a valuable contribution to the province's timber management activities by providing large-scale maps and descriptions of forest ecosystems. This material could have assisted foresters who are concerned with the management of local timber management units. The maps and reports would have provided them with a means of understanding differences in the productivity, in the brush and hardwood tree competition, in the establishment of natural and artificial regeneration, etc. of the local forest ecosystems which he is manipulating. Since the OLI is to be disbanded, there probably will be no opportunity to apply this detailed level of the Ontario System of Land Classification. In the time left, a Ready Reference for users of OLI material will be published. This should extend access to OLI materials to a much broader spectrum of potential users of land classification and land use evaluation material.

As noted above, the terms of reference of the cooperative program for the Hudson Bay Lowland envisages a biophysical project in the area "if and when....deemed necessary". This would appear to me to mean that, until bulldozers start working, producing the environtental effects of a Baie James project, biophysical mapping will not be initiated in Ontario's Lowland.

The OCRS has the staff and equipment to undertake biophysical surveys which have a large remote sensing component. Unfortunately, it is a service organization operating under contract to other provincial government agencies.

At the moment, there is little likelihood that these provincial agencies will fund biophysical surveys.

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BIOPHYSICAL CLASSIFICATION IN NOVA SCOTIA

R.E. Bailey
and
E.M. MacAulay
Nova Scotia Department of
Lands and Forests
Truro, Nova Scotia

INTRODUCTION

Biophysical classification in Nova Scotia originated as one of the many positive spin-offs of the Canada Land Inventory Program. Unlike many provinces, biophysical classification in Nova Scotia was first seen as a tool for providing relatively homogenous geographical and ecological units by which to summarize the resource information available within the province. This objective has undergone a gradual change, primarily due to the recent increase in funds allocated to forest development and management.

In the past, forest management decisions were based primarily on forest growth and yield measurements. *Today, because of the need to maximize production of all products from wildlands, there is a growing realization that resource management decisions must be based on a combination of considerations, including maintenance of site productivity, provincial resource goals, social values, wildlife and recreation considerations, and the interrelationships between growth, yield, site factors and forest land input.* The development, therefore, of resource management plans has become quite complex, requiring the assistance of specialists trained in the field of land classification and forest-soil-management input interrelationships.

In view of these facts, the Department of Lands and Forests has revamped its thinking on biophysical classification and is now actively considering the following program.

OBJECTIVES

1. (i) Divide the major crown land blocks into land systems and describe each land type primarily in terms of their pedological and topographical properties and vegetation. At this point, only land systems will be delineated. Land types will not be mapped, but their importance based on the area they occupy in each system will be specified. This rather extensive survey will provide the necessary physical and ecological information required to prepare five-year crown land resource management plans. These plans are a prerequisite to the expenditure of funds under the pending Federal-Provincial General Development Agreement (GDA).

(ii) Determine one year in advance, the resource management inputs required for each land-vegetation type delineated in the annual operating plan.

2. Classify all provincial parkland from the standpoint of providing the biophysical information required for the development of a parks resource management plan.

METHODOLOGY

1. Acquire colour infrared aerial photographs (9" x 9" format - 3" super-wide angle lens; scale 1" = 1 mi) for the area requiring classification.

2. On these photos, delineate land systems with the aid of a stereoscope and land scale photos (1:10,000 or 1:15,840).

3. Stereoscopically locate one or more field plots on each of the land types in each system.

4. Visit each of the land type sample plots on the ground and complete the land type tally sheet (see Appendix 1).

5. Complete land system and land type summary sheets (see Appendix 2) upon return to the office. Completion of these summaries is based on the land type tally sheets, airphoto interpretation and knowledge gained through field experience. At this time, the original land system boundaries are adjusted if the field work indicates the need to do so. It is anticipated that steps 1 to 5 will provide the basic data required for the development of the five-year management plan.

6. Determine the management input(s) required for each forest type or site delineated in the

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

annual plan by intensive field sampling (i.e. every forest type) and the interpretation of large scale colour infrared photographs. At this point, specialists from wildlife and recreation will also make management recommendations in order to arrive at the best possible compromise regarding the land use of each land-vegetation type.

DEFINITIONS

Land System, mapped at scale 1" = 1 mi, is an area of land having a recurring pattern of land types. The area of a system is variable and depends on the complexity of terrain conditions but usually averages 2,000 to 4,000 acres in size. The system is defined by the following criteria:

- i Stoniness
- ii Topographic Pattern
- iii Topography
- iv Relief
- v Landforms
- vi Drainage Classes
- vii Rooting Depths
- viii Textures
- ix Parent Rock Types

Land Type, mapped at a scale of 1:10,000 to 1:15,840, is an area of land having a specific soil moisture regime, texture, consistency, structure, coarse fragment type, rooting depth, parent rock type, slope, and climatic exposure. The land type is, therefore, roughly equivalent to what foresters often refer to as a site type. More importantly, the land type provides the biophysical basis for intensification of resource management. Justification for this statement is based on the fact that the forest at any given period of time is the net result of the interaction of climate, relief, parent material, living organisms and time. Since these factors tend to be the same for a given land type no matter where it is located in the land system and/or district, the forest and its response to various inputs and disturbances also tends to be the same. Hence the land type, because it is recurring and because it is described in terms of its site and vegetation characteristics, provides the basis for:

(i) extrapolating the management implications of research and operational experiments conducted on specific sites to all land types having the same site and climatic properties

(ii) predicting the long- and short-term effect of management inputs and

(iii) rationally choosing from among the management alternatives, those that are both economically and ecologically sound.

MANAGEMENT INPUTS

The management inputs required for each forest type or site delineated in the annual plan will be decided primarily on the basis of the following interrelated factors. Examples of management inputs which are dependent or semi-dependent on each of the factors are listed in brackets.

1. The silvical characteristics of the species or species association (method of harvest (selective, clear-cut, strip cut, etc.), rotation age, final products, spacing schedule)

2. Damage or projected damage by insects, diseases or animals (porcupine) (liquidation, spacing, early harvest, artificial reforestation with species resistant to the damage agent)

3. Presence or absence of advance regeneration (need to artificially reforest, logging method)

4. Soil depth, texture, moisture, rock type, etc. (final product, logging method, species, stock type and stock quality to plant, logging season, harvest method, site preparation method, spacing, chance and regime)

5. Surficial and underlying stoniness and rockiness (site preparation method, harvest method, reforestation method)

6. Stand density and stocking (spacing regime, harvest method, liquidation, rotation age)

7. Climatic factors - distance from coast, elevation, etc. (harvest method, species to plant)

8. Lesser vegetation (site preparation method, species, stock type and stock quality to plant)

9. Stand age or maturity (harvest, space, salvage)

10. Wildlife and parks considerations.

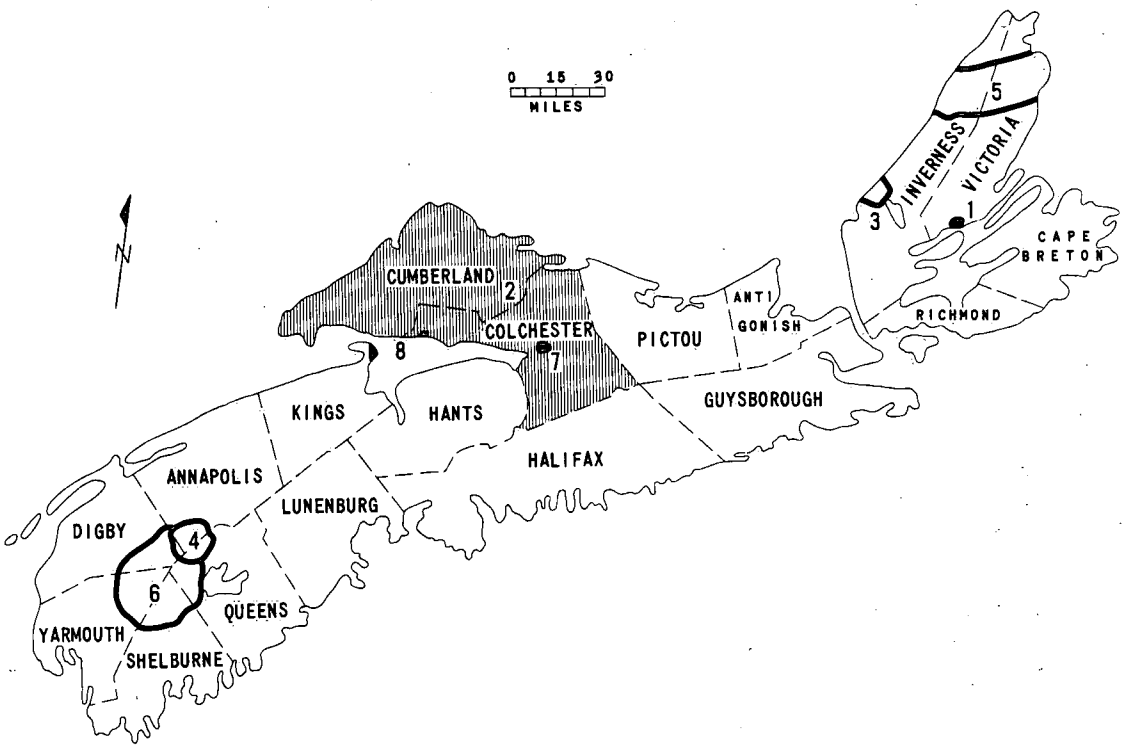
AREA COVERED

To-date, several variations of biophysical classification have been undertaken in different parts of the province (Figure 1). A brief description of each project is as follows:

1. Baddeck Area - Pilot project sponsored by the Department of Forestry and Rural Development. Area covered = 47,360 acres. Classification by Dr. G.K. Rutherford *et al.* Completed in 1968.

2. Cumberland and Colchester Counties - Pilot project undertaken by the Nova Scotia Department

Figure 1: Map of Nova Scotia



of Lands and Forests (NSLF). Area covered = 1,978,000 acres. Aerial multispectral imagery supplied by the Canada Centre for Remote Sensing. Estimated completion year 1977.

3. Mabou Highlands - Proposed provincial park. Estimated completion year 1976. Classification by NSLF.

4. Kejimkujik National Park - Area covered = 64,000 acres. Classification by Forest Management Institute and Acadia University. Completed in 1975.

5. Cape Breton Highlands National Park - Area covered = 240,000 acres. Classification by Eastern Ecological Research. Estimated completion year 1977.

6. Tobeatic Resource Management Area - Area covered = 336,000 acres. Classification by NSLF and the Canadian Forestry Service (CFS). Completed in 1975.

7. Manganese Mines Resource Centre - Student and teacher ecological educational training centre established by the Nova Scotia Teachers College. Area covered = 560 acres. Classification by NSLF. Estimated completion year 1976.

8. Various Provincial Parks - Area covered = 106,400 acres. Classification by NSLF.

ANTICIPATED FUTURE BIOPHYSICAL PROGRAM

1. Crown Lands - It is projected that under existing manpower and funding, approximately 15,000 acres per year can be classified on the extensive basis required for the development of five-year management plans. A further 10,000 to 15,000 acres, depending on the mix of stand conditions, can be classified on the intensive basis required for the development of annual management plans.

2. In September 1975, the Nova Scotia government resolved to undertake the development of a coastal zone management plan. Accordingly, it has established and funded a coastal zone management office in the Nova Scotia Department of the Environment. The identification, acquisition, and organization of information about the biological and physical characteristics of the Nova Scotia coastline will be an important input into the coastal zone planning process.

The value of a biophysical classification for coastal zone planning and management has not yet been clarified. Officials with the Nova Scotia Department of the Environment are hopeful that some such system can be soon developed not only to aid in the identification of coastal resources, but also to facilitate the integration of existing resource information.

STAFFING

The present staff includes one full-time forester, one manager responsible for the forest research and land classification programs, one full-time technician, two summer students, and six technicians and six student assistants for the month during the summer field season. Input from wildlife and recreation in the form of a professional from each discipline for a period equivalent to one month per year is projected. During the remainder of the year, the six technicians mentioned above are engaged in research studies relating response in growth and yield to various management inputs and site factors. The long-term intent of these studies is to develop ecologically sound management techniques designed to produce a specific product, on a specific site, in a given length of time. This combination of experience is considered invaluable because of their dual capability to clasify land and make management recommendations based on current knowledge gained from research projects.

PROBLEM

The major problem to-date is associated with staffing limitations. Funding for additional staff was requested under the General Development Agreement. This proposal was rejected by the Department of Regional Economic Expansion on the basis that the ongoing classification should be the responsibility of the Provincial Government. This decision makes it impossible to comply with requests from the major companies to carry out a biophysical classification of their limits.

Appendix 1: Field Tally Sheet, Biophysical Land Type Classification

Land System Name _____ Topo Sheet _____ Slide Nos. _____
Land System No. _____ Location _____ Line-Photo No. _____
Land Type No. _____ County _____ Date _____
Plot No. _____ Soil Series _____ Elevation _____
Crew _____

EXPOSURE: 1. Exposed 2. Mod. Exposed 3. Moderate 4. Mod. Sheltered 5. Sheltered

POSITION ON SLOPE: 1. Hilltop 2. Upper 3. Middle 4. Lower 5. Flat

SLOPE (%) _____ ASPECT (°M) _____ N. NW., NE., W.S. S.W., SE., E.

SITE COVER (%) Surface Boulders: Outcrop: Cutover: Moss: Residual Trees: Thick Humus:
Grass: Ericaceous Veg: Needle Carpet: Peat: Forest Stand: Non Ericaceous Veg: Woody Shrubs:

Schrebers __ Lycopodium __ Cornus __ Maianthemum __ Rododendron __ Prunus __ Juniperus __
Dicranum __ Polytrichum __ Oxalis __ Trientalis __ Ilex __ Salix __ Comptonia __
Sphagnum __ Cladonia __ Coptia __ Linnaea __ Viburnum C. __ Betula __ Pteridium __
Hylocomium __ Hypnum __ Aralia __ Gaultheria __ Vaccinium Mg __ Alnus __ Grass __
Bazzania __ Empetrum __ Viola __ Myrica Gale __ Kalmia __

TREE MEASUREMENTS

No.	Sp.	St.A	B.H.A.	D.B.H.	Ht.	L.C.
1.						
2.						
3.						
4.						
5.						

SPECIES COMPOSITION

Species					
%					
Dbh					
Age					
HT					
CRC1 (%)					

NATURAL REGENERATION

Species	$\overline{HT}$	Spacing*	Species	$\overline{HT}$	Spacing*	Species	$\overline{HT}$	Spacing*
		A-M-C-F-S-N			A-M-C-F-S-N			A-M-C-F-S-N
		A-M-C-F-S-N			A-M-C-F-S-N			A-M-C-F-S-N

HISTORY: 1. Fire __ 2. Swd. Cut __ 3. Hwd. Cut __ 4. Partial Cut __ 5. Old Field __
6. Hurricane __ 7. Pasture __ 8. Insects __ 9. Natural __ 10. Barren __

PRECEDING STAND COMPOSITION _____ SUCCEEDING STAND COMPOSITION _____

SUGGESTED SPECIES TO PLANT _____ PLANTING-SITE PREP. CHANCE E. VG. G. F. P.

LOGGING METHOD: 1. Clear Cut __ 2. Strip Cut __ 3. Selection __ 4. Thinning __
5. Cleaning __ 6. Any Method __ 7. No Management Procedure Required __

LOGGING CHANCE: E. VG. G. F. P. LOGGING SEASON: Any Season __ 2. Winter Only __

*SPACING: A. 5000+ (3' less), M. 1000-5000 (3' to 6'), C. 500-100 (6' to 9'), F. 200-500 (9' to 15'), S. 1-200 (15' greater), N. Nil

TEXTURE	LFH	Ah	Ae	Ap	Aeh	Bf	Bt	Bfh	Bg	BC	C
Sand											
Loamy Sand											
Sandy Loam											
Silt Loam											
Clay Loam											
Silty Clay Loam											
Sandy Clay Loam											
Clay											
COARSE FRAGMENTS											
1. Stony											
2. Cobbly											
3. Gravelly											
4. Shaly, Slaty											
5. Flaggy											
6. Cherty											
7. Channery											
STRUCTURE											
1. Single Grain											
2. Blocky											
3. Subangular Blocky											
4. Granular											
5. Platy											
6. Massive											
CONSISTENCE (When Moist)											
1. Loose-Noncoherent											
2. Very Friable											
3. Friable											
4. Firm											
5. Very Firm											
6. Estremely Firm											
7. Weakly Cemented											
8. Strongly Cemented											
MOTTLING											
Faint											
Distinct											
Prominent											
Few											
Common											
Many											

LAND FORMS

Glacial Till
Ablation Moraine A.M.
Basal Moraine B.M.
End Moraine E.M.
Drumlinized Till Plain D.T.P.
Steepland Till S.T.

Glacial Fluvial
Kames & Kame Terraces K.
Esker E.
Outwash Plain O.P.
Valley Train V.T.
Undifferentiated U.
Terrace G.T.

Glacial Lacustrine
Plain P.

Marine & Glacial Marine
Coastal Beach C.B.
Marine Beach M.B.
Marine Plain M.P.

Fluvial
Fluvium F.
Delta D.
Terrace T.

Aeolian
Dunes Du.
Loess L.

Organic
Raised Bog R.B.
Flat Bog F.B.
Swamp Sw.
Salt Marsh S.M.

SOIL MOISTURE
0. Dry
1. S. Dry
2. Std.
3. S. Moist
4. Moist
5. V. Moist
6. Wet
7. V. Wet
8. Wet Peat
9. Raised Peat

1. Stagnant
2. Slow Seepage
3. Strong Seepage
4. Normal

PARENT MATERIAL (Rock Type)
1. Sandstone
2. Shale
3. Slate
4. Quartzite
5. Conglomerate
6. Granite
7. Basalt
8. Schist
9. Gneiss
10. Limestone
11. Gypsum
12. Diorite
13. Syenite
14. Gabbro
15. Rhyolite

ROOTING DEPTH 1. 5" Less 2. 6-10" 3. 11-15" 4. 16-20" 5. 21-25" 6. 26-30" 7. 31" +

LIMITING FACTORS - C, H, U, M, W, X, Z, D, R, Y, E, F, I, L, N, P

SPACING 1. 0-10', 2. 11-20', 3.21-30', 4. 31-40', 5. 41-50', 6. 51-70', 7. 71-90', 8. 91' +

SIZE 1. 0-10", 2. 11-15", 3.16-24", 4. 25-36", 5. 37-48", 6. 49-60", 7. 61" +

COMMENTS:

Appendix 2: Data Summary Sheets

Land System

Land System No. Land System Name

Symbol	% Land Types	Forest Classification		
		Eco-Region	Site District	Forest Region

Area	Present Land Use	Forest Cover Type	Land Owner	Soil Cantenas

C. L. I. Classification				
Forestry M. A. I.	Forestry Symbol	Wildlife	Recreation	Agriculture

Land Type

Land Type No. Area Land System No.

Symbol	C L I			Stoniness		
		Forestry			Size	
		Agriculture				
		Wildlife			Space	
		Recreation				

Chrono Sequence

Vegetation		Present	Fire	Cut	Barren	Pasture	Field
	Tree Species						
	Ground						

Management Recommendations For Forestry

Logging			Site Prep.	Suggested Planting (sp)		Recommended Prod.
Method	Chance	Season	Rating	Ericaceous	Non-Ericaceous	

Management Recommendations

Wildlife	Recreation	Agriculture

				Species Assoc.
				Natural Succession
				Climax
				Species Assoc.
				Natural Succession
				Climax

LAND INVENTORY PROGRAMS IN NEWFOUNDLAND

B.B. Delaney
and
K.J.S. Beanlands
Department of Forestry and Agriculture
St. John's, Newfoundland

ABSTRACT

Newfoundland had an active land inventory program during the late 1960's. Since that time, not much emphasis has been placed on land classification. Recently, however, with the major thrust to develop the north, there is a need to provide new information on land resources. Some comments are given on the experience to-date in biophysical land classification in Newfoundland.

RÉSUMÉ

Il y a eu un grand programme d'inventaire des terres à Terre-Neuve vers la fin des années soixante. Depuis ce temps, toutefois, la classification du territoire n'a pas compté parmi les activités prioritaires. Etant donné l'intérêt récent pour la mise en valeur du Nord, il est devenu nécessaire d'obtenir de nouvelles données sur les ressources terrestres. Le présent document comprend des observations faisant suite aux expériences réalisées jusqu'ici dans le domaine de la classification biophysique de territoire à Terre-Neuve.

During the late 1960's and until 1971 there was an active land inventory program in the Province. In addition to the Canada Land Inventory, the following specific projects involving biophysical surveys were conducted.

1. Land Classification of the Corner Brook Area.

2. Biophysical Land Classification of the Goose Bay and Lake Melville Area.

3. Biophysical survey of the Badger Area-Newfoundland.

These projects were significant in the testing and finalization of methodology and on providing the opportunity for staff to become familiar with biophysical concepts and their value in resource planning.

The initial thrust in land classification was followed by a period of reassessment of provincial needs. Inventory programs involving land classification received low priority and professional and technical staff were assigned new responsibilities. However, in the interim, the Province embarked upon several major resource development programs in the north. For example:

1. A power development at Gull Island on the Churchill River will create a man-made lake 140 miles long.

2. A transmission line from this hydro site across Labrador to the Island.

3. A trans-Labrador highway is being considered.

4. A uranium mine is in the final stages of planning at Postville, Labrador with production expected to start in two years.

5. The recent encouraging gas and oil discoveries in the Labrador Sea may have drastic consequences for the life of the coastal population.

In addition to the above development programs, native land claims are reaching the stage where presentations to government are expected soon.

With the coming of the age of environmental impact studies, there was a sudden need for reliable and accurate information on the land resources. While attempting to evaluate development proposals, it was soon realized that there was a serious lack of information. Impact studies hastily compiled in the absence of essential resource data have not served intended purposes.

The preceding has served to give you an indication of the basis for some of our present programs in land inventories. There are four current projects which should be identified.

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

While two of these are preliminary, they reflect some of our requirements.

1. A Coastal Inventory Program was conducted in 1975 in conjunction with the Lands Directorate of Environment Canada for two locations in the Province. The published maps are on display here today for anyone interested. The Department of Regional Economic Expansion (DREE) has agreed in principle to financially assist the Atlantic Provinces in carrying out an expanded program. In Newfoundland, priority will be given to the Island and the southern one-third of coastal Labrador if an agreement is entered into.

2. During the past several months, the Department of Forestry and Agriculture and Atlantic Lands Directorate of Environment Canada have developed a joint proposal to carry out a biophysical survey of Labrador at the land system level. If approved, it is expected that this project will take at least four years and will involve both federal and provincial scientists. This year, a preliminary assessment of Labrador will be undertaken by Lands Directorate staff on a strictly informal basis, using remote sensing techniques. Logistic support in terms of flying time and cartography will be provided by the Province.

3. The recent Royal Commission Report on Labrador recommended that a land resources inventory be initiated immediately for priority areas of Labrador. In addition, a Federal-Provincial Project Group has been studying the economic opportunities for Goose Bay following the phase down and eventual closing of the U.S.A.F. Base. A tentative agreement has already been worked out with DREE for providing financial assistance for developing industrial opportunities in this area. This agreement is presently open-ended in that it contains a general clause which could allow for further resource inventories as well as socioeconomic studies in Labrador.

4. A new forest management program is underway and an important element in the policy is a large scale silviculture program. If maximum benefit is to be derived from these expenditures, it will be necessary to have detailed ecological information on all sites. The biophysical concepts are well suited to present the essential information that the forest manager requires to make informed decisions. Although it is not underway, one does not have to be a prophet to envisage a program of land type mapping prior to initiation of intensive forestry management practices.

In concluding the remarks on the programs underway or planned in the Province, it is suggested that benefits could accrue if all four were gathered under an 'umbrella' arrangement for direction and funding purposes. If not, there exists the possibility of a lack of coordination resulting in duplication of effort and a failure to focus on socioeconomic aspects of our land resources.

The major effort to-date in biophysical classification was the project in the Goose Bay area in 1971 covering an area of 4100 mi^2. There were several positive features about this initial attempt as well as a number of limitations which are perhaps worthy of note so that others can gain from our experience.

1. There was a team made up of people from the following disciplines: soil science, wildlife biology, botany, ecology, forestry and recreation. These team-members worked together as a unit in the field. However, they were not committed to the project full time and as a result, this made the final compilation of reports and maps nearly impossible. Serious problems can result if personnel have to be distracted by other work committments.

2. The Geological Survey of Canada, under the Direction of R. Fulton, developed a landform classification which is recommended for future use. If a genetic classification such as the one by Fulton were adopted on a national scale by all land ecologists, it would facilitate an understanding of each other's work and provide a common format for data collection eliminating duplication of costly field studies. Nearly all of southern Labrador has been mapped for surficial geology at the 1:50,000 scale, and this will be of tremendous value in future biophysical surveys.

3. In the north there is always the need to cover large areas. The experience in Goose Bay suggests that the area be mapped or studied one land region at a time. If field work is conducted concurrently in several land regions, masses of data will accumulate. Ideally, one region should be studied and all the vegetation successions worked out before moving to the next region.

4. If vegetation descriptions and successional patterns are not prepared for each land type, there may be severe limitations in assessing the true impact of any development proposal. This raises the question of mapping only at the land system level and how much detail can be obtained in a fixed time frame with cost restrictions.

5. Due to the non-availability of a hydrologist, no attempt was made to incorporate an

open water and wetland classification in Labrador. It is recommended that for future work this inadequacy be corrected.

In summary, our experience in Newfoundland indicates that the biophysical concepts are sound. If this information were available, it would contribute greatly to the understanding by the land manager of the resources and their best use. However, we recognize that, like all sciences, land classification is not static but will change and improve with new ideas and techniques. The Canada Committee on Ecological (Bio-physical) Land Classification will no doubt provide a major opportunity to share our experience and thus result in better utilization of our land resources.

BIOPHYSICAL-TYPE SURVEYS IN THE DEPARTMENT OF ENERGY, MINES AND RESOURCES

R.J. Fulton
Terrain Sciences Division
Geological Survey of Canada
Ottawa, Ontario

The Terrain Sciences Division of the Geological Survey of Canada is the group in the Department of Energy, Mines and Resources that has been carrying out biophysical types of surveys. These are done under one of our major objectives which is to map, describe and explain the surficial materials of Canada in order to obtain information pertinent to land use, resource development, environmental concerns and activity of geological processes, and to determine the Quaternary history. It should be noted that this activity is oriented entirely towards the physical aspects of land. Biological aspects are not mentioned. In the south, biological aspects are generally completely ignored. In the north, however, it is necessary to consider them when looking at the physical side because in areas of permafrost they play an important role in the way in which the land reacts. In the south you can cut off the bush or turn over the sod and about all that generally happens is that you lose a little top soil. In the areas of permafrost, however, removal of vegetation can and often does lead to the interplay of a completely new set of physical-geological activities that can develop a new physiography and completely changes the way in which the land reacts. Consequently we have started work, that can be described as biophysical, where the biological side has potential to profoundly affect our prime field of interest, the physical side.

Purists might argue that because much of our work is not completely integrated it is not truly biophysical or ecological in nature. Our basic approach has been to have a geomorphologist subdivide the land into homogeneous units, and then have pedologists and/or botanists characterize the plants and soils in each of these permanent or physical units and set up ecological districts and regions. This is single discipline work with an overlay of other disciplines. Pioneer work of this type was done in the Mackenzie Valley by Hughes and Rutter with the aid of Tarnocai and Zoltai. This work was extended further into the Arctic by Boydell and Tarnocai on the Boothia Peninsula, and recently to Banks Island by Vincent and Edlund, to Ellesmere by Hodgson and Edlund and to Somerset and Prince of Wales by Netterville, Zoltai and Woo.

A fully integrated approach has been applied by Barnett and co-workers in Eastern Melville, Bathurst and Cornwallis Islands. In this work, a hierarchy of units was used and biological factors were taken into account in fixing some unit boundaries.

In our present program, emphasis is on the Arctic gas pipeline route on the west side of Hudson Bay and on potential oil and gas producing areas in the Arctic Islands. Work is continuing on Banks Island.

Looking further into the future, there is some question as to how much more work of this type we will be able to do. The demise of the Environmental Social Program, Northern Pipelines will cut off our pipeline of funds from Treasury Board and stand-pat budgeting will force some retrenchment so that over the next few years we will probably have difficulty in finding enough resources to meet our primary physical objectives. However, this might be good because we might be forced into more joint projects with other agencies that could benefit both sides of the ecological coin.

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

SOIL SURVEYS IN THE CANADA DEPARTMENT OF AGRICULTURE

J.S. Clark
Soil Research Institute
Agriculture Canada
Ottawa, Ontario

ABSTRACT

Soil surveys of Agriculture Canada have evolved from traditional agricultural orientation to more diverse uses. At the same time, methodology has changed and some recent projects have utilized approaches closely resembling the biophysical scheme. Coordinated through the Canada Soil Survey Committee, surveys have responded to the rising volumes of soil data with the aid of a computerized data system (CanSIS). New information has necessitated modifications of the taxonomy to accommodate the total population of Canadian soils, and more refined methods of interpretation. This process of adaptation will continue in cooperation with other agencies, in particular the Canada Committee on Ecological (Bio-physical) Land Classification.

RÉSUMÉ

Les relevés des sols effectués à Agriculture Canada, jadis axés sur la seule vocation agricole, s'intéressent maintenant à des usages plus diversifiés. La méthodologie a elle aussi changé; certains projets récents ce sont fondés sur des approches qui s'apparentent beaucoup au cadre biophysique. Coordonnés par la Commission canadienne de pédologie, ces programmes ont donné suite au volume croissant de données sur les sols au moyen d'un système informatique (CanSIS). Des renseignements nouveaux obtenus ont amené des modifications à la taxonomie de façon à pouvoir servir pour la grande variété des sols canadiens, ainsi que des méthodes d'interprétation plus perfectionnées. Ce processus d'adaptation se poursuivra, de concert avec d'autres organismes, notamment le Comité canadien de la classification écologique du territoire.

Agriculture Canada's work in soil survey is part of a national survey program involving a cooperative and integrated effort by both provincial and federal agencies. Soil survey has traditionally been oriented to some specific purpose. The earliest work in Ontario at the turn of the century was directed towards increasing the province's food producing capacity; in the Great Plains, surveys were started to aid land settlement and combat critical soil erosion; in present-day Ontario, most effort is concentrated on resolving urban-rural conflicts and providing detailed information on soils for zoning and intensive agricultural management.

Not all soil survey work has been directed to agriculture; increasingly, soil survey has been used for non-agricultural purposes. Soil information obtained in regular soil surveys has been interpreted for forestry, engineering, urbanization, recreation assessment, and other purposes. Examples are listed in Table I. With current interests in resource conservation and

Table 1: Typical modern routine surveys with interpretive material.

Province	Survey	Date
BC	Tulameen	1974
Alberta	Oyen	1976
Sask	St. Walburg	1976
Man	Morden - Winkler	1973
Ont	Waterloo	1971
Que	Chicoutimi	1971
NB	Rogersville	(in preparation)
NS	Cumberland	1973
PEI	PEI 1:10,000 series	(in preparation)
Nfld	Gander - Gambo	1972
NWT	Slave River Lowland	1972

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

management, soil survey has been involved in a growing number of comprehensive biophysical-type surveys that treat the soil component in its environmental perspective. These have included integrated or multidisciplinary approaches and have been carried out for a variety of requirements, including environmental impact assessment, comparative resource appraisal, parks planning, and other purposes. The projects of this kind in which Agriculture Canada has been involved are listed in Table 2.

Both the traditional general purpose survey and the special purpose-oriented survey are now focussing more on total landscape relationships. This is especially true of the low intensity special surveys in more remote areas, many of which might be labelled 'biophysical'.

The interpretation and application of soil survey information for land management and planning purposes has led to the development of the Canadian Soil Information System (CanSIS). This computerized data management system accommodates information relating to soil morphology, management, productivity, and geographic distribution. Currently all survey data and maps are being entered into the information bank, and CanSIS has been expanded (in cooperation with Parks Branch, Department of Indian and Northern Affairs) to accommodate soil and related data required for parks management and planning.

Recently Agriculture Canada has embarked on a land evaluation program involving the synthesis of pedologic, landform, climatic, agronomic and economic data to determine the relative qualities of land areas, viable alternate uses, and inputs necessary to optimize utilization. The integration of provincial and federal soil survey activities is achieved through the Canada Soil Survey Committee (CSSC). The first meeting of the CSSC (then the National Soil Survey Committee) took place in 1945 with the objectives:

1. To provide greater efficiency in soil survey work by:

   (a) bringing about a greater measure of uniformity between provinces in all phases of soil survey work

   (b) utilizing the joint experience and efforts of the soil surveyors toward the solution of common problems affecting their field work

   (c) providing a clearing house whereby any new developments or improvements in technique in any one province can be made available to all others in this field in Canada.

2. To recommend the location of areas where soil survey work should be done in relation to land settlement or for other purposes.

3. To act as an advisory body on soil survey matters to the parent Canadian Agricultural Services Coordinating Committee.

One of the main concerns at the 1945 meeting was the development of a soil classification system for Canada, and this has continued as the committee's primary responsibility. The first soil taxonomic system for Canada, estab-

Table 2: Comprehensive biophysical-type surveys.

Province	Survey	Date
BC	Smithers - Hazelton	1972
BC	Nechako - Francois Lake	1974
Alta	Hinton - Edson	1973
Alta	Waterton Lakes National Park	(in press)
Alta	Yoho National Park	(in progress)
Alta	Banff - Jasper National Park	(in progress)
Sask	Prince Albert National Park	(in progress)
Man	Cormorant Lake	1975
Man	Winnipeg Regional Study Area	1975
Man	Churchill - Nelson River	1973
Ont	Pukaskwa National Park	(in press)
Nfld	Botwood	(in progress)
Nfld	Sandy Lake	(in progress)
NWT	Mackenzie River	1973
NWT	Somerset and Prince of Wales Islands	1976
NWT	Boothia	(in progress)
Yukon/NWT	Liard and Mackenzie River	(in press)

lished at the 1955 meeting of the CSSC, had six categorical levels corresponding to order, great group, subgroup, family, series and type. The orders recognized in the 1955 system were Chernozemic, Halomorphic, Podzolic, Forested Brown, Regosolic, Gleisolic and Organic.

The classification system has been modified, refined, and expanded continually over the past twenty years at the deliberations of the CSSC. The national classification system that was first accepted for general use in 1960 has resulted in "The System of Soil Classification for Canada" which is published and revised regularly by Agriculture Canada under the auspices of the CSSC.

Like any scientific endeavour, soil survey is a changing and developing field and one of the main functions of the CSSC has been to embody those changes and developments into a comprehensive national system. This of course is a continual process and, as many know, the CSSC has been criticized for its frequent modifications to the soil classification system and occasional apparent lack of consistency. The period from 1945 to the present, however, has been one of rapid advances in pedology and greatly expanded field activity and the CSSC simply had to accommodate to the realities of the science. One such reality has been the waxing flood of hard data from recent surveys, which corroborated parts of our classification and parts of our methodology, but elsewhere established new norms. Even though a national committee may have a major responsibility for ensuring consistency and continuity, it must be prepared to experiment, adapt, and if necessary retract in order to provide the kind of national leadership required.

The CSSC sees a continuing need for change and improvements in the future. The systematization of soil survey interpretations for land management and planning, and the rationalization of soil mapping systems will be two of the major immediate concerns of the committee. The CSSC looks forward to cooperating with the Canada Committee on Ecological (Bio-physical) Land Classification in the development of an effective physical land classification system.

BIOPHYSICAL LAND CLASSIFICATION IN THE ENVIRONMENTAL MANAGEMENT SERVICE, DEPARTMENT OF THE ENVIRONMENT

T.W. Pierce
and
Jean Thie
Lands Directorate, Ottawa, Ontario

ABSTRACT

The Department of the Environment (DOE), through the Canada Land Inventory Program and the National Committee on Forest Lands, has supported the development and application of a biophysical classification system for Canada. A summary of the biophysical and related surveys and research is given in this paper. Ongoing as well as planned activities are listed. At present $1.75 million and about 65 man-years carry out surveys or research directly or indirectly in support of biophysical activities. An Advisory Committee on Northern Baseline Studies was set up in the Environmental Management Service to coordinate baseline studies for the Environmental Assessment and Review Process (EARP).

RÉSUMÉ

Le ministère de l'Environnement, par l'entremise du Programme d'inventaire des terres du Canada et du Comité national des terres forestières, appuie la création et l'application d'un système de classification biophysique au Canada. La présente communication donne un résumé des études et recherches biophysiques et connexes. Les activités en cours et projetées sont énumérées. A l'heure actuelle, 1.75 millions de dollars et environ 65 années-hommes ont été consacrés à des études ou à des recherches qui appuient directement ou indirectement les activités biophysiques. Un Comité consultatif des études nordiques a été créé au sein du Service de la gestion de l'environnement pour coordonner les études de base dans le cadre du Processus d'évaluation et de révision environnementales (PERE).

INTRODUCTION

The Department of the Environment (DOE), through the Canada Land Inventory (CLI) Program and the National Committee on Forest Lands, has supported the development of a biophysical classification system for Canada. Since the completion of the pilot projects in Québec, Manitoba and British Columbia, this methodology has been applied to various surveys and inventories conducted by DOE. Some of these are described in detail in the Proceedings (e.g. see Zoltai, Oswald and Holland). This paper gives a summary overview of the DOE programs in biophysical and related surveys. The information is based on a report prepared for the Environmental Management Service (EMS) by an interdirectorate committee on Biophysical and Related Surveys, December 1975.

Surveys in the Department were roughly grouped into three types: biophysical, multidisciplinary, and disciplinary (single discipline). These were described as follows:

Biophysical Survey or Inventory - A survey or inventory which is carried out to provide a framework for environmental resource management and planning using a hierarchical classification system integrating environmental elements (land, water, climate and living organisms). Ecosystems are mapped or grouped and described according to ecological conditions and relationships, usually without direct interpretation and analysis for resource management and planning (i.e. suitability for specific or multiple use). These surveys are usually carried out by an integrated team.

Multidisciplinary Survey or Inventory - A survey or inventory carried out to provide a framework for the management and planning of more than one specific resource to determine the 'best' use within predetermined constraints or concerns. Two or more specific disciples are involved in a survey using standardized or compatible methodology for classification, evaluation and description.

Disciplinary Survey - A survey or inventory carried out to provide specific data for the management and planning of only one resource.

The activities of each of the EMS Directorates

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

(Inland Waters, Forestry, Wildlife, and Lands) are listed according to the groups defined above. Only present and planned surveys or studies are included. They are listed by directorate, though in many of them there is participation by other services and government departments. Figure 1 demonstrates, for some of the ongoing survey activities, the relationship between amount of integration (survey methodology) and objectives (as related to the components of the environmental management process).

BIOPHYSICAL SURVEYS

A. In the Lands Directorate:

Coastal Resources Inventory and Mapping Program - A federal/provincial inventory of coastal resources of the Atlantic provinces. This has involved research into the development of a coastal zone classification and pilot projects in Newfoundland and Nova Scotia.

Biophysical Survey of Labrador - In cooperation with the Government of Newfoundland and the Canadian Forestry Service to prepare maps and narratives describing the vegetation and landforms of Labrador.

Biophysical Survey of land potentially affected by Fundy Tidal Power Development.

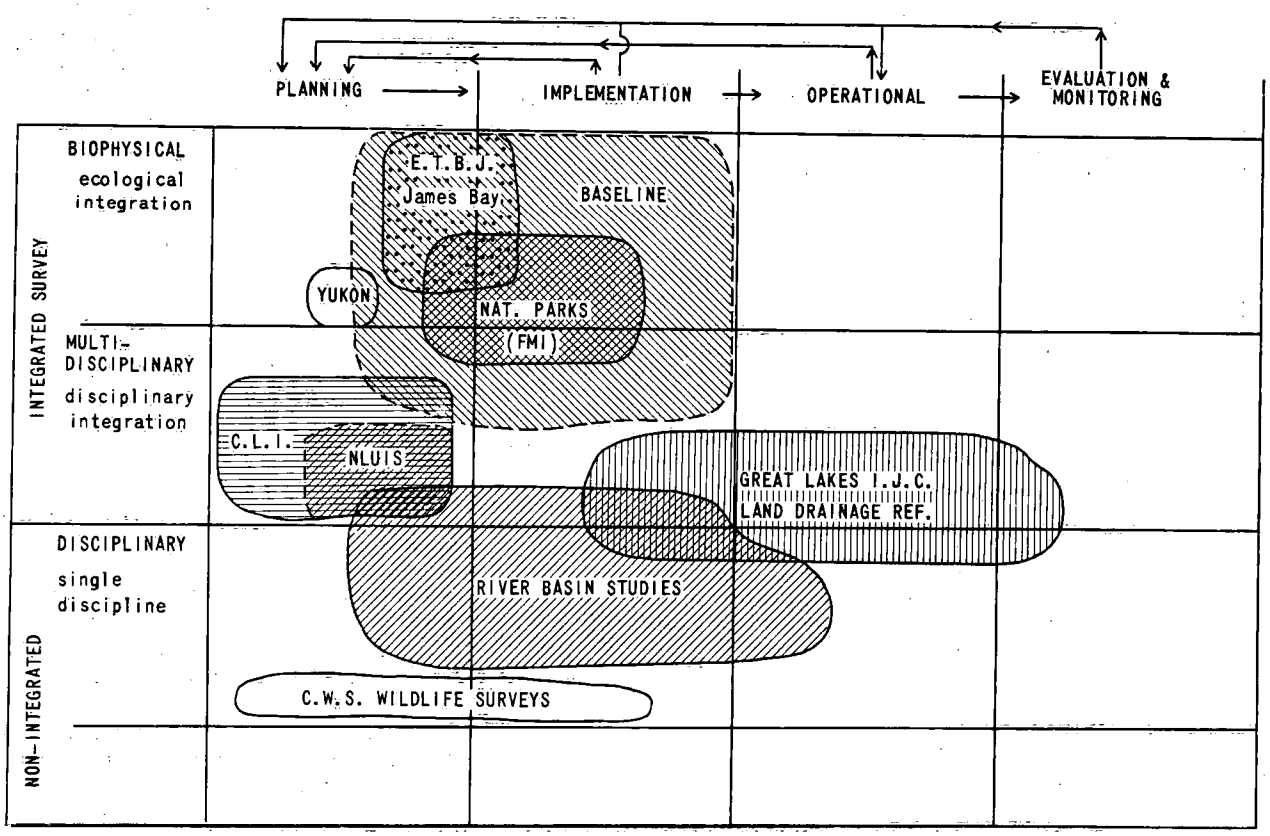
Biophysical Baie James - Involves preparation of maps suitable for interpretation covering the area affected by the James Bay power development. This project includes an evaluation of remote sensing, preparation of a methodology manual, and studies in data presentation.

Biophysical Plaine de St.-Laurent - A biophysical survey similar to the above, carried out in the St. Lawrence Lowlands.

Hudson Bay Lowlands Biophysical Studies.

In collaboration with the Manitoba Northern Resources Inventory Program - Research on the integration of water data into ecological land classification; evaluation of remote

Figure 1



sensing techniques for ecological land classification.

Caribou Range Study - In conjunction with the Department of Supply and Services and other DOE services; provides funding and coordination for a study carried out by the University of Saskatchewan (Dr. J.S. Rowe) on the Caribou Range, N.W.T. This includes biophysical mapping and studies of paleoecology, nutrient cycling and peatland vegetation changes.

B. In the Canadian Forestry Service (CFS):

National Park Biophysical Surveys - In cooperation with the National Parks Service, Department of Indian and Northern Affairs, CFS is carrying out biophysical surveys of several national parks, notably:

L'Anse Aux Meadows (Nfld.)
Kejimkujik (N.S.)
Fundy (N.B.)
Pukaskwa (Ont.)
South Nahanni (N.W.T.)
St. Lawrence Islands (Ont.)
Georgian Bay Islands (Ont.)
Banff-Jasper (Alta.)

These projects include the acquisition and analysis of data, and studies in the presentation of results. An important part of each study is user education, and a number of courses have been held to teach parks personnel how to read and interpret the results.

Avalon Peninsula Biophysical - A cooperative study with the Newfoundland Wildlife Service to prepare a land and ecological capability appraisal and management plan for a provincial park and wilderness area.

Arctic Islands Terrain Project - In cooperation with the Geological Survey of Canada (GSC) to prepare terrain maps along the eastern arctic gas pipeline route.

Yukon Biophysical - To delineate and map broad regional, vegetational, physiographic and climatic zones, and major watersheds.

Environmental Inventories in the Vancouver and Victoria areas - Preparation of a series of maps and narratives on vegetation, soils and recreational features for planning and development.

MULTIDISCIPLINARY SURVEYS

A. In the Lands Directorate:

Canada Land Inventory - Preparation of capability maps for agriculture, forestry, wildlife, and outdoor recreation, and maps of present land use. The fieldwork is virtually done and effort is presently concentrated on the publication of maps and analysis of the data.

Northern Land Use Information Series - A series of maps prepared for the Department of Indian and Northern Affairs (DINA) to portray critical considerations of social, cultural, and economic features pertaining to land or water use and management. The Canadian Wildlife Service (CWS) and Fisheries and Marine Services (F&MS) participate in this project.

B. In the Canadian Forestry Service (CFS):

Urban Forestry - At present, this survey concentrates on various cooperative programs with the National Capital Commission.

C. In the Inland Waters Directorate (IWD):

Great Lakes Land Drainage Reference Group - A cooperative study with participation by other services and government departments to prepare a report for the International Joint Commission.

River Basin Studies - Surveys and studies to prepare water management plans for a river or lake basin. They entail consideration of a wide range of water-related aspects of the natural and social environments such as economic, recreational, ecological and aesthetic. Study areas include:

Saint John Basin
Souris Basin
Peace-Athabasca Delta
Shubenacadie-Stewiake Basin
Qu'Appelle Basin
Okanagan Basin
Lake Winnipeg, Churchill and Nelson Rivers
St. Lawrence Water Quality
Churchill River (Sask.)
Athabasca River Basin
Lake Winnipeg Water Quality
Richelieu Valley - in cooperation with Lands and CFS

In addition to the surveys carried out, the various services are carrying out a number of related studies and research projects in support of biophysical classification work. These involve such subjects as development and evaluation of remote sensing classifications and methods, data storage and analysis, and presentation and application of results.

LEVEL OF EFFORT

Advisory Committee on Northern Baseline Studies

In 1976 an Advisory Committee on Northern Baseline Studies was established under chairmanship of the Senior Environmental Advisor. Members are the Regional Environmental Assessment Coordinator and representatives from the Headquarters of each Directorate. The objective of this committee is to coordinate, priorize and assess the need for Environmental Baseline Studies by EMS. The Committee has defined Environmental Baseline Studies as:

> *projects undertaken to acquire Environmental Baseline Information which has been defined as a description of environmental properties and processes within a specifically defined area taking into account the dynamic and interactive nature of ecosystems, which will allow the predictions of environmental states resulting from anticipated intrusion by man within a specified time-frame, to meet the requirements of the EARP.*
>
> *This work is not done in anticipation of any specific kind of environmental intrusion but rather is done so as to provide a basis for the prediction of the consequences of intrusions likely to occur in the area in question.*

Biophysical surveys and research are at present largely restricted to Lands and CFS. Current biophysical projects are supported by $1.5 million and about 48 man-years, about equally divided between Lands and CFS. About a third of this amount is provided by other departments (e.g. National Parks Service of DINA). Research directly in support of biophysical activities (about $250k and 15 man-years) appears to be carried out predominately by Lands. However, many of the research and survey activities of the CFS in the fields of forest inventory, remote sensing and ecology directly and indirectly play an important role in the further development of biophysical classification methodology. About $5 million and 140 man-years were required for *multidisciplinary surveys* in EMS. Major activities include the CLI, the Northern Land Use Information Series (NLUIS), and River Basin Studies. The CLI is in its finalization phase. The NLUIS is an ongoing survey financed primarily by DINA, with DOE involvement from Lands, CWS and F&MS. River Basin studies form the major component of multidisciplinary surveys. IWD is the lead agency, and other DOE Directorates may participate under the coordination of Federal/Provincial Study Boards.

DEVELOPMENTS IN CLASSIFICATION METHODOLOGY

ÉVOLUTION DE LA MÉTHODOLOGIE DE LA CLASSIFICATION

WETLAND CLASSIFICATION

S.C. Zoltai
Canadian Forestry Service
Environment Canada
Edmonton, Alberta

INTRODUCTION

In 1970 the National Committee on Forest Land established a subcommittee on Organic Terrain Classification. The immediate task of this subcommittee was to develop a system of organic terrain classification application to various land use purposes. The classification system was to be compatible with our current methods of land resource surveying, notably the Biophysical Land Classification.

The subcommittee consisted of a panel of eight experts in wetland research under my chairmanship. Each panel member represented the geographic area of a province, except that there was one representative from the three Maritime Provinces. Each member of the subcommittee was to organize provincial study groups consisting of workers in various disciplines, all experienced in wetland investigations. Thus each panel member represented not only his own thoughts and expertise on the subcommittee, but also the thoughts of a variety of experts in his own region. At the same time, an intensive literature review was undertaken by the panel members to benefit from the experiences of other workers in Canada and in other countries, especially in northern Europe and the U.S.S.R.

The subcommittee developed a tentative classification system by 1973. This classification system was presented at the Fourth North American Forest Soils Conference at Quebec (Zoltai *et al.*, 1973). By this time the parent body, the National Committee on Forest Land, had been dissolved, but the subcommittee was asked to remain active. Without active support, both moral and material, the subcommittee accomplished little after this time, other than sporadic efforts by its members to utilize the Wetland Classification framework in the course of their investigations (Jeglum *et al.*, 1974; Zoltai and Tarnocai, 1975a,b).

PHILOSOPHY

The philosophy of the proposed Wetland classification is based on the premise that wetlands are ecosystems on which a multitude of environmental factors are acting through time and changing climatic conditions (Figure 1). A classification that would stress only single or few features would find limited usefulness for many resource users. By recognizing a wide spectrum of environmental influences, the needs of various land users are met.

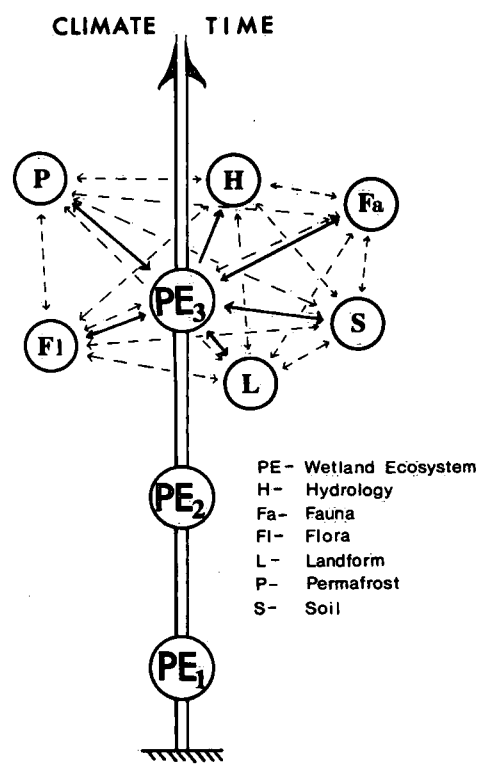


Figure 1: Diagram of interactions between environmental parameters and wetland ecosystems through time and changing climate

The proposed classification is presented in a hierarchical framework. The higher levels have been assigned ecosystemic definitive and descriptive criteria, and the lower levels have more specific, user-related criteria.

Wetlands are not conceptually different from drylands. In the past, the differences between drylands and wetlands were stressed, creating the impression that wetlands are by their nature entirely different from drylands. Wetlands have landforms (e.g. surface forms and materials), just as drylands have. Wetlands have different moisture conditions on quantitative, qualitative and temporal bases, as do drylands. Wetlands possess local climates as do drylands. Perhaps the only meaningful difference is that wetlands can manufacture their own materials and are therefore capable of changing their own site characteristics. Although site qualities may change on drylands also, the change in wetlands (especially in peatlands) is more rapid and obvious. Wetlands are, therefore, more dynamic ecosystems than drylands.

PROPOSED CLASSIFICATION*

**See Appendix of this paper for details on the proposed classification.*

In the proposed classification the broadest level, Level 1, is based on environmental factors which contribute to the broad physiognomy of the wetlands. The various kinds of wetlands recognized were Bogs, Fens, Swamps, Marshes and Shallow Lakes. Each of these is defined within regions as to moisture conditions, materials, nutrient conditions, water movement, development dynamics and vegetation. Level 2, a subdivision of Level 1, is based primarily on the surface morphology of the wetlands including the distribution of surface water and, in some cases, the morphology of the confining basin. Being a subdivision of Level 1, all the environmental parameters considered for Level 1 also apply to this level. At Level 3 the wetland types identified at Level 2 are further subdivided on the basis of broad vegetation, edaphic, hydrologic or developmental dynamic characteristics. Level 4, the most detailed level, was left open to allow further subdivision on the basis of the specialized needs of various disciplines, e.g. wildlife, botany, forestry, engineering, etc.

This hierarchical system allows different disciplines to follow a common path and diverge only at the most detailed, local study level. This overcomes the greatest difficulty that the subcommittee found: that of terminology. The same word may have totally or subtly different meanings to different persons or disciplines. Thus "muskeg", when used as a scientific term, has as many different definitions as there were people working with them. As a result of our efforts, in the Mackenzie Valley, home of the "muskeg", now even the

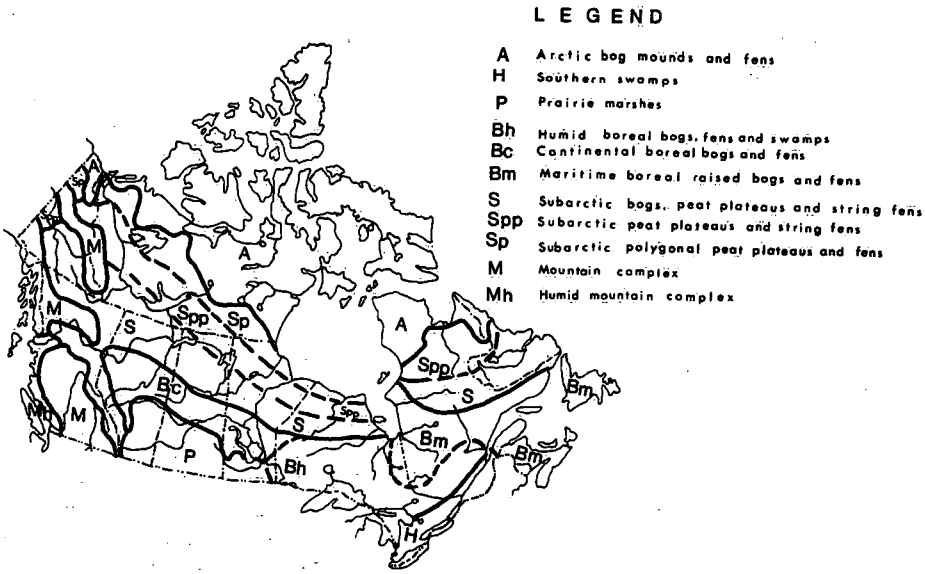


Figure 2. Broad wetland regions of Canada.

engineers are differentiating the fens from other kinds of organic terrain because of their distinctive and peculair permafrost and groundwater characteristics.

Another advantage of the proposed system is that it recognizes the dynamic processes that take place in the wetlands. Wetlands, being dynamic ecosystems, are subject to change due to their own development or due to interference with the natural system. When we examine a wetland at a point in time, we may happen to see it in a stage which is in equilibrium with its present environment. Other wetlands may be in a transitional stage, as a response to a change in its environment. Other wetlands may be in a transitional stage, as a response to change in their environment (Figure 1). Because in the classification system no single characteristic determines the type of wetland, such transition stages do not cause great problems.

A further advantage of the proposed classification system is that it adapts very readily to the Land (Site) Regions. It has been found that Wetland Regions can be established across Canada based on occurrence and dynamics of wetlands on broad areas. An initial map of Wetland Regions of Canada (Figure 2) was presented at the 4th North American Forest Soils meeting (Zoltai *et al.*, 1973). Although portions of this map were since revised, the concept of such Wetland Regions is proving very useful when investigating wetlands on a regional basis.

FUTURE NEEDS

The work of the Subcommittee on Organic Terrain Classification is not complete. In my opinion the following tasks remain to be done:

1. Establishment of pilot projects
2. Establishment of Wetland Regions
3. Characterization of wetland forms

1. Pilot Projects - The proposed classification is the concept of the subcommittee and the contributing local study groups of a system of wetland classification. It incorporates many old, tested ideas, but it also introduces new combinations deemphasizing some, and reinforcing others. It is the belief of this subcommittee that this classification is usable, and that it is suitable for the needs of a wide spectrum of resource users. However, we do not know whether this is true. We will not know until it is field tested and evaluated by multidisciplinary groups. The importance of wetlands in Canada hardly needs emphasis. To illustrate the state of our knowledge, we do not even know how much wetlands we have, never mind what kinds of wetlands we have. A common estimate is that about 500,000 mi^2 or 12% of the land surface of Canada is covered by wetlands MacFarlane, 1969). In Ontario, the estimates are that peatlands cover some 165,000 mi^2, or 49% of the Province's land area (Ketcheson & Jeglum, 1972). A current estimate for that Ablerta, a 'prairie' province, is 31,000 mi^2, or 12% of the surface of the Province is in peatlands (R. Valleau, 1974, pers. comm.). In New Brunswick there are 2,700 mi^2 of peatland, covering about 10% of the Province (Korpijaakko, 1975).

A knowledge of the resource is an essential firest step in planning the utilization of the wetland resource. The knowledge of the wetlands includes not only its geographical distribution, but its nature, dynamics and potential. Thus a workable, wide-spectrum classification system is a prerequisite to resource management and planning. Pilot projects, conducted by multidisciplinary teams, could evaluate the tentative classification system in various parts of the country. Modification and improvements resulting from such projects should lead to a system acceptable for all wetland resource managers and users.

2. Establishment of Wetland Regions - The concept of Wetland Regions is similar to that of Land (Site) Regions. It has been noted that similar wetlands tend to develop in areas of similar landform within broad regions. On the wetlands not only the vegetation chronosequence is similar, as on drylands, but the developmental trends through time on the wetlands tend to be similar within the regions.

The Land (Site) Regions can, to some extent, be used as Wetland Regions. In many instances, however, differences may be found on drylands that necessitate the recognition of a regional boundary, but without corresponding significant changes in the wetlands. This can be due to the more uniform, but often stressful, soil moisture and local climate conditions prevailing in the wetlands. As a matter of interest, in the Mackenzie Valley the vegatation and permafrost characteristics of bogs in a Wetland Region resemble the vegetation and permafrost characteristics of moist drylands on regions farther north.

The similarity and yet not complete correspondence of Wetland Regions and the Land

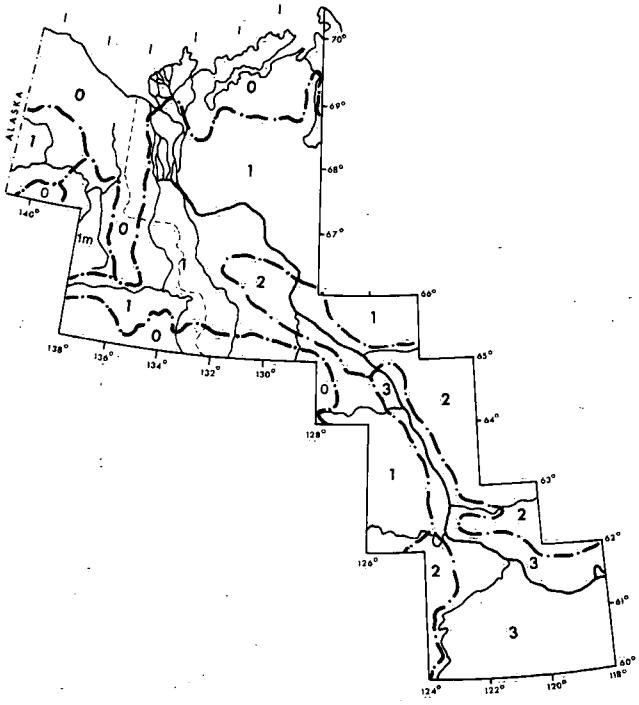


Figure 3. Land Regions of the Mackenzie Valley, N.W.T.

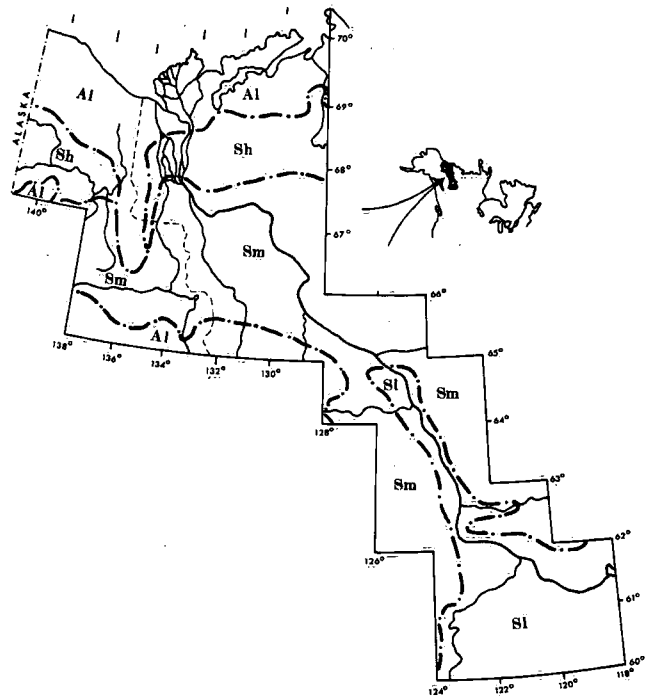


Figure 4. Wetland Regions of the Mackenzie Valley, N.W.T.

(Site) Regions is illustrated in Figures 3 and 4. Here the Regions in the Mackenzie Valley, comprising some 120,000 mi^2 are juxtaposed, showing that some boundaries coincide closely, but others do not. This suggests that while many Land (Site) Regions are also Wetland Regions, the establishment of Wetland Regions should be pursued, especially if the thrust of the particular study is oriented towards wetlands. For dominantly dryland-oriented studies, the Land (Site) Regions can be accepted as being suitable for the characterization of wetlands, realizing the possibility that the wetlands may extend into the neighbouring Land Regions.

The value of Wetland Regions is obvious. Because of similar developmental trends, the wetlands can be defined and described with a reasonable degree of accuracy within regions. The response to development or disruption will also be similar within regions, adding a powerful tool for predicting the consequences of such disruptions. Wetland Regions facilitate the description, characterization and response of wetlands, allowing a meaningful planning of their management and utilization.

3. Characterization of wetland forms - Wetland forms can be defined as (1) the surface form of the wetland, its position in relation to the containing or adjoining mineral terrain or open water, and (2) the material of the wetland. Field investigations show that characteristic wetland forms tend to develop within Wetland Regions. They are readily recognizable and mappable at a reconnaissance level. Their number is finite and within manageable dimensions.

Peatland types were found to be useful for wetland classification by Heinselman (1963). The initially proposed wetland classification for the Biophysical Land Classification (Adams and Zoltai, 1969) made use of wetland forms, and their definition and use was further extended by Tarnocai (1970). In practice, it was found that in the Mackenzie Valley there are only seven distinct perennially frozen peatland forms (Zoltai & Tarnocai, 1975a). Each of these could be described and characterized, and the descriptions can be used with a high degree of confidence to characterize the external, internal and dynamic properties of similar wetlands in the region.

Figures 5 to 9 in the appendix show a graphical characterization of wetland forms. Such diagrams and photographs should accompany the description of the internal and external characteristics of the biotic and abiotic environment of different types of peatlands.

In the opinion of the Subcommittee, a registry of peatland forms should be kept in which the detailed description and characterization of various wetland types would be kept, with periodic publications. This would ensure that the terminology will not change, achieving a degree of stability and avoiding confusion. It would ensure that superficially similar, but basically different wetlands types will not be confused in the mind of the investigatore or his audience. We believe that such a scheme would go a long way toward maintaining communication between individual works and between various desciplines.

RECOMMENDATIONS

It is my recommendation that a subcommittee or working group of Wetland Classification be reestablished. The tasks of such a group should include the finalization of the wetland classification system and the promotion of its use throughout Canada. Some of the immediate tasks may be:

1. Organizing and implementing multidisciplinary pilot projects of wetland classification in different parts of the country.

2. Defining and refining the Wetland Regions of Canada, as a spatial framework for regional wetland studies.

3. Initiating and maintaining a registry of wetland types, and preparing the publication of this information as needed.

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APPENDIX

OUTLINE OF PROPOSED WETLAND CLASSIFICATION*

At present, the subcommittee has not finalized a wetland classification. However, the following is a favoured approach which complies with the terms of reference and objectives of the subcommittee, but has not yet been tested or scrutinized by possible users. There are four proposed levels of classification:

Level 1 - This level is the most generalized and is based on site features which either constitute or contribute to the physiognomy of the wetlands. The units exhibit considerable integrity regarding surface morphology, soil type, nutrient and moisture regimes, drainage regime, and vegetative cover. The main wetland classes are: bogs, fens, marshes, swamps, and shallow open waters (Table 1). The following are definitions of these terms, based on the work of several authors.

Bogs - Bogs are peat-covered areas or peat-filled depressions with a high water table and a surface carpet of mosses, chiefly *Sphagnum*. The water table is at or near the surface in the spring, and slightly below during the remainder of the year. The mosses often form raised hummocks, separated by low, wet interstices. The bog surface is often raised, or if flat or level with the surrounding wetlands, it is virtually isolated from mineral soil waters. Hence the surface bog waters and peat are strongly acid and upper peat layers are extremely deficient in mineral nutrients. Peat is usually formed *in situ* under closed drainage and oxygen saturation is very low. Although bogs are usually covered with *Sphagnum*, sedges may grow on them. They may be treed or treeless, and they are frequently characterized by a layer of ericaceous shrubs.

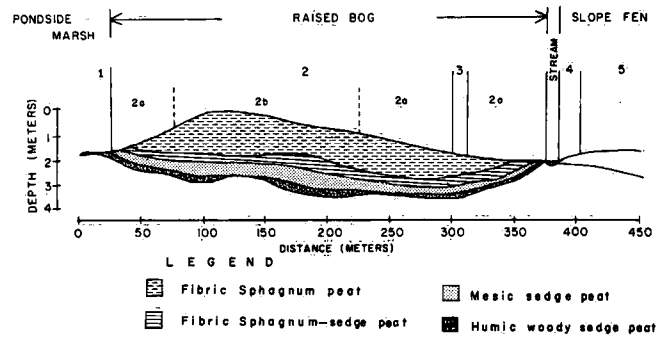

Figure 5a: Cross sectional diagram of a raised bog, maritime Boreal (Bm) Wetland Region.

Figure 5b: Ground view of a rasied bog, Maritime Boreal (Bm) Wetland Region. The bog surface is nearly level on the crest, but begins to slope away from the viewer past the clump of trees.

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* *This Appendix has been added to Mr. S.C. Zoltai's original paper by the editors to allow the widest possible distribution of the Wetland Classification Scheme. The Appendix is modified from the paper "Developing a Wetland Classification for Canada" by S.C. Zoltai, F.C. Pollett, J.K. Jeglum and G.D. Adams, in the proceedings of the 4th North American Forest Soils Conference, Quebec City, 1972, published by Les Presses de l'Université Laval. 497-511.*

Table 1: Provisional key to wetland classes.

	Class
1. Well-defined wetland basins in which at least 75% of the area is occupied by central expanses of permanent open water less than 2 m in depth	*Shallow Open Water*
1. Wetlands where permanent open water is restricted to scattered small pools occupying less than 75% of the area, or where standing water is present only seasonally or not at all	*Other Wetlands* – 2.
2. Predominantly ombrotrophic wetlands, developed on acid peat forming a level, raised, or sloping surface with elevated hummocks and wet hollows, usually overlain by a continuous carpet of spongy moss dominated by *Sphagnum*, and supporting a layer of Ericaceous shrubs, with or without trees	*Bog*
2. Predominantly minerotrophic wetlands on less acid peat or mineral soil, without a continuous moss substrate and with a water table persisting seasonally at or very near the surface	*Fen, Marsh and Swamp* – 3.
3. Open wetlands with level or depressional surfaces except for low hummocks or ridges, and dominated by sedges and grasses. Pools of open water or drainage tracks may be present	*Fen and Marsh* – 4.
3. Wooded, non-bog wetlands usually with a flat or hummocky surface and supporting about 25% cover of trees or tall shrubs more than 1.5 m in height. Associated with stream courses, lake edges, subsurface drainage, glacial depressions, and bog margins	*Swamp*
4. An open, relatively uniform and consolidated surface occasionally with subparallel ridges or elevated islands, linear drainage features, and a dispersion of small pools. Surface vegetation consists of sedges and grasses and a sparse layer of shrubs and trees	*Fen*
4. An unconsolidated open, flat to depressional surface with clumps of emergent sedges, grasses, and reeds interspersed in standing water with occasional small pools and channels, or patches of bare soil exposed during seasonal water drawdowns. Often associated with open water in streams, flowage lakes, glacial depressions, or on marine terraces	*Marsh*

Table 2: Provisional and incomplete key to bogs.

	Type
1. Surface not raised above surrounding terrain	
2. Surface concave	*Bowl Bog*
2. Surface relatively level	
3. With abrupt marginal peat walls in permafrost terrain	*Collapse Bog*
3. Without marginal peat walls	
4. With small sink pools	*Sinkhole Bog*
4. Without sink pools	
5. Adjacent to water bodies	
6. Floating	*Floating Bog* (includes Floating Island Bogs)
6. Not floating	*Shore Bog*
5. Not adjacent to water	*Flat Bog*
1. Surface raised or appreciably sloping	
7. Surface level to irregular, but not conspicuously domed or sloping	
8. With frozen core	
9. With network of polygonal fissures	*Polygonal Peat Plateau*
9. Without fissures	
10. Without thaw pockets	*Peat Plateau*
10. With oval or irregular thaw pockets	*Thermokarst Peat Plateau*
8. Without frozen core	*Bog Plateau*
7. Surface domed or sloping	
11. Abruptly domed, usually in a fen matrix	
12. Frozen core	*Palsa Bog*
12. Without frozen core	*Peat Mound Bog*
11. Gently domed, sloping or with a "stepped" surface	
13. Topographically extensive	*Blanket Bog* (includes Slope Bogs)
13. Topographically confined, usually with central pools and/or marginal wet troughs (flarks) and a marginal fen (lagg)	*Raised Bog*

Table 3: Provisional and incomplete key to fens.

	Type
1. Surface not raised above surrounding terrain except in low hummocks and ridges	
2. Surface pattern of ridges and depressions	
3. Subparallel pattern of ridges and furrows	
4. Broad pattern along lowland drainages	*String Fen* (includes Ribbed Fen)
4. Narrow ladderlike pattern along bog flanks	*Seepage Fen* (includes Water Track Fen)
3. Reticulate pattern of ridges	*Net Fen*
2. Without pronounced surface pattern	
5. Featureless, without surface water	
6. Adjacent to water bodies	
7. Floating	*Floating Fen*
7. Not floating	*Shore Fen*
6. Not adjacent to water	
8. Fitted to narrow drainages	*Draw Fen*
8. Without obvious drainage control	*Horizontal Fen*
5. With surface water or filled depressions	
9. With round or irregular ponds	*Pond Fen*
9. Depressed thaw hollows	*Collapse Fen*
1. Surface raised or appreciably sloping	
10. Mounds with frozen core in pattern fens	*Palsa Fen*
10. Without frozen core	
11. Surface irregular due to upwelling water	*Spring Fen*
11. Surface regular but sloping	*Slope Fen*

Table 4: Provisional and incomplete key to swamps.

	Type
1. Adjacent to permanent water body	
2. Adjacent to moving water	*Alluvial swamps*
2. Adjacent to non-moving water	*Lakeside swamps*
1. Not adjacent to permanent water body	
3. In topographically defined basins	
4. On perimeter of peatlands	*Peat margin swamps*
4. Not on perimeter of peatlands	*Catchment swamps*
3. Not in topographically defined basins	*Seepage swamps*

Table 5: Provisional and incomplete key to marshes.

	Class
1. Adjacent to or influenced by marine tidal water	
2. In river estuaries or adjoining bays where tidal flats, numerous channels and pools are inundated by fresh, brackish or salt-water	*Estuarine Marsh*
2. On marine terraces remote from estuaries, or in embayments or lagoons behind barrier beaches, where there is periodic inundation by tidal brackish and saltwater	*Coastal Marsh*
1. Adjacent to inland water body	
3. Adjacent to permanent water body	
4. Adjacent to moving water	
5. Occupying water courses or flood plains	*Fluvial Marsh*
4. Adjacent to standing water	
5. Occupying lake shores or bays of flowage lakes	*Lentic Marsh*
3. Not adjacent to permanent water body	
4. Occupying topographically defined basins	*Catchment Marsh*
4. Not in topographically defined basins, usually at low elevations or at the base of slopes	*Seepage Marsh*

Fens - Fens are peatlands characterized by surface layers of poorly to moderately decomposed peat, often with well-decomposed peat near the base. They are covered by a dominant component of sedges, although grasses and reeds may be associated in local pools. *Sphagnum* is usually subordinate or absent, with the more exacting mosses being common. Often there is much low to medium-height shrub cover and sometimes a sparse layer of trees. The waters and peats are less acid than in bogs of the same area, and sometimes show somewhat alkaline reactions. Fens usually develop in restricted drainage situations where oxygen saturation is relatively low and mineral supply is restricted. Usually very slow internal drainage occurs through seepage down very low gradient slopes, although sheet surface flow may occur during spring melt or period of heavy precipitation.

Swamps - Swamps are wooded wetlands where standing to gently flowing waters occur seasonally or persist for long periods on the surface. Frequently there is an abundance of pools and channels indicating subsurface water flow. The substrate is usually continually waterlogged. Waters are circumneutral to moderately acid in reaction, and show little deficiency in oxygen or in mineral nutrients. The substrate consists of mixtures of transported mineral and organic sediments, or peat deposited *in situ*. The vegetation cover may consist of coniferous or deciduous trees, tall shrubs, herbs, and mosses. In some regions, *Sphagnum* may be abundant.

Marshes - Marshes are grassy wet areas, periodically inundated up to a depth of 2 m or less with standing or slowly moving water. Surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats. Marshes are subject to a gravitational water table, but water remains within the rooting zone of plants during at least part of the growing season. The substratum usually consists of mineral or organic soils with a high mineral content, but there is little peat accumulation. Waters are usually circumneutral to alkaline, and there is a relatively high oxygen saturation. Marshes characteristically show zonal or mosaic surface patterns of vegetation, comprised of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent nonwoody plants such as rushes, reeds, reedgrasses, and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish.

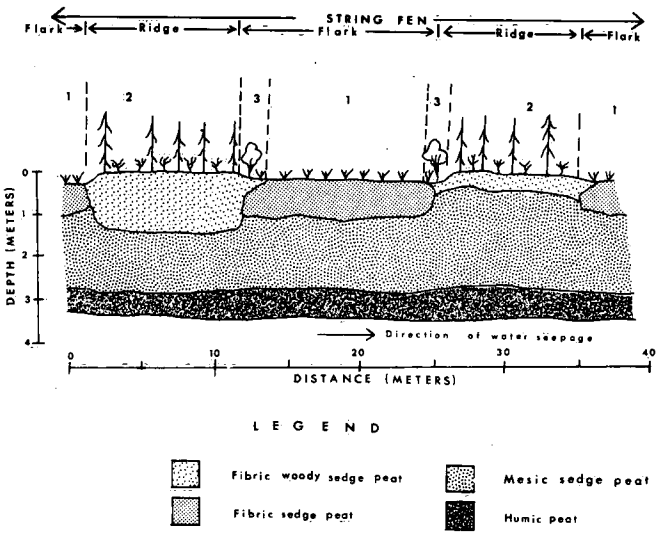

Figure 6a: Cross sectional diagram of a string fen, Continental Boreal (Bc) Wetland Region

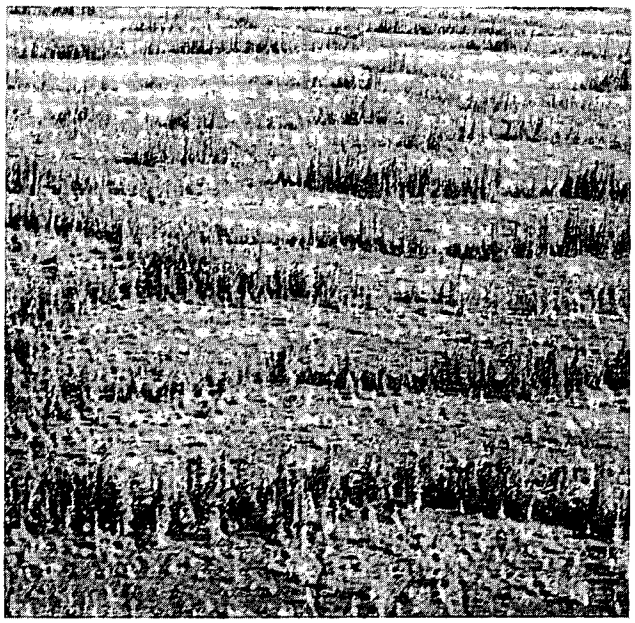

Figure 6b: Aerial view of a string fen, Continental Boreal (Bc) Wetland Region.

Shallow Open Waters - Shall open waters, which are locally known as ponds or sloughs, are relatively small, nonfluvial bodies of standing water occupying a transitional stage between lakes and marshes. In contrast to marshes, these waters impart a characteristic open aspect, with proportionately large expanses of permanent surface water that lack emergent cover, except for relatively narrow zones adjoining shorelines. Open water usually occupies most of a defined basin area, or is held within large depressions within extensive peats mats. The basin usually exhibits a saucer-shaped profile with gently sloping or recessional shorelines. The discrimination of shallow open waters from deeper lakes is based upon the relative extent of the littoral zone, usually indicated by maximum growth of rooted aquatic macrophytes. This zone, which is arbitrarily defined as the range in depth from 0 to 2 m, usually extends to the middle of the basin or occupies at least 75% of the basin area, with remaining portions occasionally attaining greater depths. Shorelines may be firm, soft or floating, and they consist of materials varying from rock or silt to organic deposits.

Forms of wetlands which are transitional between the classes described also occur. In general, the wetlands develop from marshes to fens to bogs and in certain areas bogs may develop into swamps. Many other wetland successions have been recorded; for example, in certain regions, swamps develop into bogs. Such transitional stages may be difficult to classify: it has been proposed that such stages, if identifiable, be named by composite names such as bogfens, fenmarshes, etc.

Level 2 - This level is based primarily on surface morphology of the wetlands, including the distribution of surface water, and in some cases, on the morphology of the confining basin. Such features as raised or level surfaces, patterns of ridges, depressions, or pools are noted, as shown by the key developed by Rowe (Tables 2 and 3). In contrast to bogs and fens, the marshes and swamps are not readily characterized by surface morphology. The association of marshes and swamps to hydrotopographic features (rivers, lakes, slopes, etc.) can be used to differentiate them (Tables 4 and 5). Shallow open waters may be classified according to the adjoining wetland or land types, e.g. mineral pools, bog pools, marsh pools, etc.

Level 3 - At level 3, the wetland types identified in Level 2 are defined on the basis of their vegetation characteristics.

Figure 7a: Ground view of a bowl bog, Humid Boreal (Bh) Wetland Region, looking from the centre toward the rim of the bog.

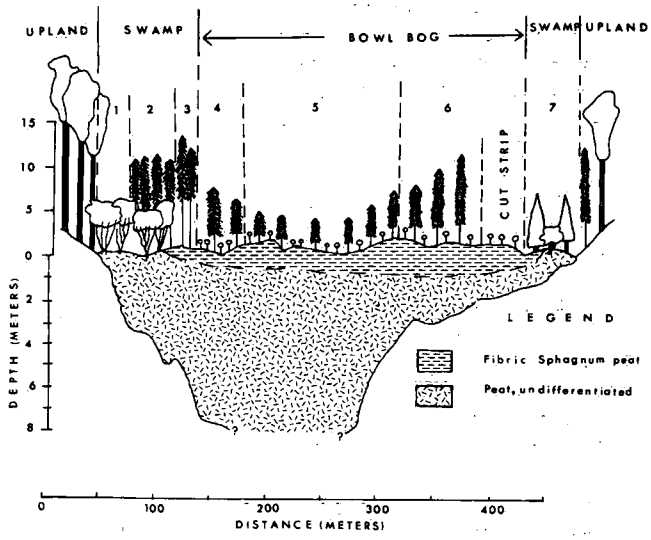

Figure 7b: Cross sectional diagram of a bowl bog, Humid Boreal (Bh) Wetland Region.

At this level, regional environmental influences, such as regional climate, edaphic conditions, or trophic levels become more important in classification and, subsequently, wetland subdivisions may be defined for each wetland region. For example, a catchment swamp in the St. Lawrence Lowlands may support a heavy growth of hardwood forest, but further north, coniferous forests become the dominant vegetation type, whereas in subarctic regions, tall shrubs will be growing on such swamps.

Level 4 - In the most detailed of classification, the specialized needs of disciplines are recognized. For example, if a particular interest lies in botany, the wetlands can be further subdivided into floristic units; wetland units can be evaluated on basis of engineering qualities, etc.

With the present information available concerning wetlands in Canada, the units in each level of classification can only be defined in descriptive terms. To prevent an uncontrolled proliferation of wetland types being incorporated into the literature, it might be desirable that each type in Level 2 be described from a 'type' location. Each description would include as much information on the external and internal structure composition, and physical and chemical characteristics as possible. It is recommended by the subcommittee that a national body scrutinize these submissions and decide whether they are significantly distinct enough to be included in wetland subtypes. Some attempts at describing certain morphological wetland types have been made by Adams and Zoltai (1969) and by Tarnocai (1970). Examples of such wetland types, representative of different regions in Canada, are shown in Figures 5-9.

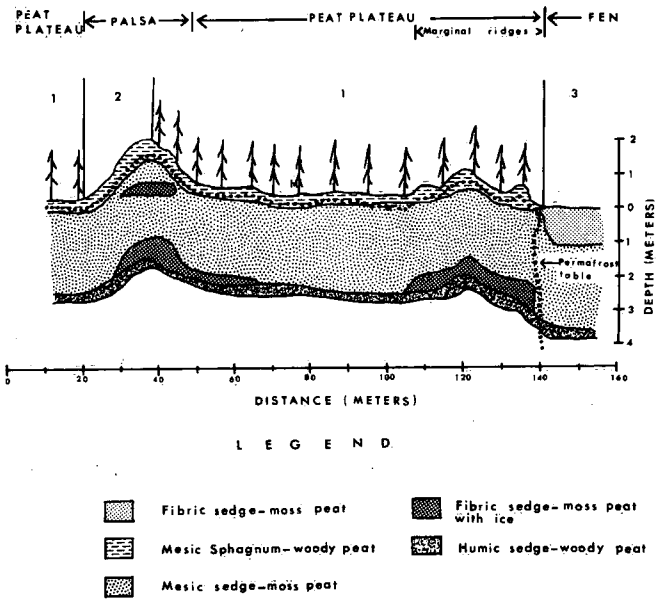

Figure 8a: Cross sectional diagram of a peat plateau and palsa, Mid-Subarctic

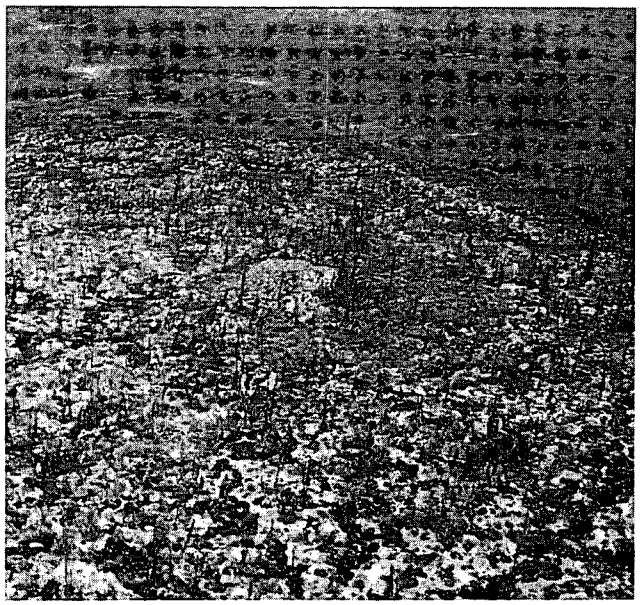

Figure 8b: Aerial view of the peat plateau-palsa complex shown in Figure 8a. The palsa is the elevated, treeless rise near the centre of the picture.

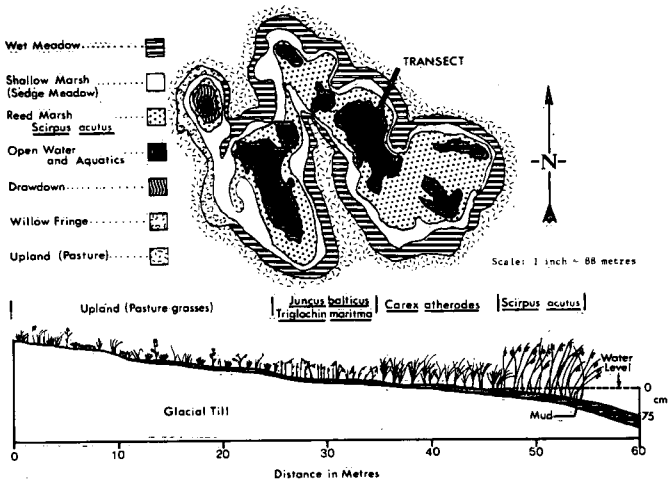

Figure 9a: Cross sectional diagram of a catchment marsh, Prairie (P) Wetland Region.

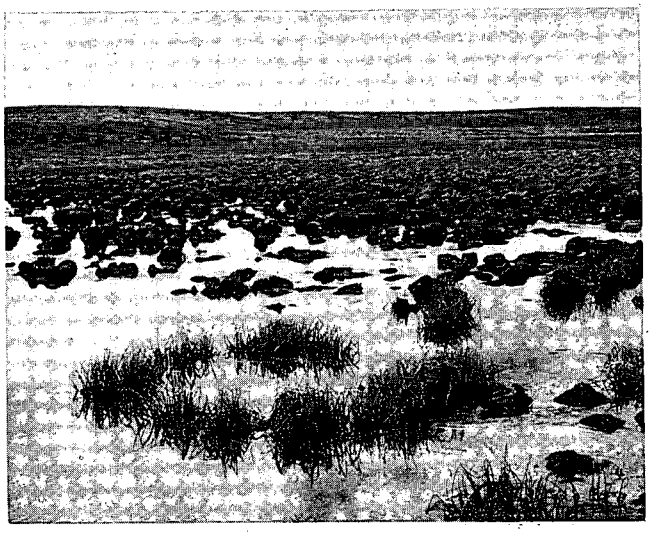

Figure 9b: Ground view of a catchment marsh, Prairie (P) Wetland Region.

AN INTEGRATED ITERATIVE HOLISTIC APPROACH TO ECOSYSTEM CLASSIFICATION

G. Angus Hills
Faculty of Forestry and Landscape Architecture
University of Toronto
Toronto, Ontario

INTRODUCTION

Toward a Definition of Ecosystem Classification - The term "bio-physical" was first applied to a national land classification program launched by the Government of Canada in 1967, a program which had previously been operating under the name of Wildland Inventory (Lacate 1969). Bio-physical was introduced to emphasize that both biotic (living) and physical (non-living) features were to be included in the classification. But was it to be a mere inventory in which living and non-living elements of the landscape are catalogued and mechanically 'hitched' together as the hyphenated term might suggest? Lacate (1969) had stated "the aim.....is to differentiate and classify ecologically significant segments of the land surface rapidly and at a small scale". These ecologically significant segments are unquestionably ecosystems and the 'bio-physical' land classification was ostensibly a classification of ecosystems (Jurdant *et al.* 1973). Furthermore, during the first days of the meeting of the Canada Ecological (Bio-physical) Land Classification Committee at Petawawa, there was developing a consensus that the program is indeed a classification of natural ecosystems, not an inventory of natural features *per se*. What then are the philosophical presuppositions on which such a program should be based?

An *ecosystem* has been aptly defined by Rowe (1961) as "a topographical unit, a volume of land and air plus organic contents extended areally over a particular part of the earth's surface for a certain time". To this he added, "with boundaries fixed by definition". Implicit in this last stipulation is that not only are the boundaries of ecosystem units established by definition, but the range of classificatory characteristics of the unit itself are likewise defined mental constructs.

Since ecosystems are mental constructs, they may be conceived at the required levels of integration (*cf.* Rowe 1961) and 'tailored' to meet specified objectives. In land use studies correlated with ecosystem classification, a specific system of integration organizes ecosystems as biological production systems (Hills 1960c). For convenience, I have chosen to restrict the concept of ecosystem units to homogeneous areas and the concept of land units to patterns of these homogeneous areas. However, these patterns may exhibit homogeneity at a broader level such as a deer-range and these are likewise ecosystems, but of another order. 'Homogeneity' requires definition of level.

A *natural landscape* is any part of the ecosphere in which the relationships between plant and animal communities and their physical environment is the focus of enquiry. Natural landscape units of all sizes are investigated as *patterns of natural ecosystems*. The latter are sometimes called 'biotic ecosystems' to distinguish them from 'human ecosystems'.

A *cultural landscape* is any part of the ecosphere in which the relationships between human communities and their non-human environment is the focus of enquiry. A cultural landscape unit may include one or more natural ecosystems (usually a pattern of them), which are investigated as part of a cultural ecosystem. The ecological constructs which indicate the relationships characterizing human ecosystems are readily formulated through the use of an extension of the format described in this paper. The capability classification used in the Ontario Land Inventory illustrates this methodology.

Site typology consists of investigation of individual ecosystems at various levels of homogeneity. (The methodology discussed below is mainly that of site typology.)

Landscape synthesis groups ecosystems into patterned units of convenience useful in mapping and evaluation of areas for various land uses.

The method of interpreting the units of site typology and landscape synthesis in site evaluation programs will not be discussed in detail here. Only a brief reference will be made to

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those units which have been used as the platform from which investigations of landuse capability, suitability and feasibility have been projected.

The Nature of Ecosystems as Homogeneous Volumes of Transactional Space - Ecosystems have already been introduced as life-containing volumes of air and earth space which are differentiated according to specified characteristics. In order to formulate the diagnostic and evaluative criteria for establishing homogeneous units, ecosystems are viewed in the context of *transactional space*. Carpenter and McLuhan (1960) have shown clearly the shortcomings of *visual space*, the view which is most common in our present culture. Their arguments for shifting from *eye* to *ear* perceptions are well taken. However, their term *acoustic space* presents a serious semantic limitation to a connotation of totality, even though these authors have suggeted that most sense perceptions may be interpreted as *associations of sound*. But, as the old Scotch expression goes, "There are many experiences which are better felt than tel't". Since philosophers Dewey and Bentley (1949) consider all of man's experiences within his total environment to be within a well-organized transactional framework, transactional space is herein deemed a key characteristic of *landscape* viewed as a pattern of ecosystems.

Transactions are interactions characterized by interdependent relationships among all the participating 'actors'. This is the type of interaction which exists in ecosystems between two or more of its component features.

Dewey and Bentley (1949), in 'Knowing and the Known', introduced the term transaction to replace their reject term 'interaction'. In enquiries concerning the nature of 'thing', Dewey and Bentley includes the 'knower' as well as the 'things known'. This means that the ecologist and other enquirers are part of the ecosystem classification framework even though they are not a physical part of the process of ecological production. As we shall see later, ecological enquiry must draw upon the 'cosmos', which is total transactional space, for the meaning of ecosystem behaviour at all levels of differentiation.

Transactions within each ecosystem result in changes in the ecosystem itself. Such changes are the result of the behaviour of the entire ecosystem and not of any specific part of it. Thus, the entire system operating over a specified period if the 'causal' factor, and the *pattern of changes* known as ecosystem production, which have occurred within that system during that period, is the'resultant'. Thus, an ecosystem is both a *circular causal system* and a *circular resultant system*.

The 'transacting' components of the ecosystem are the various individual features; plant and animal communities, climate and landform systems in the case of terrestrial ecosystems; (waterform replacing landform in limnic ecosystems). The characteristic behaviour of the various levels of these features (e.g. vegetation physiognomy, soil moisture, water temperature regime and air humidity) is understood in the context of the transactional relationships which are established between these specific characteristics and those of the other features of the ecosystem. The problems of ecological classification are accentuated by these differences in the transactional value on four specific measured feature properties.

Since space does not permit a lengthy exposition of transactional behaviour within ecosystems (this may be found elsewhere in Hills *et al.* 1970 and Hills 1974), the characteristics of ecosystems as transactional wholes are briefly summarized below:

(a) Ecosystems are *real* but their location and designation are dependent upon the definition of key characteristics selected to meet specified objectives.

(b) Ecosystem units are established within a postulational framework of transactional space by an iterative process which contemporaneously differentiates units at a lower level and aggregates them at a higher level of differentiation.

(c) Ecosystems are systems of circular causality and circular resultance. (This means there are no traditionally conceived causes and effects either within ecosystems or between ecosystems).

(d) As a corollary to (c) above, the characteristics of the component features of an ecosystem are said to *condition* not cause, ecological production, whether this production be the development of a podsol soil, the production of a hardwood forest or the modification of the regional macroclimate.

(e) Ecosystems are dynamic systems. Significant changes within a time period necessitate a definition which indicates the limit between one ecosystem and its successor within the time continuum.

(f) Ecosystems are an integral part of continua in space as well as in time. Ecosystems, the homogeneity of which is defined as a broad range of class characteristics, are characterized by a central core or dominating node or nodes. Their boundaries are lines of convenience which separate the core or nodes of one class from those of adjoining areas. The core or nodes need not be centrally located

within the mapped area.

The Objectives of a Natural Landscape Classification - This view of natural landscapes and of the biotic ecosystems of which they are constituted dictates the following objectives for the establishment of an ecological land classification designed to provide a framework for mapping, description and evaluation of areal units for all uses:

1. To subdivide the land-water surface into homogeneous units which are -
   a) *located* and *identified* by morphological features of the systems which constitute the biogeospheric envelope of the area,
   b) *classified* in terms of comparative ecological significance for all types of biological production (these two interrelated activities constitute the site typology of this paper), and
   c) *evaluated* in terms of their capability, suitability and feasibility for biological production and resource management.

2. To synthesize the homogeneous site units of above into definable patterns useful in programs of -
   a) airphoto interpretation and mapping,
   b) areal description, and
   c) resource management and planning (in this paper these procedures are introduced briefly under landscape synthesis.)

Here are some *suggested questions to test the effectiveness of an ecological land classification* fashioned on the principles enunciated above:

Does the system of classification provide for the recognition of the attributes of ecosystems as wholes? Is this accomplished through a systematic interpretation of each of the component features which condition those transactional processes which are the characteristic features of ecosystems? (Processes, not features *per se*, are the attributes of ecosystems.)

The following are corollaries of the above proposition:

Corollary 1 - Are the ecosystems identified by their physical properties? Are these properties interpreted in terms of their ecological effectivity in order to meet the requirements of an ecological classification?

Corollary 2 - Are the ecosystems classified through the interpretation of these identifying physical homologues in terms of their ecological effectivity as they function as components of specific ecosystems?

Corollary 3 - Are members of a class of morphological homologues placed into different gradients of effectivity classes owing to differences in the degree of conditioning which the various complexes of associated component features have upon their functioning? Is there a regional ecological matrix which provides a guide to the placement of specific physical property classes (homologues) into one of several feature effectivity classes (analogues)? For example, under what total ecosystem conditions does a mean annual precipitation of say 12 inches indicate an ecosystem which provides specific communities with (a) adequate, (b) insufficient, or (c) excessive moisture?

In order to investigate natural ecosystems to meet the above objectives, what presuppositional framework is applicable? It is evident that both the 'general' and the 'particular' must be established contemporaneously. Therefore, the enquiry is neither an induction nor a deduction one as normally conceived. If ecosystems could be classified as purely physical systems, strictly upon the objectivity of the scientific method, we could have an ecologist paradigm just as we have a physicist paradigm and a chemist paradigm. But, as I have reasoned elsewhere (Hills 1974), the philosophical framework required by the landscape ecologist is not the paradigm of normal science (Kuhn 1962). Perhaps the required framework should not be considered a paradigm if that leads to the dismembering of the ecosystem in order to fit it into the so-called objectively constructed scientific mould! The postulational framework required is similar to that of regional geographers approaching their field as human ecologists.

This is not the place to discuss the confusion which has characterized the philosophical framework within which the regional geographers have been working (Hartshorne 1939, 1959). Nor is there space to sort out those principles applicable to our problems proposed by the geographers (Chorley *et al.* 1970) who have recently attempted to apply scientific method to the art of geographic regionalization.

Rather I have chosen to derive the philosophical framework from a methodology based on the nature of ecosystems as I have experienced them during thirty years of field research (e.g. see Hills 1959b) and several years of expository discussion in the classroom. I then proceed to outline the type of classification needed to deal with this peculiar syndrome of phenomena complexes.

To bring concreteness to these classification requirements, I am introducing illustrations from my classification of Ontario landscapes.

For this introduction to 'provincial' terminology, I beg your indulgence. I can see no other way of demonstrating the application of the concepts I am discussing to the actual landscape.

In this approach we differentiate as we establish levels of integration. In order to investigate, in this apparently paradoxical manner, we need a three-fold approach:

1. A holistic approach
2. An iterative approach
3. An integrative approach

1. A Holistic Approach to Ecosystem Classification - A holistic approach to ecosystem classification is one which considers ecosystems as wholes (Greek *holos* meaning whole), (Hills 1959a). As has been mentioned, the concept of holism used in this classification is that of *transactional wholes* which are 'constructs' in the mind of the investigator, be he ecologist, land manager or layman (Dewey and Bentley 1949). This concept is in strong contrast to that of most holists, including Smuts (1939), who conceive discrete concrete wholes, consisting of animate and inanimate bodies, and resulting from a 'natural' process of whole-making.

Ecosystems are recognized on the ground and from air photos by the *morphological* properties of climate, landform, soil profile, waterform, vegetation physiognomy and characteristic faunal distribution (Hills 1960a and b). These quantitatively defined parameters of the systematic scientists are the characteristics used in identifying and mapping (but not classifying) ecosystem units. As stated before, the same measured quantity does not have the same degree of significance in biological production if the features having this property occur in different types of ecosystems. Therefore, the contribution of systematic science is to provide quantitatively defined benchmarks (homologues) upon which ecological interpretation is based.

The circular causality which characterizes ecosystem behaviour renders necessary the qualitative evaluation of quantitively defined properties of the component features of the ecosystem. Since the qualitative values are dependent not only on the quantitatively defined level of the property of the individual feature but upon the peculiar relationship of this with all the other features within the ecosystem, the qualitative value is an attribute of the whole ecosystem, not that of the feature whose properties are measured. Thus, in this ecological enquiry of the 'transactional' interrelationships within the ecosystem, traditional methods of scientific enquiry are not directly applicable. Ecological evaluation involves non-parametric ranking and a consensus of value judgements. Ecologists familiar with the biotic ecosystems of a region must interpret the morphological homologues of the systematic scientists in terms of classes of ecological analogues within regional gradients.

This means that regardless of the number and qualifications of the systematic scientists which comprise the field team, their joint contribution will fall far short of an ecological land classification if there is not among them a land-use ecologist who is familiar with the area and thus able, on the ground, to harmonize morphological parameters within an applicable ecological matrix.

In presenting the component systems of terrestrial ecosystems, Figure 1 shows the four systems which are initially recognized by morphological parameters, two on the extreme right and two on the extreme left. The transactions which are recognized between the two non-living systems of ecoclimate and landform through the terrestrial physiosystem to the terrestrial biosystem are described in terms of the *feature effectivity classes* discussed below. Likewise, the transactions between the living system of plant and animal communities through the terrestrial biosystem to the terrestrial physiosystem are described in terms of feature effectivity classes. An important observation to be made at this time is that in establishing types of ecosystems, whether terrestrial or limnic, both physiosystem types and biosystem types must be established contemporaneously in order that they 'fit' (see M. Jurdant's paper for example). The iterative (*q.v.*) procedure which is required to do this can be more readily understood by examining Figure 9.

Figure 2, which presents the component systems of limnic ecosystems, differs from Figure 1 only in that the waterform-soil system replaces landform-soil system. Since limnic ecosystem classification parallels that of the terrestrial ecosystems, the examples drawn from the terrestrial classification will serve to illustrate the approach here as well.

Feature Effectivity Classes - Feature effectivity classes are classes derived by breaking gradients of morphologically recognized features into classes having ecological significance. Although these classes are described in terms of morphological homolgues, they should not be called parameters since their *range* has been non-parametrically determined. These are the key units by which *a bridge* is constructed *between the morphological classification of the*

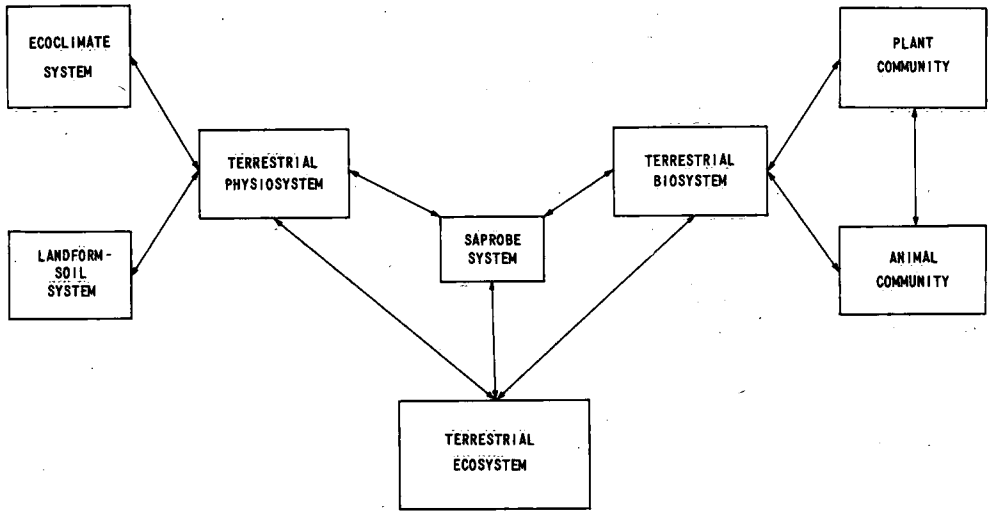


Figure 1: The component systems of terrestrial ecosystems

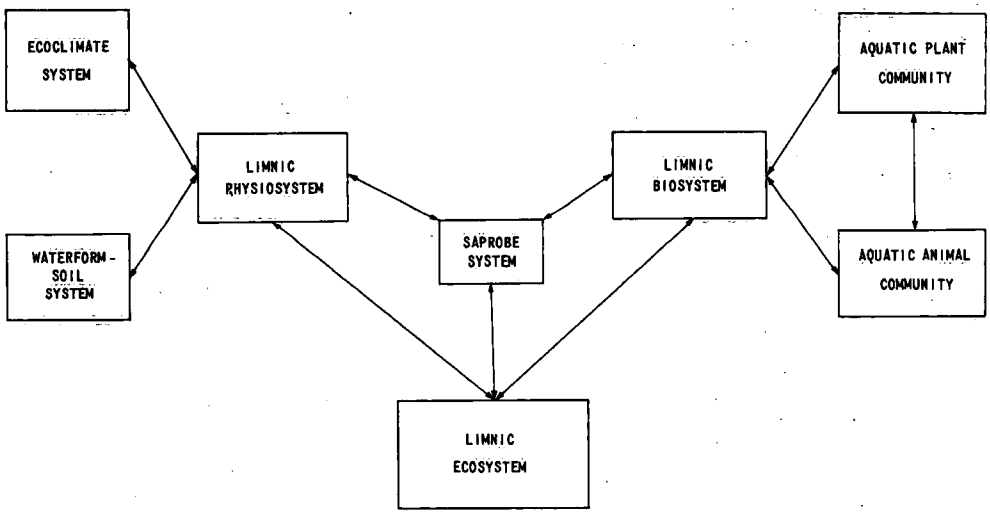


Figure 2: The component systems of limnic ecosystems

systematic scientist and the holistic classification of the ecologist.

Defined within a transactional context, a feature effectivity class is an 'ecologically homogenous' aggregation of feature analogues, each analogue of which is itself a class of morphologically defined homologues. Described conversely, individual homologues are placed into classes based on their morphological homogeneity. These morphological classes in turn become analogues when aggregated with other analogues to form a feature effectivity class based on their ecological homogeneity. Morphological homogeneity is one of structure, whereas ecological homogeneity is one of function within the ecosystem.

Feature effectivity classes are the classes into which significant component features of an ecosystem are placed in order to show their comparative effectiveness when found in the various types of complexes derived from different combinations of effectivity levels of all ecosystem components. Their comparative effectiveness is indicated by assigning, to each class, a position along regional gradients. These positions have not been assigned without cognizance of the functioning of all components which contribute to the ecological processes of each type of production system. This harmonizing of regional effectivity classes has been accomplished by the field typologist.

The soil moisture regime gradient provides an excellent example of feature effectivity classes. In differentiating local site types within the site region of Ontario, soil moisture regime was found to be the feature which provided the most significant initial segregation of plant communities. Soil moisture regime is the rise and fall of available moisture on each physiographically defined site during a complete successional cycle. Owing to variations in the conditioning of soil moisture availability by plant communities as they change from pioneer through intermediate to climax, the potential of each soil and climate combination is assessed primarily on the comparative water relationships of the climax communities. These climaxes are the communities which possess the potential to utilize most fully the potential of the physiography to retain moisture in a form available to plants. This assessment of the moisture regime of climax communities is complemented by the water relationships of the entire successional series of plant community on each area considered to be a representative of a specific class of moisture effectiveness, that is, of a soil moisture regime.

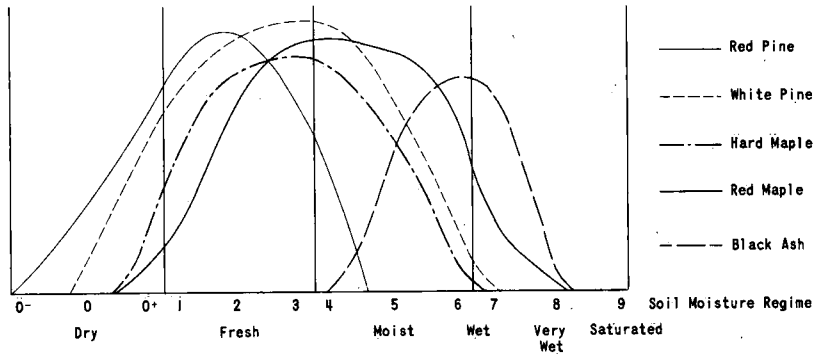
It is evident that in this system of site typology which uses vegetation response as the indicator of soil moisture supply, the criterion is the response of the entire successional series of plant communities and not the vegetation found on the site at any single point of time. The soil moisture gradient of each site region is divided into an odd number of classes. A common division of this regional gradient is *very dry, dry, fresh, moist* and *wet*. Figure 3 illustrates the type of transactional relationship between the growth of five tree species and those features of the non-living environment in Site Region 5E (now 5Hm as shown in Figure 7) which has been used to establish soil moisture effectivity classes (see Figure 8).

The above categories, derived through relationships between specific combinations of soil and climate and the successional series of communities which may develop upon them, have no simple correlation with the dry-mesic categories which botanists derive from their interpretation of the communities present on an area at the time of inspection. For example, in identifying categories of both *moisture* systems on IBP-CT classified areas in Site Region 7Hm, it was found that communities on sites having a dry soil moisture regime recognized by soil and landform features were classified as *dry* by the botanist if the stand it supported was in the pioneer stage, but the same dry site supporting a climax community was classified as dry-mesic. The difference lies not merely in the potential of the soil to supply moisture but in the relative potential of the two communities to utilize the moisture potential of the physiography. This difference in the ability of communities to utilize the water-holding, water-releasing potential of a given physiographic site type can be demonstrated by differences between the moisture cycle of deciduous tolerant hardwoods and that of pioneer stands of red oak woodland on the same physiographic site type.

2. <u>An Iterative Approach to Ecosystem Classification</u> - The term *iteration* is used in this site classification in a sense not given in most dictionaries. Here it refers specifically to a type of enquiry which consists of a series of 'to and fro' experiences between two loci of investigation. Each successive 'to' experience differs from the preceding 'to' experience in that there has been an additional input from an intervening 'fro' experience. Similarly each 'fro' experience is *not a repetition* of the previous because it, too, has been enriched by an intervening 'to' experience.

Following a suggestion from a colleague who intimated that I was using an iterative type of investigation, I used the term for several years before I discovered that psychologist

Figure 3: Production gradients of tree species relative to soil moisture in Site Region 5E



Note

1 Species have been selected to indicate differences in optimal moisture requirement.

2 Other factors controlling production such as vegetation competition, nutrient regime, pore pattern, etc. cause deviations of above curves.

Maslow (1970 p.26) used iteration to designate his technique of investigating personality syndromes. Starting with the syndrome as a vaguely grasped whole, he 'analysed' its structure into more readily understood parts. These were then used to organize a more precise whole. In terms of Dewey (1960), Maslow's whole is the *situation* and its component parts are *singulars*. Both are needed to give meaning to the other.

In the hierarchical classification of natural ecosystems, the basic singular is a measured parameter, a property of a feature of one of the systems which comprise the biogeosphere (i.e. the singular from which feature effectivity classes are iteratively derived). Relative to the feature property classes in this ecological classification, the feature effectivity classes are the situations which provide meaning to those singulars. These pairs of units, which have been conceived during the same iterative process, I am calling *iteration twins*. Furthermore, each unit in the hierarchy is a member of two sets of iteration twins. For example, in Table 1 we find that feature effectivity class plays the role of 'situation' when it 'twins' with Feature Property Class and the role of 'singular' when it 'twins' with Site Feature Systems.

Since Table 1 is restricted to levels of differentiation within the postulational framework of biotic ecosystems, two of the units, namely Feature Property Class and the Cosmos 'twin' with units beyond the natural ecosystem matrix, namely in God, its Creator. The ultimate and only real whole consists of God integrated with the universe, His Creation.

Site Feature Systems refers to the broad complexes of site features into which the biogeosphere may be divided, namely climate, landform-soil, waterform-soil, vegetation and regional fauna.

Neither feature property class, nor feature effectivity class nor site feature system are, in themselves, ecosystem wholes.

There is another type of iteration not shown specifically in Table 1. This is the iteration used in the concomitant establishment of biotic and physiographic effectivity classes in order that the transactions of both the biotic and physiographic components of a terrestrial site type (Figure 9) will have reciprocal classes.

3. <u>An Integrative Approach to Ecosystem Classification</u> - The main aspects of the proposed classification which display integrative characteristics are as follows:

1. The holistic integration of the various components of the ecosystem (discussed above).
2. The iterative integration of taxonomic units a lower level to form taxonomic units at a higher level (discussed above).

Table 1: Model designating the seven pairs of iteration twins recognized in the natural ecosystem classification

LEVELS OF DIFFERENTIATION AND INTEGRATION

Units of Specification	1 Feature Property Class	2 Feature Effectivity Class	3 Site Feature System	4 Natural Site Type	5 Site or Region Landscape	6 Continental Biogeosphere	7 Global Biogeosphere	8 Cosmos
Feature Property Class	Singular*							
Feature Effectivity Class	Situation**	Singular						
Site Feature System		Situation	Singular					
Natural Site Type			Situation	Singular				
Site (or Landscape) Region				Situation	Singular			
Continental Biogeosphere					Situation	Singular		
Global Biogeosphere						Situation	Singular	
Cosmos							Situation	Singular

* 'Singular' characterizes the level of differentiation
** 'Situation' characterizes the level of integration.
NOTE -. Each unit is a member of two sets of 'iteration twins' but the twin for Feature Property Class and for the Cosmos lie outside of the natural ecosystem model.

3. The integration of feature property classes into feature effectivity classes (both simple and complex) and these in turn into site types. This type of integration is shown in Figure 8.
4. The synthetic integration in forming standardized landscape patterns of specific uses.

THE DIFFERENTIATION OF 'LAND' LANDSCAPE UNITS

This section deals with those portions of continental areas which are 'land' as opposed to fresh water bodies and marine shore water.

An Iterative Approach to the Broad Differentiation of Continental Ecosystems - The differentiation of continents into those homogeneous units which are the highest in the taxonomic hierarchy of landscape units, namely the landscape region, is an iterative procedure which involves a contemporary integration from below and a differentiation from above (see Table 1). This is in contrast to the principle upon which the Forest Regions of Canada were established, which Rowe (1972 p 1-2) states to be a "form-above approach to form regions which are not classified but describable as major geographic belts or zones characterized vegetationally by a broad uniformity both in physiognomy and in composition of the dominant tree species".

In this ecological classification, the criteria are not restricted to differences in the latitudinal-longitudinal distribution of the dominant vegetation types recognized by physiognomy and species composition, but rather are found in the pattern of ecological relationships of vegetation types* to the landform positions on which they are located. Through the interpretation of landform complex in terms of the effectiveness of soil and local climate on vegetation development, these regional patterns reflect the changes in the location of similar vegetation types from one landform position to another

* These vegetation types are similar to those used in the geographic description of Forest Regions (Rowe 1972) but differ in that they are tailored to show differences which reflect conditioning by different combinations of macroclimate and local landform conditions.

as we go from south to north, from east to west, and from lowlands to mountain peaks across the continents.

Viewing the changes in landscapes which occur across broad continental areas has prompted many to investigate the laws of phenomena distribution. The principle of zonality was introduced initially to explain the latitudinal variation in climate from the equator to the poles and its control of the distribution of plants and other organisms.

But many anomalies became apparent. From an exhaustive study of climatic data in relation to plant and animal behaviour and distribution, Hopkins (1938 p.10) proposed his *isophanal* zonality to indicate *belts of equal phenomena*. His zones are on a continental scale, with boundaries departing from parallels of latitude at the rate of 1° for each 5° of longitude.

To account for other anomalies, the zonality of such phenomena as soil mantle, geochemical processes, ground water and soil profile have been introduced in the literature. However, only where a homogeneity of specific levels of these specified features is found over broad areas can such zones be readily recognized from above, and that only for a relatively small proportion of most regions. Furthermore, in most zonal schemes there is a tendency to assume that landform, vegetation and soil zones, independently established, will coincide with the climate zones. A careful scrutiny, from below, of the interrelationships of these features reveals that such is not the case.

A number of reconnaissance trips across several 'zonal' changes from south to north and from east to west brings to light that, rather than being homogeneous, each zone is comprised of a number of 'vegetation types' related to the type of relief and soil materials on which they are found. These are:

(a) On gently sloping well-drained areas of good structured loamy soils with well-balanced nutrient levels are found plant communities which differ from those of this same type of relief and materials in neighbouring regions. Communities similar to these are often found in adjoining regions but not in the same successional stage on the same combination of landform features.

(b) Communities which are characteristic of the well-drained, well-balanced loams of the four adjoining regions are also found in this region but on four distinctly different landform conditions, such differences conditioning local climate, soil moisture and nutrient levels etc.

(c) Within each region we find also plant communities which grow on sites which are (i) extremely wet, (ii) extremely dry, (iii) extremely deficient in nutrients, (iv) extremely impermeable to plant roots, (v) extremely toxic, etc. Some plant species may be found on most if not all of these extremely deviant sites. However, most plant evidence that such species are acidophils, calciphils, etc. There is merely the indication that it is a species which can tolerate the described condition better than it can the competition[1] found on more balanced soil conditions. Sheep Sorrel, *Rumex acetosella*, for instance grows equally well on the calcareous Chalk Cliffs of Devon as on the very acid sands of New England.

The above example illustrates the fact that many of these species grow on these extreme deviations in landform features over a wide range world-wide but generally the distribution is not limited to one of the five major climatic divisions of the earth. Therefore, these plant species-landform relationships are not as useful as criteria for regional differentiation as are the more competitive species comprising the communities mentioned in (a) and (b) above.

Since all the five vegetation-landform relationships mentioned in (a) and (b) above (combined with the associated ecoclimate, soil profile and faunal characteristics) constitute the *basic* pattern for a zone, which one of these five is zonal? Rather, are they not all zonal characteristics?

This suggests that the zone is not homogeneous but is characterized by a definite pattern of landform-vegetation relationships. But is there not one feature which remains the same throughout? No, not if we restrict our considerations to the phenomena of the local ecosystem. Local variations in landform not only condition the edaphic habitat of plant communities but also that of their climate. Earlier we inferred from the changes in vegetation seres on the same landform features from one zone to another that there is a change in the local effective climate of these landforms. Therefore, from one zone to another there must be a change in the continental system of climate lying beyond the conditioning effects of the local variations in landform and waterform and known as macroclimate.

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[1] The absence of a section discussing vegetation migration, colonization, and competition in this paper does not signify the lack of appreciation of their importance. None of these should be considered independent of the 'transactional space' into which plants migrate.

Figure 4 indicated the 14 subdivisions into which Ontario has been divided by noting the main vegetation types growing on the five types of physiographic sites described above as being those which most clearly reflect regional macroclimate. The gradients shown on the map are continental gradients of air temperature, air humidity and vegetation types. The vegetation continuum which stretches from Hudson Bay to the Gulf of Mexico can be divided into three broad zones, namely (1) the *boreal* of the cold temperature zone with its spruce-fir forests, (2) the *austral* of the warm temperature zone with its southern pine and evergreen broad-leaved trees, and (3) the *medial* of moderate temperature regions with its deciduous tolerant hardwoods often mixed with northern pines and hemlock. The first two terms have been generally recognized. The third term, 'medial', is introduced here with the hope of having a comparable organization to that of the other two.

Each of these 14 broad subdivisions of the province of Ontario are illustrative of Maslow's vague whole as observed at an intermediate stage of the investigation. The outline of the parts of the whole have become more definitive (and will be more so in the following section). In fact, the boundaries shown on the map are those of the latest stage of definition, namely the 1975 version of the

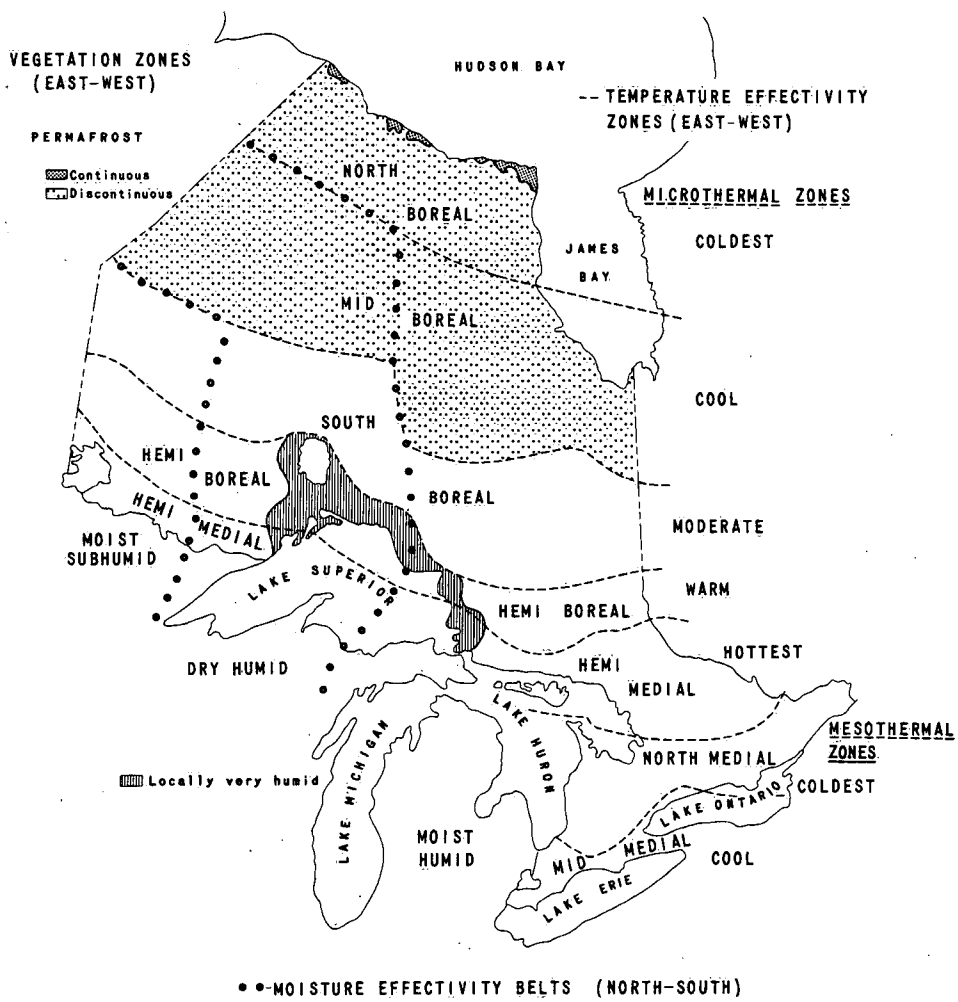


Figure 4: Landscape zones and belts of Ontario

Landscape regions of Ontario (compare with Figure 7). Furthermore, it only remotely resembles the 16 regional types which I initially proposed as Forest Site Regions of Ontario (Hills 1952). Figure 4 is presented to provide a concrete example of a stage in an iterative process of investigation. The more advanced stage, namely the 1975 version of the Landscape Regions of Ontario, is outlined following a discussion of the methodology used in establishing site regions and landscape regions.

The Five Levels of Normality in Terrestrial Site Types - In previous publications, normal site types were defined with respect to classes having characteristics defined with respect to their position along a regional feature gradient. Those site types which do not occupy this normal position were described in terms which indicated the type and degree of deviation from the defined normal.

Figure 5 is a modification of one used formerly to indicate the type and degree of deviations from normal ecoclimate and normal soil moisture (Hills 1968). Those site types with 'moderate' deviations in soil moisture and ecoclimate have been recognized, described and used together

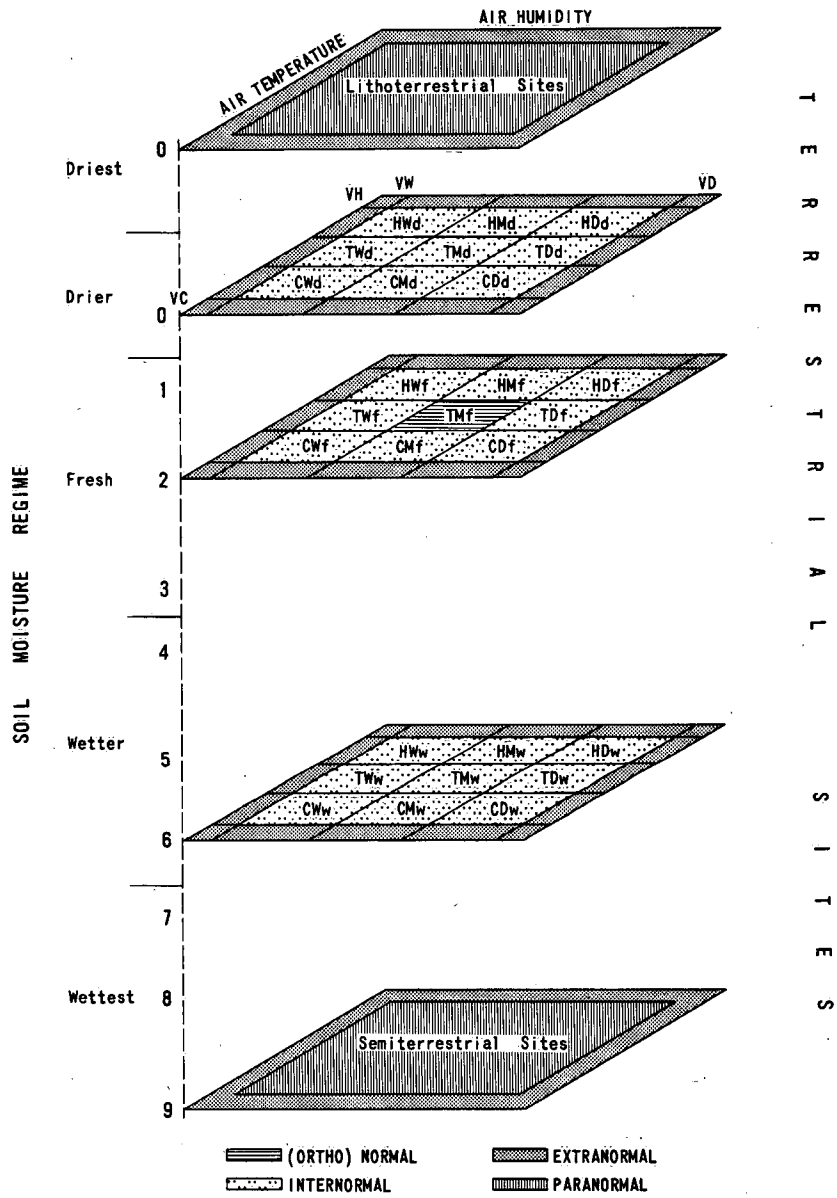


Figure 5: The physiographic orientation of the normalcy of regional site groups

with the normal in the establishment of site regions (Hills 1952, Figure 6; 1960b). Moderate deviations in a normal ecoclimate were designated as hotter than normal, colder than normal, drier than normal and moister than normal. Similarly 'Moderate' deviations in soil moisture are drier (but not driest) and wetter (but not wettest). These moderate deviations are shown on Figure 5 as *internormal* for reasons discussed below. Site types with extreme deviations in ecoclimate (that is, for the region) are shown as *extranormal* site types on Figure 5. Sites with extreme deviations in the landform features such as extremely wet or with extreme levels of nutrients (deficiency or unbalance to the level of fixation of toxicity) are classified as *paranormal*.

The characteristics of the extranormal and paranormal site types are seldom used as differentiae in the differentiation of site regions since the distribution of normal and internormal site types usually provides for a satisfactory delineation of site region boundaries. However, all extranormal and paranormal site types form an integral part of site regions with established boundaries.

Furthermore, a site region whose boundaries are established by the characteristics of the normal and internormal site types is translated into a landscape region whenever the characteristics of the extranormal and paranormal site types within it have been classified within an integrative extension of the site region classification matrix.

Normal Physiographic Site Types - The term *normal* as used in this site classification cannotes *that which does not deviate from a defined or prescribed standard*. The approach which has been used to establish 'standards' for the site region classification has been introduced already. Since the ecological processes within the site types which deviate moderately from the normal are not abnormal with respect to the 'standard' used to classify them, they, too, are a type of 'normal' termed *internormal*. In view of this concept of an assemblage of normals, perhaps the focal centre should be called 'orthonormal'. It is hoped that the simpler term 'normal' can be used in this prescribed context.

Normal and deviant site types are defined in both synoptic and benchmark terms. All site types are classified in terms of the *effective* levels of the various component features, such as local air temperature, soil moisture regime, etc. Within each feature effectivity class there are a number of analogues, each with a *benchmark* definition but collectively identified by a *synoptic* definition. From among the benchmark definitions of the various analogues within the class, a key benchmark definition is selected to provide an adequate point. *A normal site type is one in which all the component features are normal.* The centrality of the normal ecoclimate in the normal terrestrial ecosystem has already been stressed, also the requirement that all the features of this ecosystem type be normal. The normality of these other features within the normal site type is relative to that of the normal ecoclimate. For instance, the *normal soil moisture* benchmark in the humid mesothermal climate of Southern Ontario is fresh; that is, there is an adequate supply of moisture for the production of the natural vegetation adapted to the region. The fresh soil moisture class is located at a point on the soil moisture gradient for this region which is closer to the dry end of this specific regional gradient than to the wet end. It is not possible to have a wide range of significantly different classes drier than normal in a humid climate.

Normality of soil nutrients, soil aerations, etc., is also defined in terms relative to the requirements of sites with normal ecoclimate and soil moisture, thus providing for the normal development of the natural vegetation of the region on these sites.

Internormal Physiographic Site Types - The internormal group of ecosystems focuses around the moderately deviant ecoclimate classes recognized by four main characteristics, *viz.* 1. Hotter than normal 2. colder than normal 3. drier than normal 4. moister than normal. This internormal group of ecosystem types in combination with the normal are used as differentiae in the recognition of site regions. The prefix 'inter' refers to the fact that the vegetation on these sites resembles the vegetation which is characteristic of normal sites in one of the adjacent regions. In each region under examination, for example, a hotter than normal site is so designated because the vegation in the climax or subclimax stages resembles that found on the normal sites in a warmer site region.

In the broadest of regional description, only two deviants in air temperatures, namely colder than normal and hotter than normal, are used. In these cases the air moisture is construed as normal.

Eight combinations of these deviations with one another and with the normal are shown in Figure 5. Since only site types with a fresh moisture regime (i.e. in mid-humid regions) are normal, those with drier than normal and wetter than normal soil conditions in normal ecoclimates

are also internormal site types.

Figure 5 shows graphically the 27 focal classes used in site region differentiation of which one (TMf) is normal and the remaining 26 are internormal.

Extranormal Physiographic Site Types - Extranormal site types are those site types with climolandform and climowaterform features which express extreme deviations from normal air temperature and air moisture or both. Extranormal site types are characterized by vegetation landform relationships which show affinities with normal site types in regions more distant than those within which affinities with the internormal site types have been established.

Thus internormal site types exhibit affinities with those in an *inner ring* of site regions and extranormal with an *outer ring* of site regions. However, because of the overriding conditioning of the pedolandform features of the lithoterrestrial and semiterrestrial sites, these also show affinity to the more extremely deviating sites in the inner ring.

The prefix 'extra' refers to the affinity of these site types *beyond* that of the internormal (i.e. to the outer ring).

Paranormal Physiographic Site Types - The paranormal site types are those site types which, though conditioned by ecoclimates which are normal or near normal for the site region, are so conditioned by pedolandform features that the development of vegetation does not reflect differences in macroclimate over relatively broad areas. Thus paranormal site types in one region are basically the same as those in the adjoining inner ring of site regions. It is not until the regions of the outer ring are reached that differences of significance may be registered.

The prefix 'para' refers to the close resemblance of vegetation-landform relationships throughout a broad assemblage of site regions in which differences in vegetation landform relationships on normal and internormal sites do reflect differences in the macroclimate.

Figure 5 shows paranormal sites occupying two main sections of the climate-soil moisture grid, namely (a) the very wet sites (designated semiterrestrial) and (b) the very dry sites (designated lithoterrestrial). The characteristic differentiating feature of *semiterrestrial sites* is that of excessive soil moisture. On the other hand, extreme dryness is but one of the criteria used to differentiate *lithoterrestrial sites*. To present a more comprehensive picture of lithoterrestrial sites with paranormal characteristics, a fourth dimension, namely that of soil nutrient regime, must be added to Figure 5. This would show sites which are paranormal owing to the extreme deficiency or excess or unbalance of the mineral composition of the substrate even though the air temperature, air humidity and soil moisture are normal or near-normal.

The Ontario Example of Site Regions - Initially, that part of the Province of Ontario which is not occupied by the waters of the Great Lakes nor of Hudson and James Bays was divided into site regions. These subdivisions provided the regional 'situation' within which the 'particulars' of site types were expressed (Table 1). Subsequently the concept of landscape region has been introduced to provide an organization for investigating all types of land and water sites, within the boundaries of the site region.

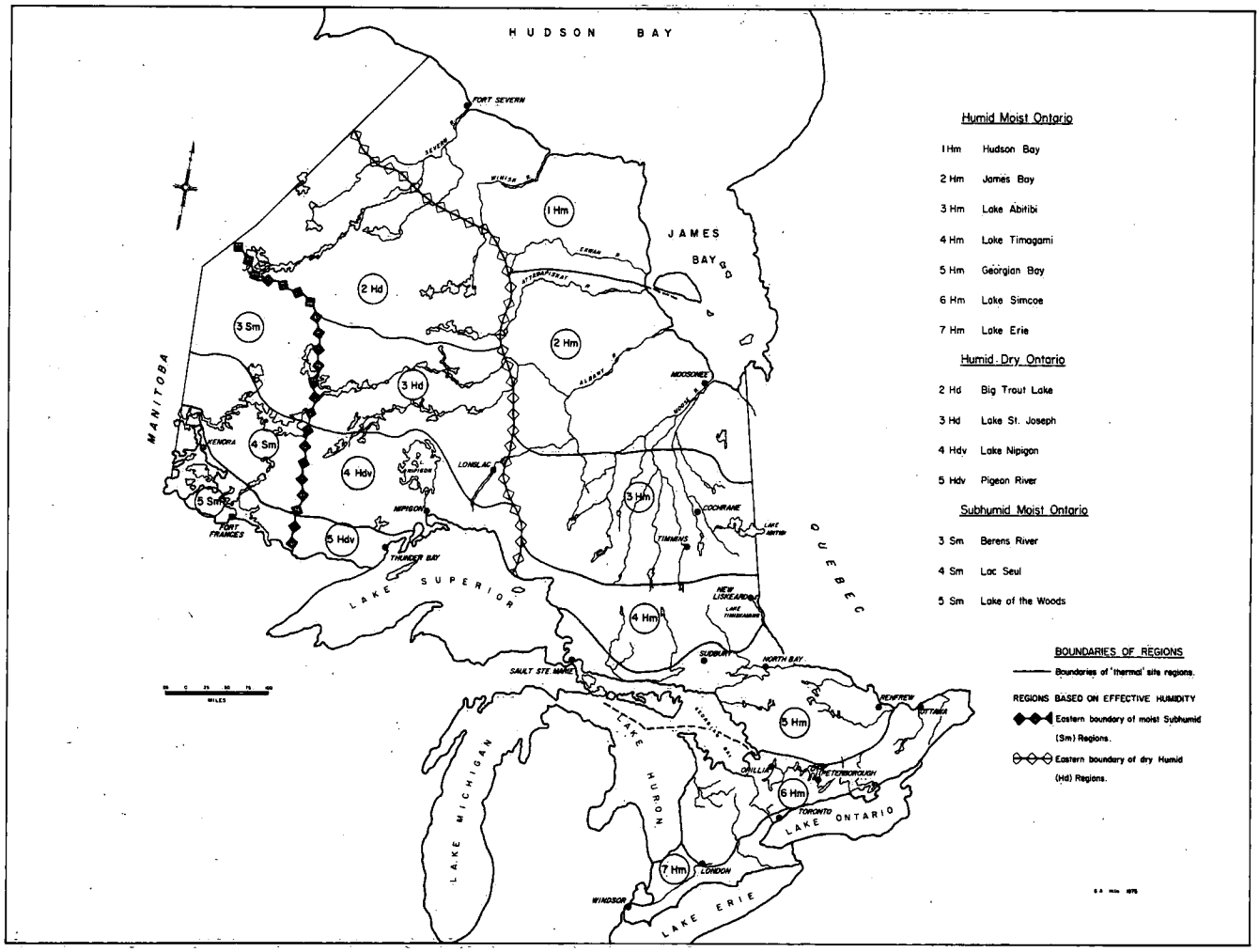
A *site region* is a broad terrestrial area having a characteristic pattern of site types which reflect the effectiveness of the air temperature and the air humidity of its macroclimate. This effectiveness is determined, not by meteorological data, but by the response of the succession of natural communities of terrestrial plants growing in normal and near-normal physiographic (non-living) habitats. This normalcy does not refer to the proportionate distribution of the sites of the region but rather to the degree to which the succession of plant communities reflects the effectiveness of the regional climate to the degree expressed by the normal and internormal sites described in the foregoing section. It is true that if there are large areas which are very wet, very dry, very shallow or unbalanced chemically, these may render the placement of regional boundaries more difficult.

However, site regions are not limited to the blotchy distribution pattern of normal and internormal sites but are areas coincident with continuous areas of macroclimate overhead. Therefore, the site region is also continuous, being co-extensive with the distribution of normal and internormal sites but *inclusive* of the extranormal and paranormal sites which happen to be within its boundaries.

The 1975 version of the Site Regions of Ontario is shown in Figure 6. A paper as yet unpublished (Hills 197?) was prepared to show the differences between this and preceding versions and the dynamics of the classification system.

The Site Regions of Ontario have been assigned geographic names, usually those of large (or distinctive) lakes and rivers. For their indication on maps or charts, symbols based on the character of their effective climate have

Figure 6: Province of Ontario showing Site Regions



been designed.

It has been stated that a site region is that area which lies in one section of a thermal effectivity zone and in one section of an air-moisture effectivity belt. The thermal and humidity belts which have been designed with the objective to define site regions are shown in Figure 4.

The site region symbol consists of two parts, a number and a letter or letters.

The *number* refers to *thermal zones* not to single regions. In the 1952 version, each thermal zone in Ontario was considered a site region. However, in the 1954 version some thermal zones were divided into two site regions and assigned distinguishing names such as Big Trout Lake and James Bay. The thermal designation of the seven numerals used are:

1.	Coldest	Microthermal
2.	Cool	microthermal
3.	Moderate	microthermal
4.	Warm	microthermal
5.	Hottest	microthermal
6.	Coldest	mesothermal
7.	Cool	mesothermal

The *letter* part of the symbol indicated a level of air humidity. In earlier versions, the letter used indicated the relative position of a humidity belt within the province. To overcome the awkwardness of such designation (already discussed), letter symbols specifying humidity classes were introduced in the 1975 version as follows:

Hm	Moist (or moderate) Humid
Hd	Dry Humid
Hdv	Dry to Very Moist Humid
Sm	Moist Subhumid

The nature of site regions can best be under-

stood by examining the organization used to *identify* and *classify* the most southerly region of Ontario, namely Site Region 7Hm. Figure 7 is an up-to-date version of an earlier one used to introduce the methodology of classifying and describing site regions. This figure indicated clearly that the characteristics of Site Region 7Hm are the *interrelationships* between vegetation types and a combination of macroclimate, ecoclimate and landform (a key consideration of the latter is that of normal soil moisture). It is the complex of relationships expressed by Figure 7 which are the characteristics of Site Region 7Hm and not the restricted climatic connotation derived from its label 7Hm.

Figure 6 is a map of the 14 regions into which Ontario has been divided using site region criteria of differentiation, namely the vegetation-physiographic relationships of normal and paranormal sites. The key to the map (Table 2) presents an outline of these relationship throughout the province.

In this key, nine physiographic site groups are shown to constitute the non-living grid for differentiating the spectrum of vegetation which develops upon terrestrial sites which are normal or internormal. Such sites are neither very poorly drained nor very shallow, nor very deficient in nutrient supply nor have excessive amounts of chemicals which retard or inhibit plant growth.

There are three designated class of ecoclimate (i.e. the climate of a vegetation stand):

1. *Normal* - the local climate, which neither amplifies nor attentuates the effect of the macroclimate on vegetation. (Symbol T - normal temperature; M = normal air moisture).

2. *Hotter than Normal* - the local climate which is reflected by the development of vegetation which grows on sites in the neighbouring region to the south where they are considered to be normal for that region; hotter than normal ecoclimate is recognized by landform

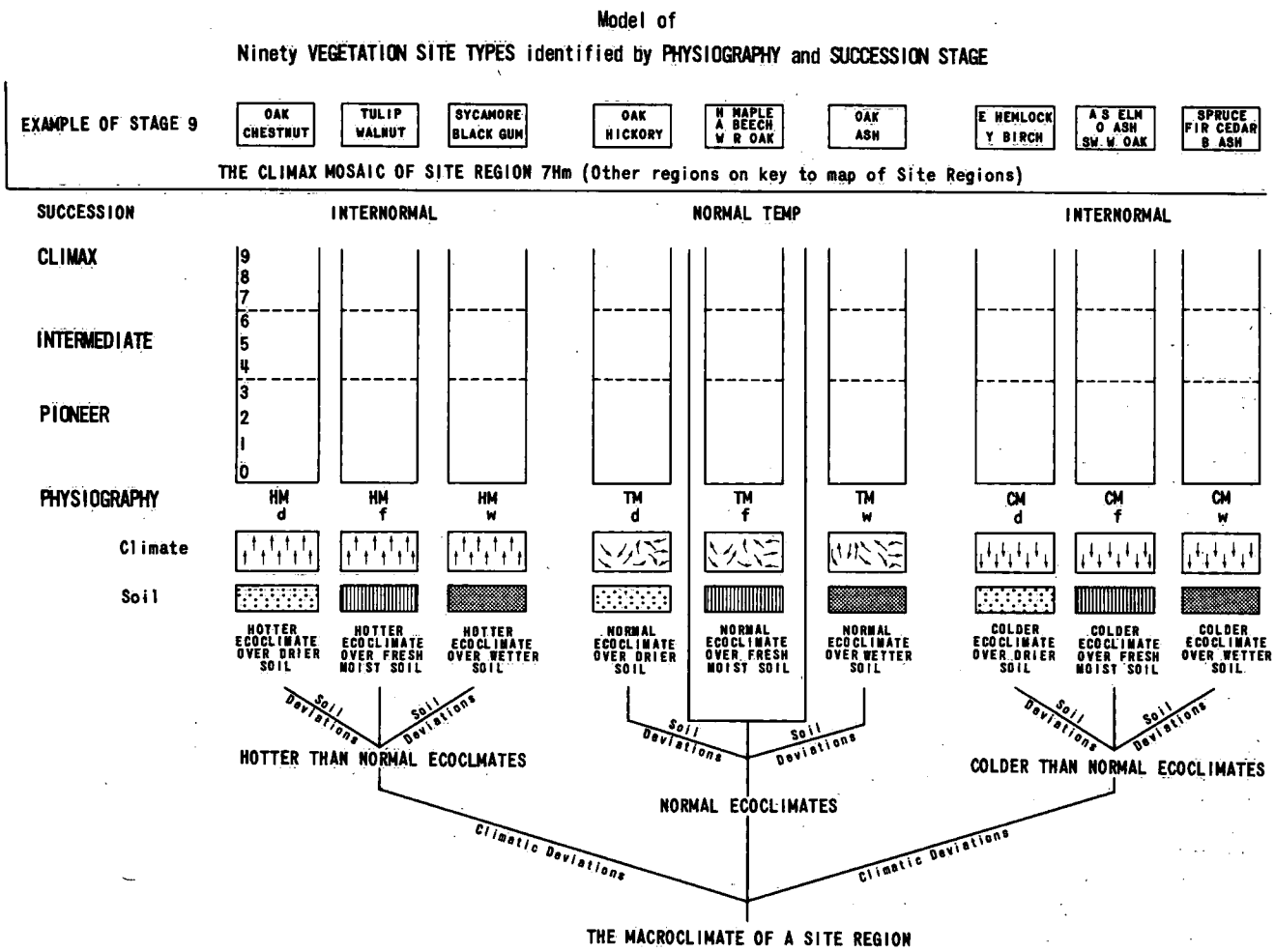


Figure 7: Orientation of normal and internormal groups within a Site Region

Table 2: Synoptic key to the characteristics of the Site Regions of Ontario

SITE REGIONS	PHYSIOGRAPHIC SITE GROUPS WITHIN SITE REGIONS — ECOCLIMATE — HOTTER — SOIL — DRIER	FRESH	WETTER	NORMAL — DRIER	FRESH	WETTER	COLDER[3] — DRIER	FRESH	WETTER
	VEGETATION SECTORS COINCIDENT WITH SITE GROUPS								
Hm Moderate Humid Eastern Ontario									
1 Hm Hudson Bay	OPEN SPRUCE - (LARCH) - LICHEN - HEATH	SPRUCE - MOSS - HERB - SQUASHBERRY - POPLAR - HERB	OPEN - SHORT SPRUCE - LARCH - SPHAGNUM - ALDER	LICHEN - HEATH OPEN SCRUBBY - SPRUCE - WILLOW	OPEN SHORT - SPRUCE - LICHEN (SPRUCE - LARCH - MOSS)	SPHAGNUM - LICHEN OPEN SCRUBBY - SPRUCE - LARCH	HERB - SHORT SHRUB - MOSS : LICHEN - HERB - SCRUB SPRUCE	LICHEN - ROSEBAY - MOSS - HERB	MOSS - LICHEN - HERB - CRANBERRY
2 Hm James Bay	HEATH - LICHEN OPEN - SPRUCE - BIRCH	SPRUCE - FIR - POPLAR MOSS - HERB - ALDER - SQUASHBERRY	SPRUCE - FIR - ALDER - MOSS - SEDGE	LICHEN - HEATH - OPEN SPRUCE	SHORT SPRUCE - MOSS - ALDER	SPHAGNUM - LICHEN OPEN SHORT - SPRUCE - LARCH	LICHEN - HEATH OPEN SCRUBBY - SPRUCE - WILLOW	SEDGE - LICHEN OPEN SHORT - SPRUCE - LARCH	SPHAGNUM - LICHEN OPEN SCRUBBY - SPRUCE - LARCH
3 Hm Lake Abitibi	BIRCH - SPRUCE - POPLAR - HERB - HEATH PINE - LICHEN - ALDER	SPRUCE - FIR - POPLAR - BIRCH - PINE - HERB - MOSS	POPLAR - CEDAR - FERN - ELM - ASH MAPLE - HERB	SPRUCE - PINE - MOSS - BIRCH - POPLAR - HERB	FIR - SPRUCE - POPLAR - BIRCH - MOSS - HERB - SQUASHBERRY	SPRUCE - FIR - ALDER - MOSS	SPRUCE - PINE - MOSS - HEATH	SHORT SPRUCE - SPHAGNUM	SPHAGNUM - LICHEN OPEN SHORT - SPRUCE - LARCH
4 Hm Lake Timagami	PINE - BIRCH - POPLAR - MAPLE - ALDER	MAPLE - BIRCH - PINE - FIR - SPRUCE - ASH - HOBBLE BUSH - HERB	BIRCH - CEDAR - ELM - ASH - HERB - MOSS - MAPLE	PINE - MAPLE - BIRCH - BLUEBERRY - HERB	PINE - FIR - SPRUCE (BIRCH - POPLAR) - MAPLE - HERB	FIR - SPRUCE - MOSS - ALDER	PINE - ALDER - HEATH FIR - CEDAR - HEATH	SPRUCE - FIR - MOSS - SQUASHBERRY	SPHAGNUM - SEDGE OPEN - SPRUCE - LARCH
5 Hm Georgian Bay	OAK - PINE - BLUEBERRY OAK - CHERRY - GRASS	MAPLE - OAK - BEECH - HEMLOCK - PINE - MOSS - LEATHERWOOD - HERB	ELM - ASH - MAPLE - SPRUCE - HEMLOCK - MAPLE - MOSS - HERB	PINE - HEMLOCK - MOSS - BEECH - ASH - OAK - BLUEBERRY - HERB	MAPLE - BIRCH - ASH - HOBBLEBUSH - HERB - PINE - HEMLOCK	MAPLE - ASH - BIRCH - PINE - SPRUCE - ALDER - MOSS - HERB	PINE - SPRUCE - FIR - HERB - MOSS - HAZEL	FIR - SPRUCE - HAZEL - HERB - MOSS - CEDAR - BIRCH	FIR - SPRUCE - (LARCH) - ALDER - MOSS
6 Hm Lake Simcoe	BEECH - HEMLOCK - OAK - ELM - ASH - HERB - CEDAR - SHRUB - HERB	OAK - HICKORY - MAPLE - ELM - BUTTERNUT - HERB - SHRUB	MAPLE - BIRCH - ELM - WALNUT - CHERRY - PLUM - BUCKTHORN	MAPLE - OAK - ASH - ELM - HORNBEAM	MAPLE - BEECH - OAK - HEMLOCK - LEATHERWOOD - HERB	HEMLOCK - BIRCH - ELM - CEDAR - SPRUCE - FIR	PINE - HEMLOCK - ASH - ELM - HERB	PINE - HEMLOCK - FIR - SPRUCE - HOBBLEBUSH - HERB	FIR - SPRUCE - PINE - POPLAR - MAPLE - ASH - HOBBLEBUSH - HERB
7 Hm Lake Erie	OAK - CHESTNUT - HERB TULIP - DOGWOOD OAK - GRASS - HERB	BEECH - MAPLE - OAK - HICKORY - (TULIP - PAPAW - SASSAFRAS)	MAPLE - BLACK GUM - ASH - SPICEBUSH - FERN - OAK - ELM - HICKORY	OAK - HICKORY - ELM - MAPLE - WITCH HAZEL - CEDAR - ASH - GRASS	BEECH - MAPLE - OAK - HICKORY - BASSWOOD - LEATHERWOOD - HERB	OAK - ASH - HICKORY - ELM - WALNUT - FERN - ARROWWOOD - DOGWOOD	ELM - MAPLE - ASH - OAK - BEECH - HEMLOCK - WITCH HAZEL - HERB	ELM - MAPLE - ASH - OAK - HONEYSUCKLE - HERB	MAPLE - BIRCH - FIR - HEMLOCK HEATH - SPRUCE - ALDER
Hd Dry to Very Humid Central Ontario									
2 Hd Big Trout Lake	PINE - BIRCH - POPLAR - SPRUCE - WILLOW - SQUASHBERRY - HERB	SPRUCE - POPLAR - BIRCH - MOSS - HERB - SASKATOON BERRY	SPRUCE - FIR - ALDER - SQUASHBERRY - MOSS POPLAR - ASH - HERB	LICHEN - HEATH - HERB - OPEN SPRUCE - ALDER - BILBERRY - SEDGE	SPRUCE - MOSS - ALDER - SQUASHBERRY (BIRCH - POPLAR)	SPHAGNUM - LICHEN OPEN SCRUBBY - SPRUCE - LARCH	LICHEN - HEATH - HERB OPEN SCRUBBY - SPRUCE - ALDER	SEDGE - LICHEN OPEN SHORT - SPRUCE - LARCH	SPHAGNUM - LICHEN OPEN SCRUBBY - SPRUCE - LARCH
3 Hd Lake St. Joseph	PINE - BIRCH - CRANBERRY - HEATH	PINE - SPRUCE - MOSS - SASKATOON BERRY	POPLAR - SPRUCE - LARCH - SPHAGNUM - ASH - ELM - HERB - MOSS	PINE - SPRUCE - HEATH - BLUEBERRY	SPRUCE - FIR - POPLAR - BIRCH - MOSS - HERB	SPRUCE - LARCH - ALDER - MOSS	PINE - MOSS - HEATH - SQUASHBERRY	SHORT SPRUCE - LARCH - SPHAGNUM	SPHAGNUM - LICHEN OPEN SHORT - SPRUCE - LARCH
4 Hdv Lake Nipigon	PINE - BIRCH - POPLAR - BLUEBERRY - HEATH	PINE - SPRUCE - POPLAR - BIRCH - SHRUB - HERB	FIR - SPRUCE - POPLAR - CEDAR - MOSS	PINE - POPLAR - HEATH - HERB	FIR - SPRUCE - BIRCH - POPLAR "PINE" - MOSS - HERB	FIR - SPRUCE - SPHAGNUM - ALDER "ASH"	FIR - SPRUCE - CEDAR - BIRCH - MOSS - ALDER - BRACKEN - HEATH	SPRUCE - FIR - BIRCH - MOSS - SQUASHBERRY	SPRUCE - LARCH - ALDER - SPHAGNUM
5 Hdv Pigeon River	OAK - MAPLE - GRASS - PLUM PINE - BIRCH - LEATHERWOOD	MAPLE - BIRCH - PINE - BASSWOOD - HEMLOCK - SPRUCE - HERB	ELM - ASH - CEDAR - MAPLE - BIRCH - HERB - MOSS	PINE - HEATH - SEDGE	MAPLE - BIRCH - HERB - BRAMBLE - (HEMLOCK) "SPRUCE - PINE - FIR"	FIR - SPRUCE - CEDAR - ASH - MOSS - HERB	FIR - BIRCH - MOSS - CLUBMOSS - HEATH	SPRUCE - FIR - BIRCH - POPLAR - MOSS - CLUBMOSS	SPRUCE - LARCH - ALDER - SPAGNUM
Sm Moist Subhumid Western Ontario									
3 Sm Berens River	PINE - BIRCH - BLUEBERRY - HEATH	SPRUCE - FIR - POPLAR - HERB	SPRUCE - FIR - ALDER - MOSS	PINE - SPRUCE - BLUEBERRY - HEATH	SPRUCE - POPLAR - FIR - MAPLE - HERB	SPRUCE - FIR - ALDER - MOSS	LICHEN - HEATH - HERB OPEN SHORT - SPRUCE - PINE	SHORT SCRUB OPEN SPRUCE - PINE - SPHAGNUM - HEATH	SPHAGNUM OPEN SHORT - SPRUCE - LARCH
4 Sm Lac Seul	PINE - BIRCH - HEATH - BLUEBERRY - PINE OAK - GRASS - SEDGE	SPRUCE - POPLAR - PINE - MAPLE - HERB	SPRUCE - FIR - PINE - POPLAR - HERB	PINE - SPRUCE - BLUEBERRY - HEATH	SPRUCE - FIR - POPLAR - BIRCH - FORB - SEDGE	POPLAR - FIR - SPRUCE - ASH - BIRCH - HERB	PINE - SPRUCE - LICHEN - HEATH	SPRUCE - FIR - PINE - MOSS	SPRUCE - LARCH - SPHAGNUM
5 Sm Lake of the Woods	OAK - ELM - MAPLE - PRAIRIE GRASS - SEDGE - POPLAR - PLUM - HERB	PINE - POPLAR - HERB - MAPLE - BASSWOOD - NANNYBERRY - HERB	ASH - ELM - MAPLE - COTTONWOOD - HERB - SPRUCE - FIR - CEDAR	SPRUCE - BIRCH - POPLAR - PINE - BRACKEN - HERB	SPRUCE - FIR - POPLAR - BIRCH - FORB - GRASS	SPRUCE - POPLAR - FIR - CEDAR - MOSS	BIRCH - PINE - MOSS	FIR - SPRUCE - MOSS	SPRUCE - LARCH - SPHAGNUM

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FOOTNOTE 1

1a Each sector of the regional vegetation pattern is designated by formations, ie groups of communities having a common physiognomic appearance. Examples are –

(i) CLOSED SPRUCE-FIR FOREST WITH FEATHER-MOSS; the characteristic formation on moist soils in the normal ecoclimate of Site Region 4 Hm, and on fresh soils in the hotter ecoclimate of S.R. 1 Hm and others.

(ii) OPEN SPRUCE WOODLANDS WITH LICHEN; the characteristic formation on dry soil in hotter than normal ecoclimate of S.R. 1 Hm and others.

(iii) HEATH SCRUBLAND WITH DWARF SPRUCE; the characteristic formation on the dry soils of the colder ecoclimate of S.R. 1 Hm, etc.

Note: Within each vegetation sector there are other formations than those designated in this key as characteristic.

1b CHARACTERISTIC SPECIES are selected from the major layers of each formation.,

1c The species selected from all the layers with each formation are HYPHENATED.

1d The ORDER of the listing of the species from the various layers indicates the dominance of that layer (not necessarily the dominance of the species) within the whole stand

1e The formations selected as indicators are usually terminal i.e 'climax.' BRACKETS indicate a stage in succession other than terminal

1f A COLON indicates there are two or more characterizing formations in the same stage in succession. Additional formations comprised of species from several of these may be also common but not indicated in the key

1g QUOTATION MARKS indicate characteristic species or formations whose regional distribution is limited by features not included in this key

1h NAMING OF SPECIES

Trees: R.C. Hosie, Native Trees of Canada, 1973

Shrubs: Soper, 100 Shrubs of Ontario, 1961

F. Moss: Feather Moss: e.g. Pleurozium, Ptilium, Abietinella, Dicranum; Thuidium

Herbs: All non-woody plants, including Forbs, Ferns, Grasses and Sedges: Gray's Manual.

Heath: Dwarf ericaceous shrubs, mainly Labrador Tea, Leatherleaf and Laurel.

FOOTNOTE 2

Sites with extreme conditions such as drainage and shallowness of soil are not included in this key.

FOOTNOTE 3

In site regions 4Hdv and 5Hdv; the formations listed under colder than normal also reflect very moist Air Humidity.

features which are known to amplify the effectiveness of the regional macroclimate. (Symbol H).

3. *Colder than normal* - the local climate which is reflected by the development of vegetation which grows on sites in the neighbouring region to the north where they are considered to be normal for that region. Colder than normal ecoclimate is recognized by landform features known to attenuate the effectiveness of the regional macroclimate. These are known locally in some regions as frost pockets. (Symbol C).

Two other ecoclimates, namely *drier than normal* and *wetter than normal*, are recognized in most regions but occupy sizeable areas in only a few. This two dimensional climatic grid has been applied in some areas but is considered too unwieldy for a general framework at this stage in the development of the system. (Drier than normal - Symbol D; wetter than normal - Symbol W).

Within each of these three ecoclimate classes, three classes of effective soil moisture are recognized for the purposes of differentiating site regions. These are:

Fresh - That is the normal moisture regime for that moderately humid belts of the temperate zone. This includes classes 1, 2 and 3 on the 12-point scale.

Drier - Although the supply of available moisture limits growth during part of the growing season, the degree of dryness is relative to the region and does not include the very dry or extremely dry range which have been excluded from the key. Using the 12-point scale, drier refers to class 0^+ and 0^- but not 0.

Wetter - Growth is limited by excessive moisture and restricted aeration during part of the growing season. Wetter refers to moist, rather than wet, having generally the range of 4,5 and 6 in the 12-point regional scale.

Although not so labelled, the nine normal and internormal site groups used in the key for the purposes of indicating the main trends of vegetation development within a region are normal in every way except for that feature which is designated internormal. For example, in a site group labelled hotter than normal and wetter, there are no sites in which the nutrients are deficient or toxic, no restriction in root development such as bedrock or impermeable subsoil, no extreme climatic restrictions such as exposure to strong winds.

Earlier it was mentioned that paranormal and extranormal site groups are component parts of site regions, even though their characteristics are not used as differentiating criteria. Furthermore, large areas of wetlands, bare rock lands, etc. may have a significant effect on adjacent areas of normal and internormal sites. The effect of adjoining water bodies on the local climate of land areas is also included in the classification scheme.

The Nature of Landscape Regions - A natural landscape region is a broad continental area of land and water (fresh in most regions) which is characterized by the relationships of its natural plant and animal communities to their geomorphological habitat within a narrow range of macroclimate.

For convenience in the identification, classification and interpretation of the site units, the range in macroclimate conditioning the ecosystems of landscape regions has been established to be identical to that which characterizes site regions. This notion of the coincidence of site region and landscape region has already been introduced earlier in this paper. Although landscape regions are coincident with site regions, they are classified and described by a grid of interrelated taxonomic units of all the landscape features: semiterrestrial, lithoterrestrial, limnic and marine, as well as terrestrial.

A landscape region includes not only the inland bodies of fresh water within its boundaries, but also the coastal waters of the Great Lakes and of Hudson and James Bays. Islands in the Great Lakes and those of the coastal areas of James Bay are incorporated within the landscape region with the most compatible characteristics. Those inclusions would not be necessary if each Great Lake, James Bay and Hudson Bay were organized as a landscape region.

Terrestrial sites - are ecosystems located on the deeper, better-drained soils of land areas. Vegetation-physiography relationships reflect the relative effectiveness of climate to a greater degree. They occupy the normal and near-normal portions of the gradients used in the regional site system.

Lithoterrestrial sites - are ecosystems located on 'bare' bedrock, badly eroded surfaces, marl and other unweathered mineral deposits, permafrost soils and on extreme landform positions such as the 'subarctic' portions of Ouimet Canyon in Site Region 4Hdv. These sites occupy many of the extreme deviant classes of the site classification scales such as extremely shallow, extremely dry, extremely deficient or unbalanced in available nutrients etc..

Semiterrestrial sites - are ecosystems located on the poorly drained portions of land areas occupying classes 7, 8 and 9 of the soil moisture scale. Owing to the deficiencies in soil aeration and the limitations of poor drainage, these sites were not included in the grid used to establish and classify site regions. Semiterrestrial sites include bogs, fens, swamps and marshes, terms which have a vegetation overtone.

Limnic ecosystems - are located in open bodies of fresh water. The features of these sites are not classes on the scales established in the site classification used for site regions.

Marine ecosystems - are restricted in this classification to the saline (or brackish) waters of the coastal zone and estuaries of Hudson and James Bays.

The criteria used for the identification of both site regions and landscape regions are the characteristic landform-vegetation relationships of the normal and internormal sites. Likewise, their boundaries coincide since these are determined by the distribution of normal and internormal site types which distinguish one region from the next.

Landscape regions differ from site regions in that additional criteria are used, namely the vegetation-landform relationships of the lithoterrestrial, semiterrestrial, limnic and marine sites. This means that the extranormal and paranormal site types are an integral part of the landscape hierarchies of site units. Also included in these categories are some terrestrial sites omitted in the site region matrices.

How is it possible that an area, mapped twice using identical boundaries can be designated as two different units, namely site region and landscape region? Both of these regions are ecosystem units, and we have seen from earlier discussions that the differentiae used in the classification of ecosystems do not consist of a mere catalogue of all their features but rather a classification of interrelationships viewed from a specific perspective and based on the objective of the classification. Therefore, the same area can be two different ecosystems if so classified. Although the basic approach to the classification of landscape region units is the same as that which has been applied to site region classification over the years, the extension of the classification to include a recognition of *all* site types has necessitated an extension and elaboration of the hierarchical structures.

Hierarchical Levels of Differentiation-Integration Ecosystem Units Within Regions - The hierarchical organization outlined in Table 1, ranging from significant properties of the component features of local ecosystems to the global whole, is a generalized one. This table indicated the site region to be at the level just above the site type. In the preceding discussion of site and landscape regions, the site type was used as the building block of the ecosystem region. We now turn for a brief but more critical look at the nature of the site type as the intermediary stage between the feature effectivity class and the region as one of several intervening levels of integration-differentiation.

The Nature of Terrestrial Site Types - The component systems of terrestrial ecosystems have been outlined in Figure 1. The regional gradients of feature effectivity classes used in the differentiation of the local site types have also been introduced.

A *site type* is a small area of land which is homogeneous with respect to all features effective in conditioning the development of natural vegetation on a local area. This homogeneity is derived from that of the complex of its non-living or physiographic components. A site type is a natural ecosystem comprised of the non-living physiographic site type and a biotic site type, namely, a biotic community, the plant portion of which represents one of the several stages of succession which become established on the landform and within the associated ecoclimate.

Since the non-living physiographic site features are the most stable parts of a total site type, they are used to locate site types which are identified by the interrelationships between the physiographic and vegetation features. Although named in landform and climate terms, the area is nevertheless a total ecosystem since ecological relationships were used to provide unity for the classes.

A *physiographic site type* is a total site type identified by the significant component features of landform (soil) and climate. The character of these component features does not vary beyond the limits set for one of the several classes established on a regional effectivity scale. This narrowness of the range of all of the significant physiographic features conditioning vegetation development provides defined homogeneity of the site type.

The significant component classes which characterize a physiographic site type are:

1. Effective air temperature (ecoclimate) classes (correlative landform features)

2. Effective local air humidity (ecoclimate) classes (correlative landform features)

3. Soil moisture regime classes (correlative soil aeration regime)

4. Broad classes of effective size of unconsolidated particles (texture and stone size)

5. Effective interparticle spaces (pore pattern) (correlative soil aeration regime)

6. Broad petrography classes (effectivity classes of nutrient and toxic chemicals; physical-chemical classes of soil solution)

7. Bedrock effectivity classes: Petrography, weatherability (relief of bedrock surface)

8. Soil profile type

The first seven classes are feature effectivity classes. The eighth is not an effectivity class *per se* but its features have been considered with nonprofile features in the determination of classes 3-6 inclusive.

The above classes are not listed in hierarchical order. In fact there is no rigid order for ecosystem differentiation. For example, the differentiation of site regions first into soil moisture groups was found the most practical approach in the initial investigations of terrestrial sites. Later, however, it was proven that soil materials provided a broader initial physical base. On the other hand, soil moisture continues to be the most useful initial differentiae for semiterrestrial sites.

The first seven gradients of effectivity classes listed above are at the first level of nonparametric interpretation of the physical homologues of the systematic scientists such as the climatologists and geomorphologists. However, for convenience in generalization at certain levels, two or more of these gradients may be integrated to form a complex effectivity gradient. Such integrations are shown in Figure 8. For example, the gradient of pore pattern (originally termed permeability) is an interpretation of the ecological effectiveness of texture and structure in conditioning the functioning of plant roots. For some types of classification, pore pattern has been found to be most convenient; for others pore pattern classes are further differentiated by texture and/or structure (see Hills 1954).

Figure 9 presents an overview of the method by which classes of the various components of an ecosystem are established in iterative progression. Classes from one gradient are 'tailored' in anticipation of their fitting those of other gradients until the total site is finalized. For example, the range in the size of the various voids in landform fabric, which constitute

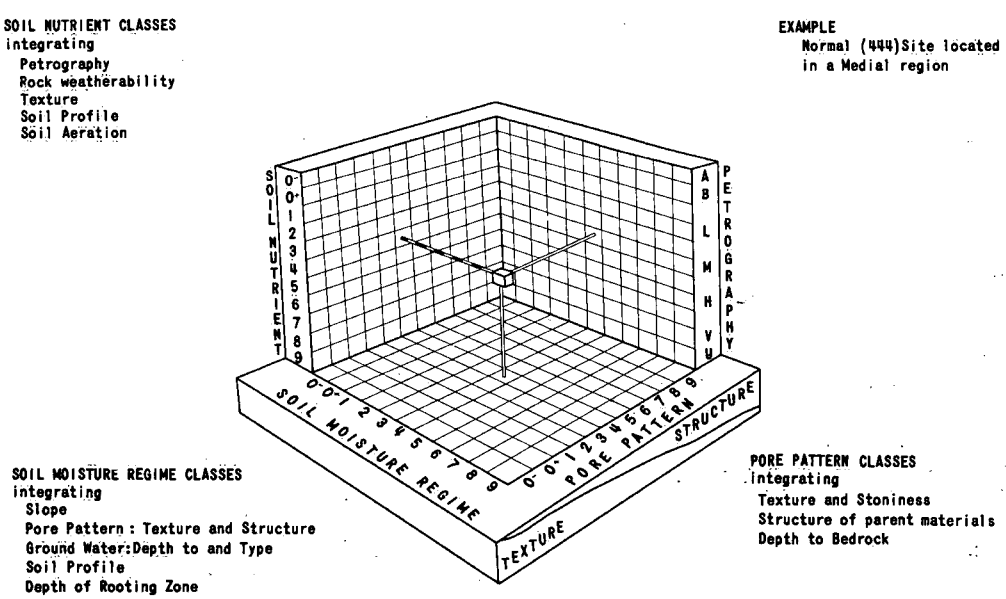
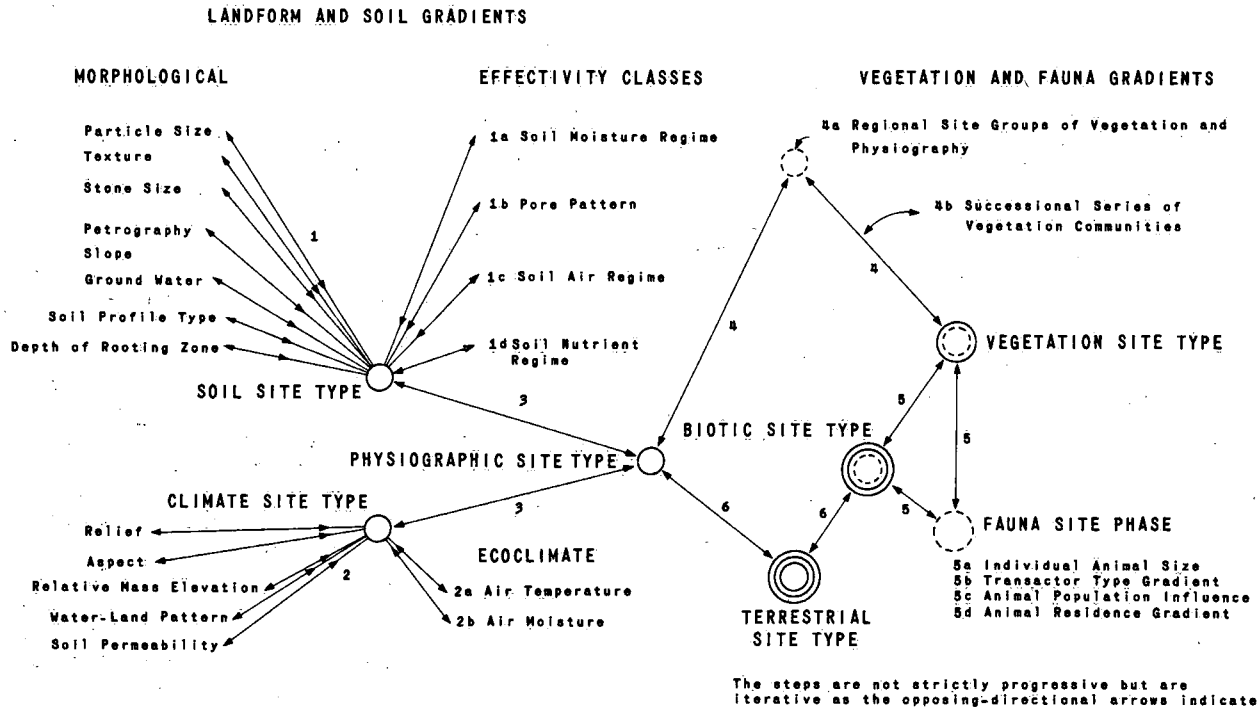


Figure 8: Terrestrial soil site type
(An integration of soil moisture pore pattern and soil nutrient effectivity classes)

Figure 9: Steps in the integration of total site types



a pore pattern class, facilitates the typing of classes on the soil moisture regime gradient. The pore pattern gradient is broken at those intervals of levels which fit the soil moisture classes used in breaking the vegetation spectrum into meaningful types of biotic communities within each range of local climate.

Hierarchies of Taxonomic Site Units - During the development of the regional site typology in Ontario, types of site units were established at various levels of differentiation to meet specific objectives. These units were placed within a hierarchical framework to meet the need of a system of classification which has integrated at all levels of differentiation. Four hierarchical systems evolved of which three were comprised entirely of taxonomic units. These are:

1. A taxonomic hierarchy which presents a *theoretical regional model.*

2. A taxonomic hierarchy which presents a *field key to the identification of homogeneous site units.*

3. A taxonomic hierarchy which provides the greatest *convenience of mapping homogeneous site units.*

The site type and site region are component units of all three of these hierarchies. Other units may also be components of more than one of the hierarchies.

It should be made clear at this point that each of these hierarchies is characterized by a specific series of differentiations which follow a specific order in the subdivision of site regions into units having an increasingly greater degree of homogeneity with respect to those characteristics used in the differentiation . This means that although each hierarchy is comprised of units formed at specific levels of diffentiation, the hierarchy may be more readily idenified by the characteristics of the feature effectivity classes used at each level. This is illustrated in the theoretical model discussed below where no site units other than the site region are mentioned in Figure 6.

Since many of the same gradients of feature effectivity classes are used in the three taxonomic hierarchies, it is the order in which they are used which constitutes the distinguishing feature of those hierarchies. That this order depends upon the purpose which the classification is to serve will be seen in the following discussion.

The Theoretical Regional Model - This type of taxonomic hierarchical differentiation is illustrated by Figure 6, in which the vegetation-

landform relationships within Site Region 7Hm are highlighted within a hierarchical framework. This framework is based on the concepts of normal and internormal site types shown graphically in Figure 5.

It will be noted that differentiating features, not site units, are used to indicate levels of differentiation. By working from the bottom of Figure 6 upward, we find that the broad area of a site region, identified by a narrow range of macroclimate, is subdivided by ecoclimate gradients at the very first level of differentiations. In theory, this is a logical first step since it brings into focus the key characteristics of site regions. It does present a practical problem in that the several thousand km^2 of a site region is subdivided in one operation into myriads of small local areas usually measured in terms of hundreds or thousands of m^2. This immediate shift in size from the largest unit (region) to areas corresponding to the smallest unit, namely the site type (or phase), imposes a problem in that these very small areas cannot be identified as site types and phases until the entire series of differentiations has been effected. As discussed in the following section and illustrated in Table 3, the work is much more easily accomplished by introducing the ecoclimate differentiation as the last, rather than the initial procedure. The advantage of the latter alternative is based on the fact that ecoclimate reflects landform conditioning and the landform gradients of soil moisture and pore pattern provide localized situations within which the additional controls of features such as slope, aspect and relative mass elevation may be superimposed.

The reason for the designation of Figure 6 as a theoretical model requires no further elaboration.

A Hierarchical Key to the Field Identification of Taxonomic Physiographic Site Units - The major activity of site typology is to identify, classify and describe those units which are homogeneous with respect to all the features effective in conditioning the development of vegetation on a local area, namely the *site type*. In the section entitled "The Nature of Terrestrial Site Types", the nature of these key units was discussed. This discussion included a listing of the eight feature effectivity gradients used in the differentiation of

FEATURE EFFECTIVITY GRADIENTS

	CONTINENTAL	R E G I O N A L				
UNIT NAME	*MACROCLIMATE*	*ECOCLIMATE*	*SOIL MOISTURE REGIME*	*SOIL DEPTH*	*SOIL PETROGRAPHY*	*SOIL TEXTURE*
SITE REGION	D[1]	u[1]	u	u	u	u
ECOCLIMATE GROUPS[2]	D	D	u	u	u	u
CLIMATE-SOIL MOISTURE GROUPS[2]	D	D	D	D	u	u
NORMAL-DEVIANT SITE GROUPS	D	D	D	D	D	u
PHYSIOGRAPHIC SITE TYPE	D	D	D	D	D	D

1. *Differentiated (D)* and *undifferentiated (u)* identify the hierarchical level of the units. Differentiated means that the area has been differentiated by the effectivity class under which the term appears. Undifferentiated means that areas recognized as the unit so described may have the full range or any part of the feature gradient so indicated.

2. The use of these units is generally restricted to theoretical considerations such as the type of furcation presented here to show a logical differentiation of site regions into physiographic site types.

Table 3: Taxonomic hierarchy of physiographic units of terrestrial areas.

physiographic site types. In that section, it was pointed out that there was no rigid order for ecosystem differentiation. This is true unless an objective for using a specific order is introduced other than that of establishing a site type *per se*.

In the section preceding this, we did introduce a reason for following specific orders and suggested that Table 3 indicated an order which provided a practical scheme for the field identification of a hierarchy of site units.

The levels of integration of Table 3 following those of Figure 8 were used extensively in the site survey of the 1950's such as the detailed mapping of University of Toronto Forest and other areas. Owing to the skill required by field men to integrate soil texture and soil structure within the complex gradient of 'pore pattern', these simpler gradients have been used in most of the subsequent surveys. This shows up in Table 6, in which the soil texture (but not the pore pattern) gradient is used to differentiate the landtype, a common mapping unit.*

It will be noted that in Table 3, the soil moisture gradient provides the basis for the initial subdivision of a site region into soil moisture groups. These groups of site types are perhaps the most easily recognized distinctive difference in land ecosystems within a site region.

Mapping Hierarchies of Taxonomic Units - The hierarchies of taxonomic mapping units of terrestrial, lithoterrestrial and semiterrestrial areas are shown on Tables 4, 5 and 6 respectively. Although the names of the units for each of the (ortho) terrestrial, lithoterrestrial and semiterrestrial sites fall into the same broad categories (e.g. landtypes, soil site types, etc.), certain variations have been made to place different emphasis in the order and the complexing of the feature effectivity gradients.

The units so established are comparable in concept yet sufficiently diverse to accommocate significant differences in the relative weight of conditioning of the component features in each of these types. For example, the texture and petrography of the unconsolidated materials are the differentiae used to establish landtypes of the (ortho) terrestrial areas. On lithoterrestrial areas, the petrography, weatherability and slope pattern of the bedrock are given more weight than that of the shallow covering of unconsolidated materials. On semiterrestrial areas, soil moisture and aeration regime is given a preeminent position.

The Hierarchy of Synthetic Landscape Units - Synthetic landscape units were introduced as patterns of homogeneous taxonomic units. Owing to the difficulties of maintaining strict homogeneity in the designation and mapping of taxonomic units, synthetic units are being used extensively. This does not indicate that there are no problems in synthesis once a typology is established. It is not merely a matter of grouping or not grouping but one of how to group and for whose convenience.

On the one hand, the classifier must decide upon the objective of the synthesis and the grouping which best meets that objective. Also, he must determine the most convenient device or formula for indicating that pattern on maps. On the other hand, the interpreter of the maps must be able to recognize on the ground the member of each homogeneous unit in the formula. An alternative to the formula method of designating synthetic patterns which recur over broad areas, is to apply a term which describes the unit as a whole and accompany this term with benchmark descriptions.

Since the process of landscape unit synthesis varies according to the objective of the classification, there are several alternative methods of synthesizing taxonomic units. The objective of the synthesis described in this paper is to facilitate the description of natural ecosystems and their distribution. For this reason, the definitions of site associations and site systems presented here will be restricted to the use of those criteria which are either morphological homologues or gradients of landform features interpreted in terms of their effectiveness in natural biological production.

Since site association is the conceptual framework in which the biological production of the natural ecosystem is evaluated with respect to a wide range of production of all kinds, many benchmark definitions of site associations have been established (Hills *et al.* 1970, p.121-149). In a way similar to that by which the site association provides a physical format for planning, the site system provides the physical arena for regional landuse decisions (Hills *et al.* 1970, p.150-154).

A *site association* is a local grouping of physiographic site types or phases which are so

* Another important consideration is that a larger mapping scale is usually required to map pore pattern than that required for soil texture mapping.

Table 4: Mapping hierarchy of the taxonomic units of (ortho) terrestrial areas

	FEATURE EFFECTIVITY GRADIENTS					
	CONTINENTAL	R E G I O N A L				
	MACROCLIMATE	*SOIL TEXTURE*	*PETROGRAPHY*	*PORE PATTERN*	*SOIL MOISTURE*	*ECOCLIMATE*
SITE REGION	D[1]	u[1]	u	u	u	u
BROAD LANDTYPE	D	D	u	u	u	u
LANDTYPE	D	D	D	u	u	u
SITE CATENA	D	D	D	D	u	u
SOIL SITE TYPE	D	D	D	D	D	u
PHYSIOGRAPHIC SITE TYPE	D	D	D	D	D	D

1. *Differentiated (D)* and *undifferentiated (u)* have been used to identify the hierarchical level of the units. Differentiated means that the area has been differentiated by the effectivity class under which the term appears. For example, areas designated as landtypes are differentiated with respect to macroclimate, soil texture and petrography and are undifferentiated with respect to pore pattern, moisture regime and ecoclimate. This means that each area designated as a landtype has the designated macroclimate of the site region and designated soil material classes. But the area mapped may have the full range of the soil moisture regime and ecoclimate gradients, or any part of these ranges, for these are 'undesignated'. Therefore, the break between differentiated and undifferentiated indicates the level of differentiation.

Table 5: Mapping hierarchy of taxonomic units of lithoterrestrial areas

	MACRO-CLIMATE	UNCONSOLIDATED MATERIALS				IMPERMEABLE STRATUM				
		PETRO-GRAPHY	*SOIL TEXTURE*	*PORE PATTERN*	*DEPTH*	*PETRO-GRAPHY*	*WEATHER-ABILITY*	*SLOPE*	*SOIL MOISTURE*	*ECOCLIMATE*
LANDSCAPE OR SITE REGION	D[1]	u[1]	u	u	u	u	u	u	u	u
LITHOTERRESTRIAL BROAD LANDTYPE	D	D	u	u	u	D	D	D	u	u
LITHOTERRESTRIAL LANDTYPE	D	D	D	u	u	D	D	D	u	u
LITHOTERRESTRIAL SITE CATENA	D	D	D	D	D	D	D	D	u	u
SOIL SITE TYPE	D	D	D	D	D	D	D	D	D	u
PHYSIOGRAPHIC SITE TYPE	D	D	D	D	D	D	D	D	D	D

1. *D - differentiated; u - undifferentiated.* See the discussion following Table 4 for a guide to an interpretation of the levels of differentiation shown on this Table.

Table 6: Mapping hierarchy of taxonomic units of semiterrestrial areas

	MACRO-CLIMATE	*SOIL MOISTURE-AERATION REGIME*	*SOIL MATERIAL FABRIC*	*SOIL NUTRIENT REGIME*	*ECOCLIMATE*
SITE REGION	D[1]	u[1]	u	u	u
WETLAND GROUP	D	D	u	u	u
SEMITERRESTRIAL LANDTYPE	D	D	D	u	u
SEMITERRESTRIAL SITE TYPE GROUP	D	D	D	D	u
SEMITERRESTRIAL SITE TYPES	D	D	D	D	D

1. *D - differentiated; u - undifferentiated.* See the discussion following Table 4 for a guide to an interpretation of the levels of differentiation shown on this Table.

intimately associated that, for certain aspects of ecological description and of biological production evaluation, it is most convenient to consider the pattern as a whole rather than as a mosaic. Difficulties arise from the fact that there is seldom a consistent ratio of the distribution of the various site types in any given pattern from place to place. The homogeneity of the designated parts of the association pattern is at the level of physiographic site phase or physiographic site type. However, each of these component parts may be members of site types from different site catenas or from different landtypes.

An individual site association may have representatives from one or more of the great groups of landscapes; terrestrial, semiterrestrial, etc.

A *site system* is a relatively broad area of land and/or water, usually more than 1 mi^2 in area, which has a recognizable pattern of ecosystems reflecting a common pattern of geological fabric with respect to origin of the geological materials and in the type of their deposition and/or their erosion. Thus a site system is a pattern of landtypes with specific range in the texture, petrography and geological fabric of the soil materials. A site system also has a characteristic pattern of slope patterns and of surface and drainage.

Site systems have been previously presented as landform patterns (Hills *et al.* 1970) and as landscape units (Hills and Wilson 1970).

A site system may consist of site types from a specific group of landscapes, - terrestrial, lithoterrestrial, etc.. Generally, however, they are comprised of representatives from two or more groups, for example:

1. Esker trains of sand and gravel with kettle lakes.
2. Glacier-scoured granitic knobs with clay pockets and sluggish streams with marshy banks.

A FINAL COMMENT

Unfortunately, this paper has been devoted almost entirely to a discussion of those features of the non-living physiosystems which provide a basis for establishing homogeneity at various levels of investigation. It is hoped that the reader will see in Figure 6 and Table 2, and in discussions which accompany them, some indication of the hierarchy of vegetation site types which have been conceptualized in formulating the non-living physiographic matrices.

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A REVIEW OF COASTAL CLASSIFICATION

N. Lopoukhine
and
H. Hirvonen
Lands Directorate, Atlantic Region
Department of Environment
Halifax, Nova Scotia

ABSTRACT

Canada's coastline is being subjected to ever increasing developmental pressures from various, and often divergent, resource users. To aid in the sound management and planning of the coastal zone, a biophysical inventory of resources is required. The proven biophysical land classification methodology is applicable to the coastal scenario but with modifications to incorporate the influence of the sea and the processes therein.

Some problems identified in the implementation of one coastal classification approach, as part of a pilot study of the resources of a segment of the Newfoundland coast, are discussed. Two such problems that emerged, which deserve immediate attention, are the adequate integration of water and land and the categorization of the nearshore water itself. A manual for planners and coastal managers seems an appropriate means of demonstrating the utility of coastal classification.

RÉSUMÉ

Les côtes canadiennes font l'objet des pressions sans cesse croissantes de nombreux utilisateurs des ressources, souvent fort variés. Un inventaire biophysique des ressources est donc nécessaire pour permettre la gestion et la planification raisonnées de la zone côtière. La méthodologie de classification biophysique du territoire, déjà mise à l'épreuve, vaut pour les régions côtières, moyennant certaines modifications propres à incorporer l'influence de la mer et le processus qui s'y rattache.

Le présent document analyse certains problèmes de la mise en application d'une approche de classification des zones côtières, observés à l'occasion d'une étude pilot des ressources d'un segment de la côte de Terre-Neuve. Des problèmes ainsi mis en lumière, deux commandent une attention immédiate: l'intégration suffisante de l'eau et des terres et la catégorisation des eaux côtières elles-mêmes. Un manuel à l'intention des planificateurs et des gestionnaires du littoral semble être un moyen approprié pour démontrer l'utilité de la classification des régions côtières.

INTRODUCTION

Land classification concepts and procedures in Canada have gained acceptance among land managers since the advent of the Canada Land Inventory program in the mid 1960's. Yet, efforts at extending the biophysical concepts to the coastal zone have been minimal. British Columbia and the Atlantic provinces are just beginning to study the coastal zone and its resource use problems in some orderly fashion. Our activities to-date have been largely a learning experience. By way of this meeting, an opportunity now exists to report on the roadblocks that we have encountered and the resulting detours that have been followed.

To provide a basis for further discussion on coastal classification concepts, methodology and procedures, a 'W5' format is presented beginning with the question *Why*. In Atlantic Canada, for instance, there are some 20,000 miles of coastline portraying the complete spectrum of human activity from the man-modified harbours of metropolitan areas to the pristine subarctic coast of Labrador. Relentlessly, man is pushing forth into the last vestiges of the coastal frontier. As a consequence, estuaries, marshes, and other sensitive and critical areas are being irreversibly altered, more often than not, to the detriment of society. To cite an example, hanging on the boardroom wall of the Atlantic office of the Environmental Protection Service is a map of shellfish closure areas in the Maritime Provinces disclosing, only too vividly, the few remaining uncontaminated estuaries. This map, incidentally, is one of the few coastal maps of the Maritimes which depicts additional information besides the geographical features of the coast. Although considerable

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site-specific data are available on Canada's coastal zone, very little is in readily accessible formats. This realization has led to a proposed five year federal/provincial Coastal Resources Inventory and Mapping Program (CRIMP). The primary objective of this program will be to provide a biophysical and socioeconomic information base "under one cover" for planning, management, education and promotion purposes. A biophysical classification of the coast will be an integral part of this program since it provides an excellent integration and interpretation mechanism for the other data. With such an integration of resource information, environmental impacts can be assessed, comparisons of the implication of alternative uses of coastal resources may be achieved and ecologically critical areas may be identified. In the event of major disasters such as oil spills, contingency plans may more easily be formulated and areas of potential interest for varying public use may be identified.

The next W is *What*. The title of coastal zone classification requires elaboration on the definition of the coastal zone. The boundary on both the water and land side is arbitrary. The water limit is really undefinable but the nine m depth may serve as a functional boundary for inventory purposes. At this approximate depth, the surf begins to affect the bottom, thus providing a recognizable field feature which may be utilized to arbitrarily define the near shoreline from open water. Inland, the boundary is also a problem. The point where the water stops having an influence inland is a nebulous demarcation. Should it be based on biological criteria? For instance, is it where white spruce, which can tolerate the salt spray, gives way to the less tolerant black spruce? Is it a climate factor such as the mean extent of fog penetration inland? What about the headwaters of rivers which originate many miles inland and have such an important role in the water quality of estuaries? The definition of the coastal zone has been bantered about and a universal acceptable definition has not been attained. So, as a starting point, the coastal zone may be defined as that linear geographical area that is contained by the nine m bathymetric contour (five fathoms - limit of physical processes) and the extent of the inland mass which lends the identifying character to the shoreline and back shore. The land boundary is purposely unspecific, thus permitting biological, physical, climatological or hydrological factors to be used interchangeably or in combination as the basis for delineating the inland coastal zone boundary.

The third W is *Where*. Our present interest is obviously Atlantic Canada, but the west coast is as important to B.C. as the east coast is to the Atlantic Provinces, and both have irrefutable significance in a national context. And what of the Arctic where the term "sensitivity of terrain" was given meaning? If blowouts or spills from the anticipated offshore drilling were to occur, what base exists to adequately assess environmental consequences to the shoreline? One has only to recall the oil spill resulting from the sinking of the 'small' tanker *Arrow* in Chedabucto Bay. The biological and physical effects will continue for many more years. Only after the fact did the Bay receive considerable attention *re* biophysical resources and processes. Had a sound data base been available, at the very least, some cursory environmental decisions could have been made. Perhaps ecologically sensitive areas could have been protected at the expense of areas less susceptible to extended environmental damage.

Thus, in response to where, the known susceptible areas should get immediate detailed biophysical attention while at the same time an overall evaluation should be launched at a reconnaissance level to determine other potentially susceptible areas.

The fourth W is *Who*. Reference was made above to a proposed five year federal/provincial coastal mapping program. Although the start-up time has been somewhat delayed, the program has a good chance of materializing. It will probably be under this program that a biophysical coastal classification will be applied in Atlantic Canada. Meanwhile, pilot studies have been carried out in Newfoundland to which further mention will be made. In any case, initial involvement in coastal classification is envisioned to involve federal/provincial personnel engaged in various pilot studies to develop a basic framework. Once methodology and procedures are well established, consultants may take over at the operations level. Prior to any further work, this committee, a subcommittee, or some other organized body should be assigned to develop guidelines and then oversee the proposed work.

The final W is *When* and that is as soon as possible because development in coastal areas has a considerable head start.

HISTORICAL BACKGROUND

The study and analysis of coastal processes and morphology has occupied the minds of researchers since the mid-1800's. Pioneering efforts at classification were heavily subjective and often verbose. The lack of a sound data base prevented assessements to proceed beyond the conceptual stage. Yet, from the notes and descrip-

tions of these early researchers, a genetic classification crystallized that set the trend of future analysis. In 1898 Davis presented his dichotomous classification. He advocated delineating coastlines as either *first class* (or *emergent*) for uplifted zones which he described as smooth and simple with shallow water overlying weak strata, or *second class* (or *submergent*) for depressed zones characterized as irregular and complicated with deep water abutting rocky shores (Cotton, 1954). This emergence/submergence dichotomy provided the catalyst for subsequent controversy which researchers often thrive upon.

Modification and more precise definitions of the emergence/submergence concept were put forth. Johnson (1919) expanded on the two divisions with the addition of two more primary categories: *neutral* and *compound*. These two categories encompassed such features as delta shorelines, volcano shorelines, coral-reef shorelines and complex coastlines composed of elements of the original two classes.

Cotton (1952) introduced a dynamic element into the classification system by placing various emergent and submergent processes into two groupings based on structural mobility. He considered the delineation between *stable* versus *mobile* regions as essential in coastal classification. At the same time, Valentin (1952) also recognizing the non-static nature of the coastline, proposed a delineation that considered coasts as *advancing* (gaining of land) or *retreating* (loss of land). Subdivisions were based on contemporary coastal processes. Bloom, in 1965, took Valentin's work one step further and imposed a time axis to the existing ones of erosion/deposition and emergence/submergence and came up with a three-dimensional basis for describing coasts (Silk, 1975).

To be sure, not all researchers followed the early concepts of Davis. Shepard (1937) was a notable exception who 'bucked the trend'. His synthesis, which is fully outlined in his book entitled *Submarine Geology*, was to consider coasts as either *primary* (resulting from non-marine agencies) or *secondary* (resulting from marine agencies) with a further subdivision according to process. More recently, Davies (1964) veered from the inordinate emphasis placed on geological typing of coastlines and advocated an integrated approach which, simplified, is based on consideration of climate, tidal regimes, geological structures and sediment transport systems.

A novel approach, though hard to grasp at first reading because of its unique concept, is that introduced by Odum and Copeland (1974) advocating energy as a basis of delineation. Coastal systems are grouped into five kinds of energy ecosystems (e.g. arctic ecosystems with ice stress and new artificial systems linked to man-induced energy sources) and various subsystems based on characteristic energy sources and stress.

Many more systems and concepts have been espoused and we feel somewhat remiss at offering you this cursory outline. However, we shall remain firm and resist the temptation to set forth a comprehensive coastal zone encyclopedia. A more detailed outline is provided in the Appendix. The intent thus far has been to provide a historical and conceptual framework for coastal classification studies with as few pertinent examples as possible. Also, purposely, we have omitted discussing the relative merits and shortcomings of each approach. Of course, the ideal system to develop would be one that encompasses all the physical and biological parameters and dynamic processes of the marine and terrestrial sectors of the shoreline for any given level of detail in comprehensible and practical form - simply a bio-geo-physio-marine-clima-graphic system. At the same time, one must recognize the folly in striving to develop such a system. The problem really centres around what parameters to exclude without rendering the classification system inutile.

Thus, given the realities of the task at hand, let us turn our attention to several classification systems presently utilized or proposed for the U.S. and Canadian coastlines. With the advent of the Coastal Zone Management Act of 1972 in the United States, most coastal states have accepted the challenge of coastal zone management and some have instigated continuing inventory programs.

Two related hierarchical approaches are favoured. One, termed a tier system, divides the coastal zone into three zones: (1) offshore, (2) estuary, and (3) shore and coastal upland. Each tier is individually studied and delineated in some manner and integrated with the other two tiers for a total overview of the coastal section under scrutiny. Nomenclature may change from state to state or study to study but the underlying theme is standard. The second approach, sometimes employed in conjunction with the tier concept, is a biogeographic regional system that has been developed and used particularly along the western seaboard. Biogeographical regions are subdivided in Subregions with further divisions into Reaches based on differentiation of climate, landform, vegetation and land-water configuration. The names are different but a distinct biophysical flavour exists - a sort of coastal cousin to Lacate's biophysical land classificaton (Lacate, 1969).

For use on a broader basis, the current work of Dolan and his colleagues (1972) in his studies into coastal climates, wave climates and coastal marine fauna cannot be overlooked.

As noted earlier, Canadian efforts in coastal classification (if one excludes various environmental impact assessments and small scale specific purpose classifications) has been minimal with one notable exception: Owens' (1974) integrated, though geologically oriented, 10-order hierarchical system. His system ranges from continental features with time frames of 10^9 years to micromorphological features with time frames of less than one hour. Though complex in description and no doubt in implementation, this system will prove to be a valuable aid in the understanding of the problems associated with coastal classification.

ACTIVITIES

The Lands Directorate Atlantic Office's interest in coastal classification began with the letting of contracts which produced the two reports by Silk (1975a, 1975b). Concurrent with these contracts, meetings were held with an informal committee composed primarily of a few Halifax-based federal personnel. This committee was intended as a precursor to a larger formal committee which was to be struck with the signing of CRIMP agreements.

The committee members were of two categories, those who foresaw a need for a classification system or those who could contribute to the scientific data base required for a comprehensive classification. The objective of the committee was to develop a classification system based on a biophysical approach which would provide a common basis for comparing and evaluating intrinsic natural features of coastal areas as they may relate to recreation, conservation, preservation and developmental objectives.

The committee was hampered by its *ad hoc* nature. Nevertheless, a few members managed to contribute basic requirements; of particular note was the contribution by the National Parks representative[1] (six out of seven Atlantic Region Parks are situated on the coast) and the Fisheries Resources representative[2]. The latter's list of parameters deemed important for the purposes of aquaculture, fisheries production and protection also incorporated most of the other committee members' projected requirements for a biophysical coastal classification.

With the third meeting of the *ad hoc* committee, it became obvious that a classification exercise was required since the theoretical requirements expressed by committee members needed testing. The Newfoundland government at this time expressed an interest in the CRIMP Proposal and wished to cooperate with the Land Directorate on a pilot study of two areas in Newfoundland: St. George's Bay and Conception Bay. Maps depicting and interpreting the resources of these areas have been prepared. At the time of writing, copies were not available for circulation pending completion of the accompanying reports.

One of the four maps of each area contains a coastal classification. A hierarchical approach was utilized and the categories have a strong resemblance to Lacate's (1969) wildlife guidelines. The categories utilized for coastal classification of pilot areas in Newfoundland were as follows:

Coastal Region: (Scale of mapping - 1:1,000,000 or smaller). A coastal zone area characterized by a distinctive regional climate as expressed by vegetation and gross marine characteristics such as the seasonal occurrence of ice, macrotidal influences and coastal orientation features.

Coastal District: (Scale of mapping - 1:250,000 - 1:1,000,000). A coastal zone area characterized by a distinctive pattern of geology, geomorphology, vegetation, coastal configuration, bathymetry and water quality. These serve to identify the homogeneous units which make up the coastal region.

Coastal System: (Scale of mapping - 1:50,000 - 1:250,000 depending on complexity). A coastal zone area characterized by a recurring pattern of landforms, shoreforms and marine parameters. This level, in particular, takes into account the processes which have led to the development of and maintenance of these patterns.

Coastal Type: (Scale of mapping - 1:10,000 - 1:20,000). At this detailed level of mapping, each tier of the coastal zone would be considered independently for field data purposes. The land component would conform to the land type definition of Lacate (1969). The intertidal component or shoretype would be form-centred with vegetation, stability and soil modifiers. The water component or water type would be differentiated on the basis of quality and process modifiers.

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[1] P. Skydt, February 1975, personal communications.

[2] T. Rowell, February 1975, personal communications.

The classification depicted on the Newfoundland pilot study maps is based primarily on interpretation of aerial photography and a minimum of field work. The coastal type level was not mapped because of monetary and time constraints. This cursory look at the pilot areas' resources leaves room for improvement but the exercise was valuable in that a number of problems were identified. These will be enumerated later and hopefully provide a basis for discussion.

This summer, Lands Atlantic, as part of its contribution to the Environment Canada Atlantic Region Bay of Fundy Working Group, is conducting a resource inventory of certain coastal areas that may be altered if Fundy tidal development becomes a reality. An integral aspect of this program will be a biophysical inventory at a land system and land type level. In addition to providing valuable data with respect to the Working Group mandate, the procedure will be invaluable for assessing the potential of a biophysical approach to coastal zone mapping.

In the longer term, modifications and additions to the classification process will be investigated on a continual basis with a view to developing a practical and operational coastal classification system for the proposed Coastal Resources Inventory and Mapping Program.

SUMMARY

The necessity to utilize the dynamic interaction of the biosphere, lithosphere and atmosphere as a basis for sound ecological land use planning is well known. Canada, through the development and implementation of biophysical land classification concepts for various environmental surveys across the country, has emerged as one of the world's leaders in this regard. In contrast, coastal zone classification within Canada is in its infancy. In principle, the philosophy of biophysical land classifications can be extended to the coastline. However, the impediment to blanket applications is the necessity to integrate dynamic marine parameters and their various influences with the relatively stable biophysical land patterns.

Historically, coastal zone mapping methodology was developed to achieve specific objectives. The *holistic* approach, inherent in the land-based biophysical framework, was not recognized as a prime objective. Nevertheless, much can be gained from previous attempts at coastal classification in terms of gleaning methodology and developing appropriate frames of reference for future work.

The methodology utilized in the pilot study was adapted from Lacate's hierarchical biophysical classification. This methodology, which relies heavily on interpretation of aerial photography, proved workable at the three smaller scale levels. A problem is encountered at the coastal type level. Aerial photography, by its temporal nature, has limited application to interpretation of the dynamic hydrosphere and many of the ephemeral features of the coast. The problem really is not photography *per se* as repeated coverage could overcome the time problems, but more so the absence of relatively inexpensive biophysical methodology on the water side at the type level. In trying to circumvent this problem, an attempt was made to utilize existing information as a supplement to aerial photography. The dearth of available marine data quickly extinguished this hope. Even bathymetric data are incomplete, let alone the more exotic parameters such as dissolved oxygen levels or indices of biological productivity. The first roadblock then is that 'conventional' methodology of biophysical classification is relevant to the coastal scenario only down to the system level.

A second problem again occurs at the coastal type level. One of the objectives of the coastal classification system is to depict the water and land component in an integrated manner, and this objective has only been achieved down to the system level. At the coastal type level, this integration may be impractical as the classification tends to fall into separate water or land classifications. Perhaps the problem lies with the objective of integration. Is it a valid one? For inventory purposes, can it be applied at three levels and disregarded at the fourth?

A third problem can be summarized by the question - what constitutes a water type? Inland, the trend with respect to water classification has been to deal with the container rather than the contents. Shorelines in terms of degree of convolution, textural predominance and slope are all described, but water *per se* is not. The incompatibility of water and aerial photography is the root of the problem. Yet, in many cases, aerial photography is useful in determining nearshore bottom properties and marine physical processes which permit a first approximation of cataloguing water. Is that all that can be expected? Is it enough? If not, what are the options?

One alternative may be to consider the production of a classification manual which would be based on the premise of providing coastal zone managers with the level of detail they require for various decisions. In addition to technical and methodological details, such a manual could include benchmark examples and a few worked

solutions to indicate how to deal with the classification as a management tool.

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APPENDIX — HIGHLIGHTS IN THE HISTORY AND DEVELOPMENT OF COASTAL ZONE CLASSIFICATION

RESEARCHERS	DATE OF SIGNIFICANT PUBLICATIONS(S)	MAJOR CONTRIBUTION TO COASTAL ZONE MANAGEMENT
Richtofen	1866	- First ordering of shorelines
Suess	1888	- noted the different geological trends of the Atlantic and Pacific coasts
Davis	1898	- emergence/submergence theory on coastal classification
Johnson	1919	- formulated a system to classify coastal landforms
		- added neutral and compound categories to emergent/submergent concept
Putnam	1937	- advanced the concept of cyclic marine erosion to the Pacific coast
	1960	- produced an illustrated description of world coastal zones in conjunction with contemporaries
Shepard	1937	- advanced the concept of primary and secondary coasts
	1948	- 1st edition of his book titled Submarine Geology
Stephensen and Stephensen	1948	- published a now standard reference on intertidal zonation as applied to Australian coastlines
Cotton	1952	- presented concept of stable and mobile coast regions
Prince	1954	- proposed the sub-division of coasts on the basis of mechanical energy calculated from ramp angles on the coastal shelf and on mean breaker heights
Fleming and Elliott	1956	- proposed a delineation of coasts based on factors such as size of drainage basins, supply of fresh water and sediments to the ocean and degree of coastal indentation
Powers	1958	- developed a geomorphological systems for fresh water shorelines
Tanner	1960	- introduced an equilibrium concept based on a balance between coastal energy and littoral drift for the Florida coast
Ballantine	1961	- developed an exposure scale based on biological factors
Alexander	1962	- proposed a system based on vertical shore profile and the shore outline in plan
Ottman	1962	- proposed a five-category geological typing of coastlines based on form
	1965	- published a book on marine geology

* Emphasis is placed on North American research from the 1960's to present.

RESEARCHERS	DATE OF SIGNIFICANT PUBLICATION(S)	MAJOR CONTRIBUTION TO COASTAL ZONE MANAGEMENT
Davies	1964	- outlined the application of oceanographic processes to coastal classification
	1972	- published a book on coastal classification
Bloom	1965	- proposed a three-dimensional framework encompassing time, the emergence/submergence theory and local processes to describe shorelines
Zenkovich	1967	- introduced a classification of coastal accumulation forms
Mann *et al.*	1970	- coordinated a group that produced a report describing techniques for evaluating and classifying coastal landscape
	1974	- produced a report outlining present classification procedures used in the United States
Brown *et al.*	1971	- introduced "resource capability units" for the Texas coastal zone encompassing physical, biological and process units as well as man-made units
Inman and Nordstrom	1971	- developed a hierarchical tectonic system of coastal classification
Dolan and Hayden, *et al.*	1972 1975	- introduced a classification of world coastal environments incorporating various marine, biological and geological parameters
Fisher *et al.*	1972	- published environmental information on the Texas coast in Atlas form
King	1972	- a contemporary text on coastal geomorphology with a review of major coastal classification systems
Dubois	1973	- produced a system of mapping physiographic and sedimentological units for parts of the St. Lawrence River coastlands
Odum and Copeland	1974	- presented a novel classification based on energy source and stress of natural and man-modified ecosystems
Owens	1974	- proposed a 10-order hierarchical, geologically oriented, classification ranging from continental to micro-morphological features
Welsted	1974	- divided the coastline of the Bay of Fundy basically on the presence or absence of cliffs

THE INTEGRATION OF WATER INTO ECOLOGICAL LAND CLASSIFICATIONS

D.M. Welch
Lands Directorate
Department of Environment
Ottawa, Ontario

ABSTRACT

Philosophies of ecological land classifications tend to stress spatial uniformity of stable attributes of finite land surfaces, and recurring patterns of those surfaces. However, water bodies commonly display dynamic properties which transcend ecological dry-land divisions. Current approaches to inland water resource classification are summarized in the light of ecological classification theory. Most water classifications emphasize morphologic criteria along with one or two others, such as shoreline geomorphology and water quality. Few classifications consider aquatic biology, scenic and cultural data, or the problem of grouping water bodies into spatial hierarchies. Ecological water classification should be based on defined purposes, the kind and detail of parameters required and measurable, and the intended method of data handling and reduction to manageable forms. In particular, one should examine the relationship between the relatively stable reference data used in dry-land ecological classifications, and the steady and unsteady dynamic properties of water.

RÉSUMÉ

Les principes des classifications écologiques de territoire tendent à insister sur l'uniformité spatiale d'attributs stables d'étendues de terres bien précises, et sur leurs caractéristiques dominantes. Toutefois, les plans d'eau présentent habituellement des propriétés dynamiques qui dépassent le cadre des divisions écologiques applicables aux terres sèches. Voici un résumé des approches actuelles de la classification des ressources en eau intérieure, dressé à la lumière de la théorie de classification écologique. La plupart des classifications mettent l'accent sur les critères morphologiques ainsi qu'un ou deux autres, tels que la géomorphologie du rivage et la qualité de l'eau. Par contre, très peu de classifications tiennent compte de la biologie aquatique, des données scéniques et culturales, ou du problème que pose le regroupement des plans d'eau en fonction d'une hiérarchie spatiale. La classification écologique de l'eau devrait viser des objectifs précis, c'est-à-dire le type et la portée des paramètres nécessaires et mesurables et la méthode voulue de manutention et de traitement des données aux fins de la gestion. Il conviendrait notamment d'analyser le rapport qui existe entre les données de référence, relativement stables, qui servent dans les classifications écologiques des terres sèches, et les propriétés dynamiques stables et instables de l'eau.

WATER IN THE LANDSCAPE

"Water is...a highly variable and mobile resource in the widest sense. Not only is it a commodity which is directly used by man, but it is often the mainspring for extensive economic development, commonly an essential element in man's aesthetic experience, and always a formative factor of the physical and biological environment" (Chorley, 1969, p. 3).

These formative roles include water regimes in solid formation, evapotranspiration and photosynthesis, and rainsplash erosion of cultivated land. At a visible scale, the variety of lakes, rivers and shoreline types which cover the Canadian landscape attests to the pervasive importance of water as a resource. These resources not only supply water for consumptive use, but they are also used in industrial processing, fish production, as objects for recreation and aesthetic perception of the environment, and frequently as attractions for land-based activities. Alongside the recent and current efforts in ecological land inventory, there is therefore a need to collect water information.

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Water bodies display a remarkable variety of types and features in space, and highly changeable flow, circulation and quality in time. This spectrum of properties must somehow be reflected in any ecological water classification. The following examples reveal some of the variety, the dynamics and the complexities of spatial groupings of water bodies. Figure 1 shows the variety of water as a landscape element. This LANDSAT image of central Manitoba displays lakes of various sizes, shapes and degrees of integration into drainage systems, oligotrophic lakes on the Canadian Shield, mesotrophic Lake Winnipeg, reflectance patterns revealing discrete bodies of water within single lakes, artificial, meandering and bedrock-controlled rivers, spits, islands and lagoons.

By contrast, the next two photos stress the need to understand the short and long term dynamics of water bodies. Figure 2 shows that the Red River north of Winnipeg can simultaneously deposit and erode flood-plain materials.

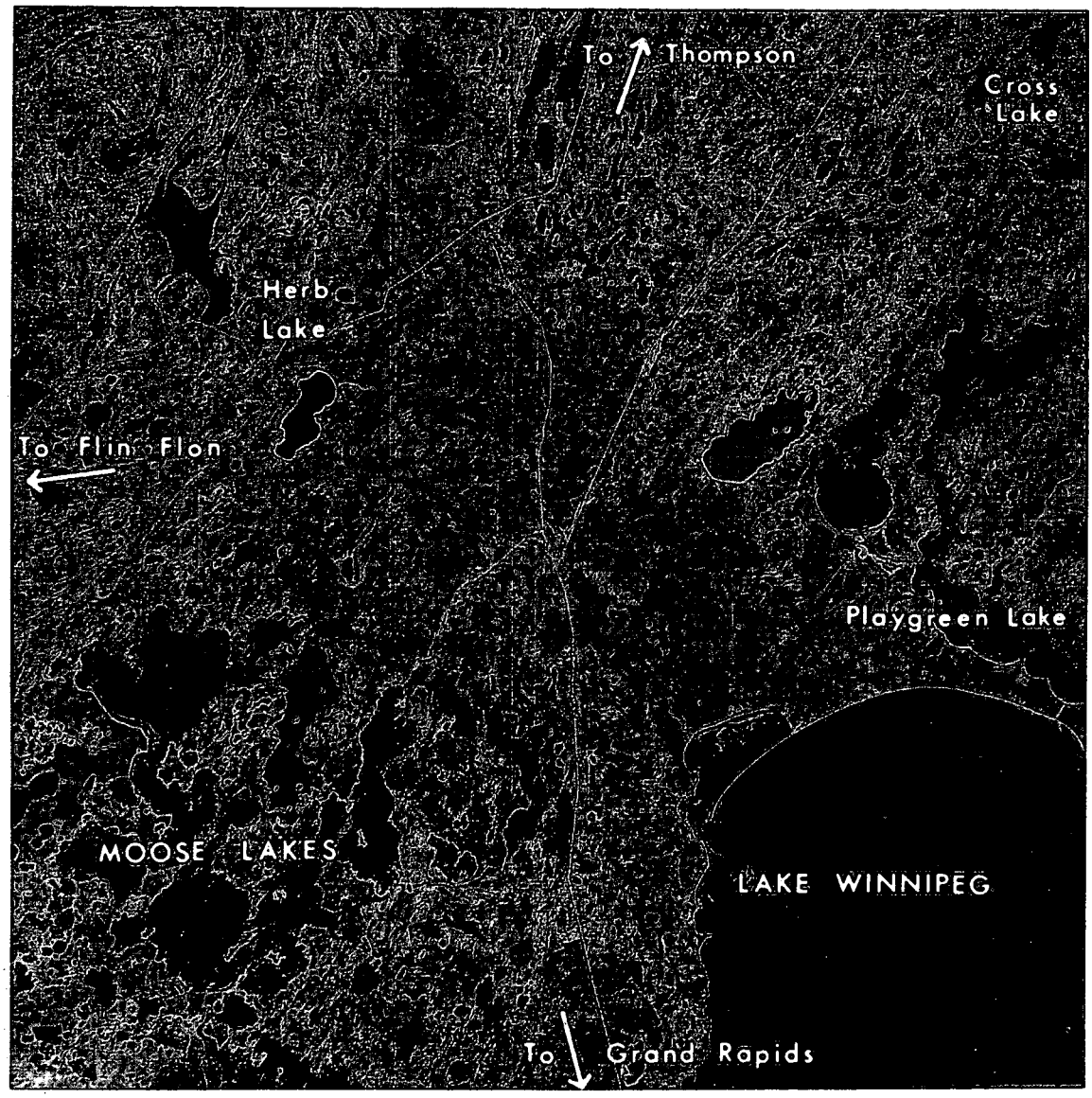


Figure 1: Central Manitoba, including the north end of Lake Winnipeg. ERTS/LANDSAT image, frame centre 3622, 20 September, 1973. Composite of bands 4, 5 and 7.

Figure 2: A bank of the Red River, St. Andrews, Manitoba, April 1972. Note the sequence of silt and organic layers indicating depositional sequence on a levée and flood-plain. Deposits above the thick organic layer are mainly twentieth century; the lowest organic layer is approximately 4,000 B.P. Note that erosion is concurrent with modern deposition.

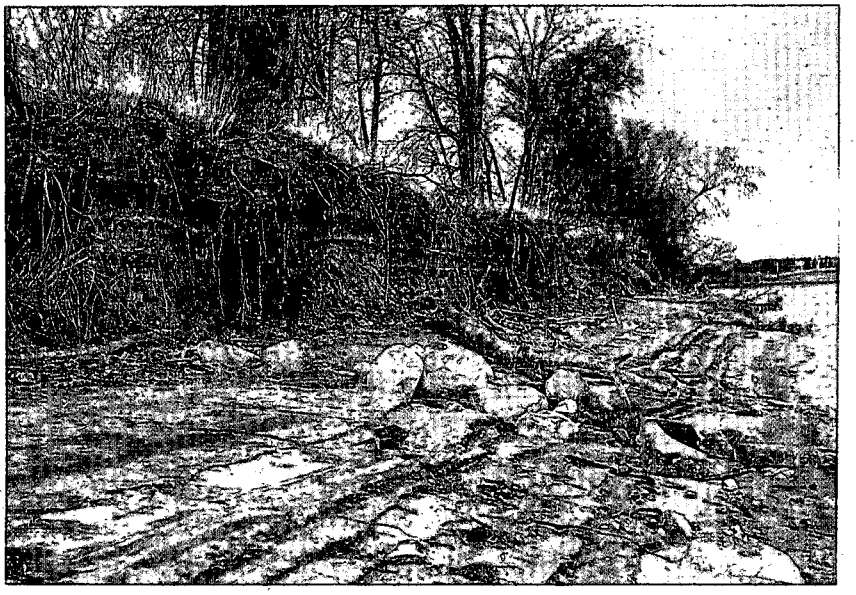
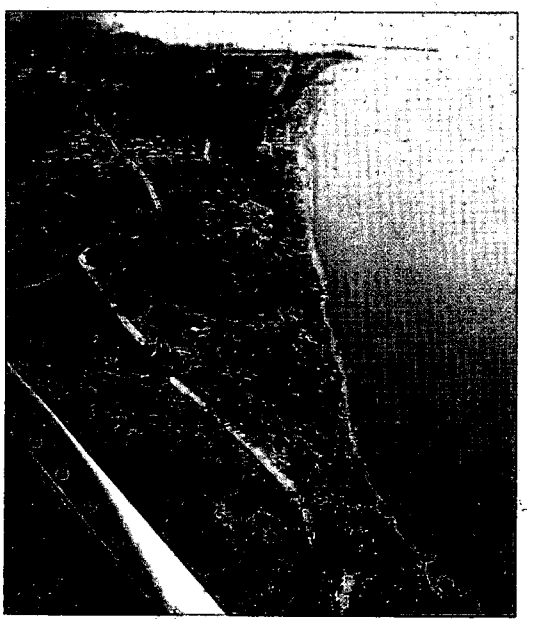


Figure 3 shows a natural beach caused by construction of breakwaters at Port Stanley, Ontario. At the same time, the trapping of this longshore drift sediment has removed its protective effect further along the coast, resulting in accelerated bluff erosion.

Figure 3: The Beach at Port Stanley, Ontario, July 1969. Note the breakwater and beach accumulated by longshore drift away from the camera. Increased erosion of background bluffs results from loss of beach sediment supply.



While individual water bodies are themselves significant, river or lake patterns frequently reveal the geology and geomorphology of a landscape. The lakes shown in Figure 4 indicate hummocky moraine on the Horn Mountains and drumlinized terrain to the north. While boundaries of morphologic patterns are easy to identify on this image, the number of highly reflecting lakes increases gradually from south to north across this drumlinized area. Thus, it may be that land boundaries defined by lake morphology may not agree in place or sharpness with those defined by, say lake turbidity.

Figure 4 also displays a parallel drainage pattern between the hummocky and drumlinoid areas, and an area of irregular drainage in the northeast. These patterns remind us of the close relation between water and surface materials and topography, yet demonstrate the dangers of considering ecological land-water integration simply as a problem of lakes: it is the lakes and rivers together which characterize the waterscapes of the Horn River region.

Apart from their individual and group proper-

ties, water bodies display readily apparent cyclic and long-term responses to environmental influences such as seasonality and human disturbance. Figure 5 shows Southern Indian Lake during the spring of 1974. Major flow areas are the first to melt. From 1974 to 1975, the lake level was raised so that sensitive materials were subjected to shore erosion for the first time, increasing lake turbidity.

These examples demonstrate some of the reasons for including water data in ecological surveys, namely that by his very nature, man's activities and problems are land-related in some way, even when the prime focus is upon water. Whether these data are cartographic, numerical or textual should be a question for future discussion, the answers to which will probably reside in the complex roles of water in the environment and the ability of existing ecological philosophy to incorporate such information. As a step towards these answers, the following section summarizes some of the relevant literature.

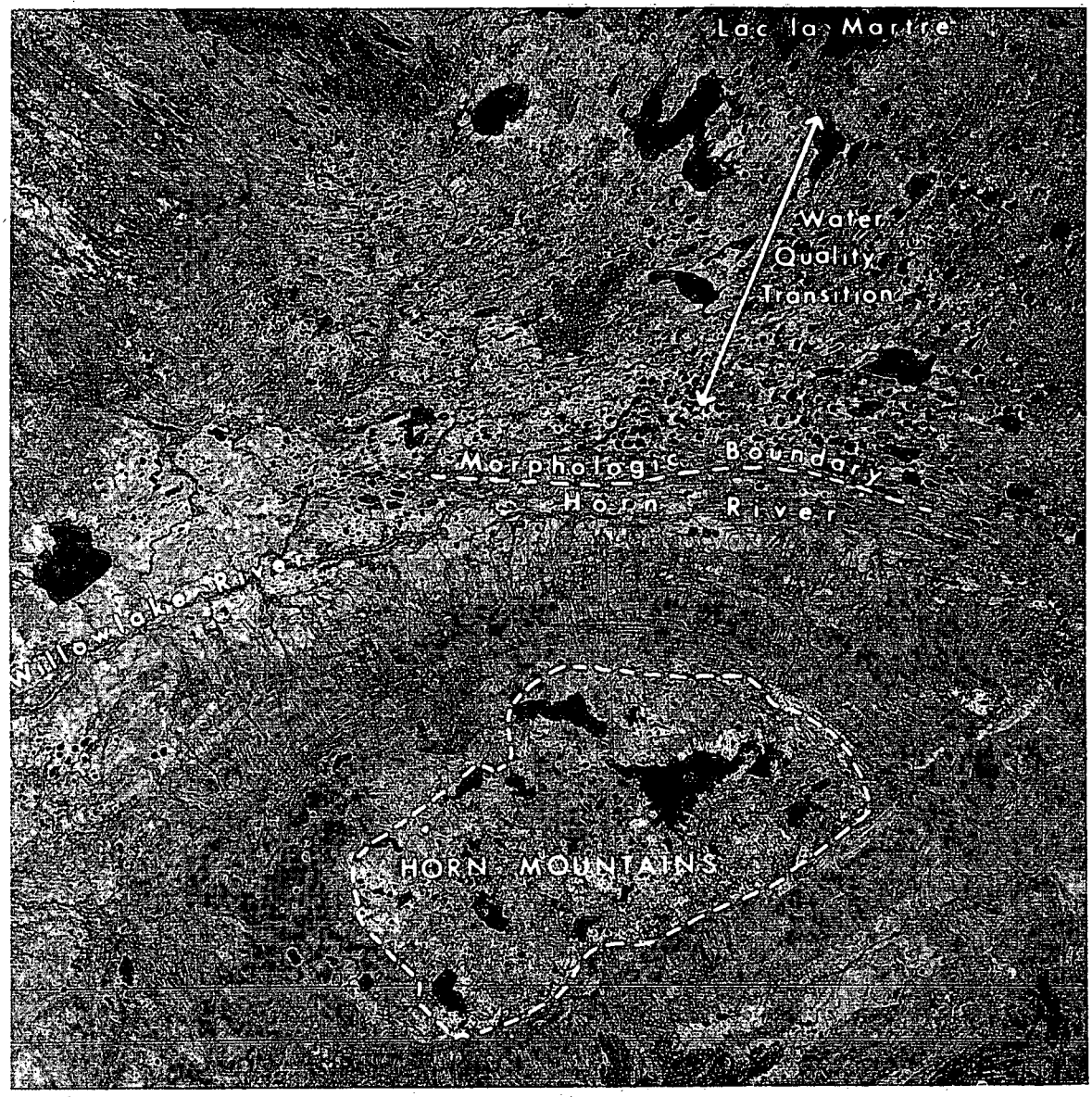
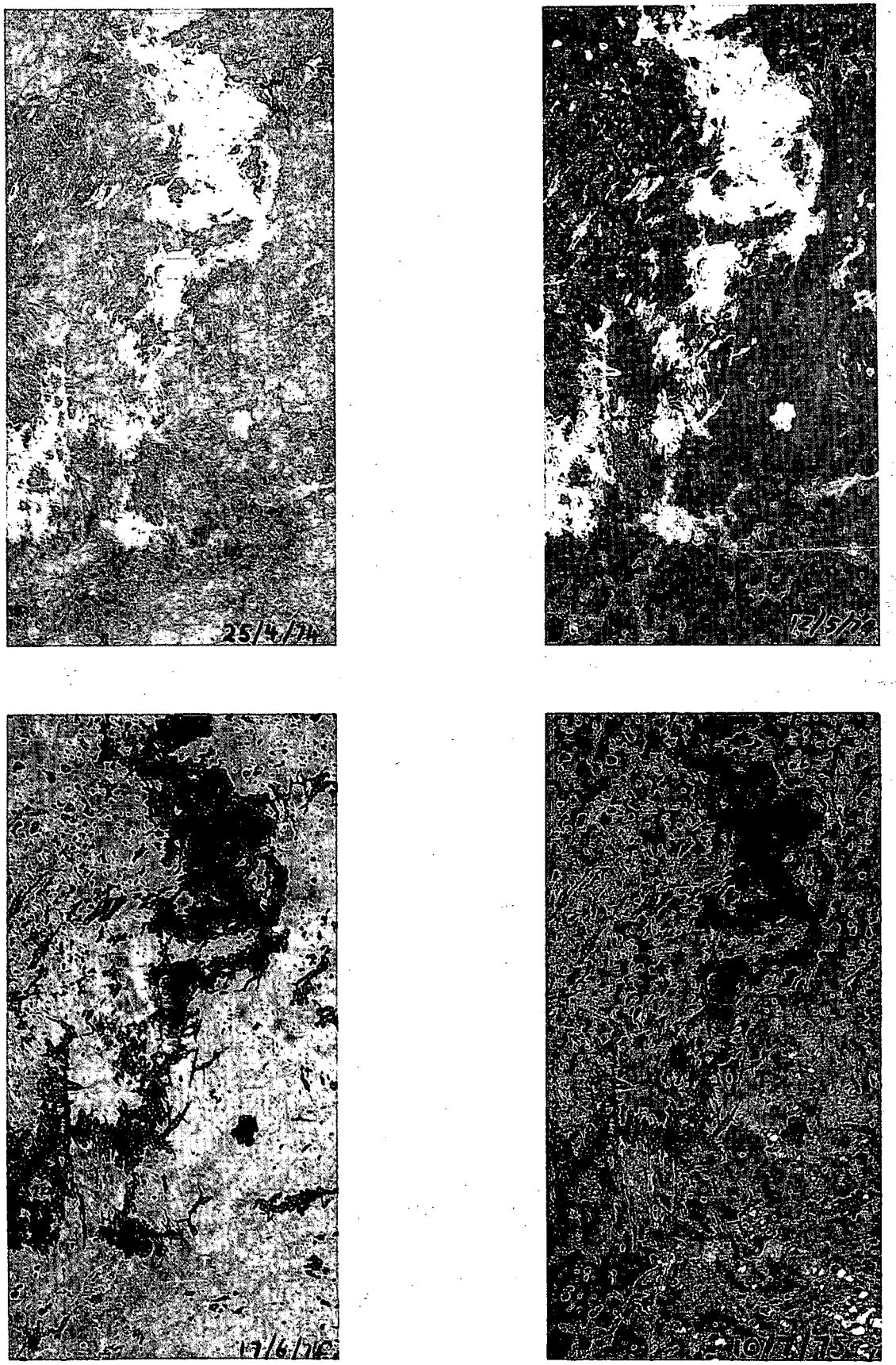


Figure 4: The Horn Mountains and Lac La Martre, District of Mackenzie. ERTS/LANDSAT image, frame centre 5316, 24 September, 1973. Composite of bands 5, 6 and 7.

Figure 5: Southern Indian Lake, Manitoba. Portions of ERTS/LANDSAT images, frame centre 3720, 25 April, 12 May and 17 June 1974, and 10 July 1975. Composites of bands 5, 6 and 7.



ECOLOGICAL (BIOPHYSICAL) PHILOSOPHY AND WATER

"An (ecological) survey...is carried out to provide a framework for environmental resource management using a hierarchical classification system" which integrates a number of "environmental elements" (Can. Dept. of Envir., 1976, p. 1). So far, biophysical classifications have been built upon the recognition of boundaries which enclose surfaces displaying certain uniform properties. To ensure a reusable data base, these properties are normally permanent over several years (e.g. climate, morphology and vegetation chronosequence). Since movement requires work and an energy gradient, or at least the transition from one state to another across the ground, then it is only natural that biophysical philosophy has tended to overlook water, its flow, and its seasonal regimes[1]. The passage of flood crests through drainage systems, longshore drift of sediment from eroding cliffs to sheltered lagoons, lake circulation and annual turnovers, water level fluctuations in deltas and marshes, and the chronology of freezing and thawing are some examples of this relatively short-term dynamism of water in the environment. The mere fact that major drainage systems, such as the Peace-Mackenzie, Saskatchewan-Nelson, and the Great Lakes-St. Lawrence transcend topographic, climatic, geologic, land use and other regional boundaries should alone be enough to warn of the dangers of too rigidly applying current methodology for integrated surveys to water systems.

The open water and wetland classification proposed by Adams and Zoltai (1969) states that "the classification system must be oriented to serve the needs of several disciplines, (such) as wild ungulates, fish, waterfowl and furbearers, as well as hydrology, forestry, recreation and agriculture" (*Ibid.*, p. 23). Despite the apparent agreement that water should be integrated into ecological surveys, attempts at classification have so far focussed upon specific areas, certain types of landscape features, or specific uses of natural resources. Examples are the Saguenay-Lac-St.-Jean and the James Bay ecologic surveys in Québec (Jurdant *et al.*, 1972, 1976), the wetland classification of Zoltai *et al.*, (1975), and the classification of lakes in terms of biomass productivity (e.g. Rawson, 1960; Donaldson, 1969). Even the classification of Adams and Zoltai (1969) has limitations: it is hierarchic only in an informational rather than a spatial sense.

A spatial hierarchy in the tradition of Christian and Stewart (1968) and Lacate (1969) is present only in the context of dry-land units and those aquatic qualities of a similar static nature at the land system level.

While the guidelines of Lacate (1969) and of Adams and Zoltai (1969) are a useful step towards the collection of biophysical water data, one should also consider, for example, geomorphic and hydraulic properties, river and lake regimes, relationship between terrain, climate, vegetation and water quality, the phenology of ice and the mixing of lakes, the aesthetic qualities of scenery, aquatic biology and the indigenous use of water resources. Although it may not be possible to map and inventory all of these subjects in any detail, reconnaissance or baseline surveys at the regional level should consider all of them, whether or not they fit conveniently into the methodologies of mapping for integrated surveys.

WATER CLASSIFICATIONS

A number of water classifications are documented below. Excluded from the list are marine coastal classifications, since these are the subject of independent investigation (Silk, 1975; Lopoukhine, this meeting), and wetlands, since their ecological classification is already quite advanced (Stewart and Kantrud, 1969; Zoltai *et al.*, 1975; Millar, 1976; Zoltai, this meeting). Considered here are streams and rivers, lakes of all kinds and sizes, and lacustrine and riverine shorelands, since shoreline types are viable management units in themselves, and also are the sensitive interface between events in water and on land. Groundwater and watershed runoff response have received little attention in ecological land classification. Since many of the factors controlling runoff response are visible on air photos, they are worthy of future inclusion in land classifications.

While the parameters and purposes of ecological water classifications are highly varied, the classifications can nevertheless be grouped according to the kinds of information described. For example, Aukerman and Chesley (1971) deal only with measures of water quality, hydrology and morphology of rivers for purposes of optimum or multiple water use. Thus, they use three approaches based on landscape feature, kinds of data and ultimate objectives.

Land and water classifications can also be grouped according to their principal methodology, being either genetic, functional, descriptive, spatially hierarchic, or some combination of these. Genetic classifications group objects according to their origin and history. Functional classifications assemble

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[1] Incidentally, the exact same reasoning explains which migrating-wildlife inventories have difficulty in applying biophysical classifications.

objects with respect to their processes or their relationship to other phenomena. Attributes such as shape, size, texture, chemistry, mass, etc. are used as bases for descriptive classifications.

All classifications are intrinsically hierarchic, in that their purpose is to reduce large masses of data to smaller, manageable sets. Here, however, a hierarchic classification is one that provides for the spatial grouping of neighbouring land surfaces at various scales. By this definition, the open water classification of Adams and Zoltai (1969) is hierarchic only in its level of description, rather than the spatial syntheses proposed for watersheds by Bukowsky (1976) after Nelson and Falkner (1971) and Fedoruk (1970). In contrast, the wetland classes of Zoltai *et al.* (1975) are built upon descriptive data in such a way as to allow for grouping into spatial hierarchies.

Table I summarizes selected water classifications according to the four criteria of landscape feature, principal methodology, type of data input and declared or implied applications. In Table II, the types of data used are cross-tabulated with the three other criteria of Table I. This second table shows the predominant use of morphology in characterizing water bodies. Morphologic properties are easy to measure, they contain and route water bodies and flows, and are relatively time independent; thus, although their widespread use is not surprising, it is the near ubiquity of their use which is noteworthy here.

Also to be expected is the overwhelming dominance of descriptive methodology over genetic and functional ones. The origins of water bodies are simply of little interest or relevance to resource planners and managers. Conversely, functions, or processes, require monitoring over a time often longer than the operational restraints of ecological surveys. More alarming, however, is the paucity of water body classifications using spatial hierarchies. That this is possible is clearly demonstrated by the spatial hierarchies of genetic data by Davis (1890), of functional data by Fedoruk (1970) and of descriptive data by Zoltai *et al.* (1975). Recalling that ecological land classifications usually specify that small areas be integrated into the equivalent of systems, systems into districts, and so on, this lack of spatial grouping is even more evident. This finding probably reflects the inherent problems of integrating water into ecological classifications as outlined at the start of this paper. It is also certain that this is a problem at the forefront of any discussion of the philosophy of ecological classification and of land-water integration within ecological classification.

Table II reveals the absence of aquatic floral and faunal data in ecological water classifications, probably due to manpower restraints on sampling large areas. By contrast, it is surprising to see that cultural data such as scenery aesthetics, indigenous peoples and historical value are barely recognized. Only one scheme, that for river evaluation by Morisawa (1969, 1971) in the U.S.A., pursues aesthetics as a principal objective rather than as a by-product of other information. If the planning objectives of water body inventories are to include recreation, conservation and environmental impacts, then surely they should measure the historical, geological and biological interest and uniqueness of an area.

Table II also shows that water body classifications have tended to ignore cultural objectives such as sportfish and other forms of recreation, aesthetics, conservation and environmental impact and water use. Conversely, shoreline classifications have tended to focus upon recreation and environmental impact while omitting data on the aesthetics of scenery, on water quality and on littoral biology.

A review of each classification in a complete literature search awaits to be done. The present analysis is intended merely to draw together a number of efforts in the field of land-water integration in ecological surveys. Several expected trends emerge, but so do some unexpected trends and omissions. One goal of any programme to develop an ecological water classification should be to define the aims and objectives of such a classification, rather than to synthesize existing schemes and risk omitting critical information.

DIRECTIONS

The foregoing discussion of water in the environment and the literature review establish certain problems facing ecological water surveys. Firstly, there should be an awareness of the planning and management interests within a given area, such as identifying the potential clients and the likely developments in the area. In effect, these are the objectives referred to in Tables I and II. Once these objectives are known, the solutions to the second problem will normally follow.

The second requirement of an ecological survey is to establish the parameters requiring measurement. Should lake trophism be included, and if so, according to which indicators (e.g. biological oxygen demand; chlorophyll *a;*

TABLE I: Seclected Classifications of Inland Water Bodies

				Data Inputs							Objectives						
Landscape Feature	Principal Methodology	Author(s) (*et al.)	Date	Geology and Process	Morphology and Morphometry	Environmental Controls	Hydrology, Water Dynamics	Water Quality	Scenery, History, Aesthetics	Aquatic Biosphere	Biophysical and General	Limnology, e.g. Trophism	Animals and Ecology	Conservation, Aesthetics	Recreation	Environmental Impact	Water Resources
LAKES	GENETIC	Harding	42	x								x					
		Hutchinson	57	x								x					
	FUNCTIONAL	Bogoslowsky	66			x	x										x
		Donaldson	69		x			x		x		x					
		Brylinsky*	73		x			x		x		x					
		Sälbach	76			x	x	x				x	x			x	
	DESCRIPTIVE	Rawson	60					x		x		x					
		Fla. Bd. Cons.	69		x		x								x		
		Hills*	70		x						x						
		Conroy	71	x	x			x				x					
		Schindler	71		x							x					
		DOE/IWD	73		x												x
	HIERARCHIC	Hills	61		x	x					x						
RIVERS	GENETIC	Davis	90	x	x												
		Zernitz	32	x	x												
		Melton	36	x													
	FUNCTIONAL	Leopold, Wolman	57	x	x	x											
		Schumm	63	x	x												
	DESCRIPTIVE	Aukerman*	71		x		x	x					x	x	x	x	x
		Morisawa	71	x	x		x	x	x					x			
		Galay*	73		x												
	HIERARCHIC	Horton	45		x	x										x	x
		Fedoruk	70		x		x				x						
		Nygren*	7_		x	x	x	x									
RIVERS AND LAKES	DESCRIPTIVE	Solman	65		x		x	x					x				
		Herrington*	67		x	x									x		
		Adams, Zoltai	69	x	x		x	x			x						
		Jurdant*	72	x	x						x						
		Jurdant*	76	x	x						x						
		Dodge	76		x			x		x			x				
		BC/ELUC	76	x	x			x		x	x						
	HIERARCHIC	Eco. Task Force	73		x			x			x						
		Bukowsky	76		x		x				x	x					
SHORES AND ISLANDS (non-coastal)	FUNCTIONAL	Veatch	66	x	x	x											
		Hands	70	x												x	
	DESCRIPTIVE	Bowers*	42		x	x									x		
		Baker	64	x	x	x									x		
		Bishop	67		x	x									x		
		Cressman	71		x										x		
		Haras	72		x										x	x	
		Dirschl*	74	x		x	x									x	
		Newbury	75	x	x	x										x	

Table II: Criteria Used in Selected Water Body Classifications

Criteria	Data Inputs: Physical Geology Geomorphic Process	Morphology Morphometrics	Environmental Controls	Hydrology Water Dynamics	Water Quality	Aesthetics, Cultural Historical	Aquatic Biology Species, Variety, Etc.	Totals
LANDSCAPE FEATURE								
LAKES	3	8	3	3	5	0	3	25
RIVERS	6	10	3	4	3	1	0	27
LAKES AND RIVERS	4	9	1	3	5	0	2	24
SHORES AND ISLANDS	5	7	6	1	0	0	0	19
SUB-TOTAL*	18	34	13	11	13	1	5	
PRINCIPAL METHODOLOGY								
GENETIC	5	2	0	0	0	0	0	7
FUNCTIONAL	4	5	4	2	3	0	2	20
DESCRIPTIVE	9	21	6	6	8	1	3	54
HIERARCHIC	0	6	3	3	2	0	0	14
SUB-TOTAL*	18	34	13	11	13	1	5	
OBJECTIVES								
BIOPHYSICAL AND GENERAL	4	9	1	3	3	0	1	21
LIMNOLOGICAL	3	5	1	2	5	0	3	19
ANIMALS AND ECOLOGY	0	3	1	3	4	0	1	12
CONSERVATION, AESTHETICS	1	2	0	2	2	1	0	8
RECREATION	1	8	4	2	1	0	0	16
ENVIRONMENTAL IMPACT	3	5	5	4	3	0	0	20
WATER RESOURCES	0	3	2	2	1	0	0	8
SUB-TOTAL*	12	35	14	18	19	1	5	

*Sub-totals for landscape features and principal methodology are identical since each classification scheme appears only once according to those criteria. With respect to objectives and data inputs, however, each scheme may have one or more entries according to the scope of the classification. Therefore, sub-totals of objectives differ from the foregoing sub-totals.

phosphorus or total dissolved salts, etc.; or some combination of these)? Should river flow be recorded, and if so whether by annual regime, flood recurrence intervals, hydraulic geometry, or channel pattern and changes over time, etc., or, again, by some combination of these? A complete list of possible parameters is too long to discuss here. However, a subsidiary question is to what detail and precision should such data be measured. For example, should discharge be metered, or should width, stage, surface velocity and channel morphology suffice? Should lakes be sampled near the surface at one central point, or should each basin within a lake be sampled throughout its depth? These questions relate largely to cost-effectiveness and redundancy of data at district and regional levels of mapping and planning. Beyond considering the kind and detail of measurement, should such an inventory cover a continuous space, as in conventional ecological surveys, or should random sampling suffice? Equally, what are the needs for repeated or even continuous monitoring of certain phenomena?

A third group of questions concerns the techniques for collecting data. Like the foregoing set of questions, the answers will depend on the operational resources and the required detail of a proposed ecological water survey. Techniques can range from single or sequential satellite data to on-site monitoring of continuous phenomena over several years. In between are multispectral and panchromatic aerial photography, field crews, one-time and repeated fly-ins. While these techniques are well-tried, there remains much to be done towards the selection of simple remotely sensed and field data which can act as surrogates for more complex and detailed properties and processes.

Finally, there must be decisions related to the handling of data. In one sense this is merely a question of how data should be collected, stored and retrieved. In a more profound sense, however, there should be careful consideration of whether certain water properties can be mapped and grouped into spatial hierarchies corresponding to those of many ecological land classifications. Where the important water properties present almost closed systems, as in many lakes and their basins, such spatial grouping of recurring patterns of stable landscape elements may indeed be possible.. In other cases, such as extensive drainage systems which integrated several regional climates, data reduction may have to be a function of flow systems (e.g. Bukowsky, 1976), or perhaps a grouping of information unrelated to coterminous land areas (e.g. Ecosystem Task Force, 1973).

These four topics, namely objects, data needs, techniques for data collecting and data handling, must be considered in every ecological water survey. However, there is also an immediate need for a universal set of working definitions of water features, a comparison of several ecological water classifications in each of several test areas, and a need to explore ways of generating data on water dynamics from the stable environmental data usually collected during ecological water surveys.

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RECENT DEVELOPMENTS IN ECO-CLIMATIC CLASSIFICATIONS

B.F. Findlay
Atmospheric Environment Service
Environment Canada
Toronto, Ontario

ABSTRACT

Eco-climatic classifications have been produced on an ad hoc *basis for various uses in Canada, but many fundamental problems remain in deriving systems having more universal applications. There is a need to incorporate more measured site-specific data into biophysical land surveys. Also, the existing meteorological network data can be used to greater advantage. To illustrate strengths and weaknesses in our present state of eco-climatic knowledge, this paper comments on four types of classifications.*

RÉSUMÉ

Diverses classifications écoclimatiques ont été réalisées, pour divers usages, au Canada dans le cadre de projets spéciaux, mais de nombreux problèmes fondamentaux demeurent sur le plan de l'analyse des systèmes dont l'application est plus universelle. Il existe un besoin d'incorporer dans les relevés biophysiques des terres un plus grand nombre de données provenant de mesures effectuées dans des endroits spécifiques. Il reste aussi encore beaucoup à faire pour en arriver à une meilleure utilisation des données provenant des réseaux météorologiques existants. Le présent document étudie quatre types de classifications destinées à illustrer les points forts et faibles dans l'état actuel de nos connaissances.

INTRODUCTION

Climate is a primary factor influencing ecological systems on all scales. Nevertheless, the climatic factor has not always been well-integrated into the scientific appraisal of land as practised in Canada. Many explanations are possible, including, among others, network deficiencies, a paucity of specialists, and imperfect communications. Over the years, however, some progress in developing climatic classifications useful for land management can be noted. Four such classifications are discussed in this paper.

(a) Inferential Classifications
(b) National Classification for Agricultural Capability (CLI)
(c) Regional CLI-type Classifications
(d) *Rational* Classification for Recreation and Tourism

INFERENTIAL CLIMATIC CLASSIFICATIONS

This is the simplest of the classification methods, but can be the most demanding in terms of judgement skill. Here, climate is *inferred* from vegetation, soils or landforms. Few actual measurements are introduced beyond certain base information, said to represent a particular ecological regime. Changes, reported in terms of colder, wetter, drier, etc., are noted as tree species, soil units, or slopes change. The techniques have been well described by Hills *et al.* (1970) and Jurdant *et al.* (1974). While the method functions reasonably well when employed by experienced field workers, professional judgement is critical, and the lack of actual measurements makes the climatologist sceptical. Biophysical field parties should make use of meteorological instruments to check inferred climatic boundaries. Such measurements provide real information on present conditions and form the statistical base, the essential predictive element of the science.

THE (CLI) NATIONAL CLASSIFICATIONS FOR AGRICULTURAL CAPABILITY

In 1966 Chapman and Brown generated a combination of temperature and moisture indices computed from the records of the national meteorological network. From their computations, 40 agroclimatic regions in southern and non-mountainous districts of Canada were distinguished.

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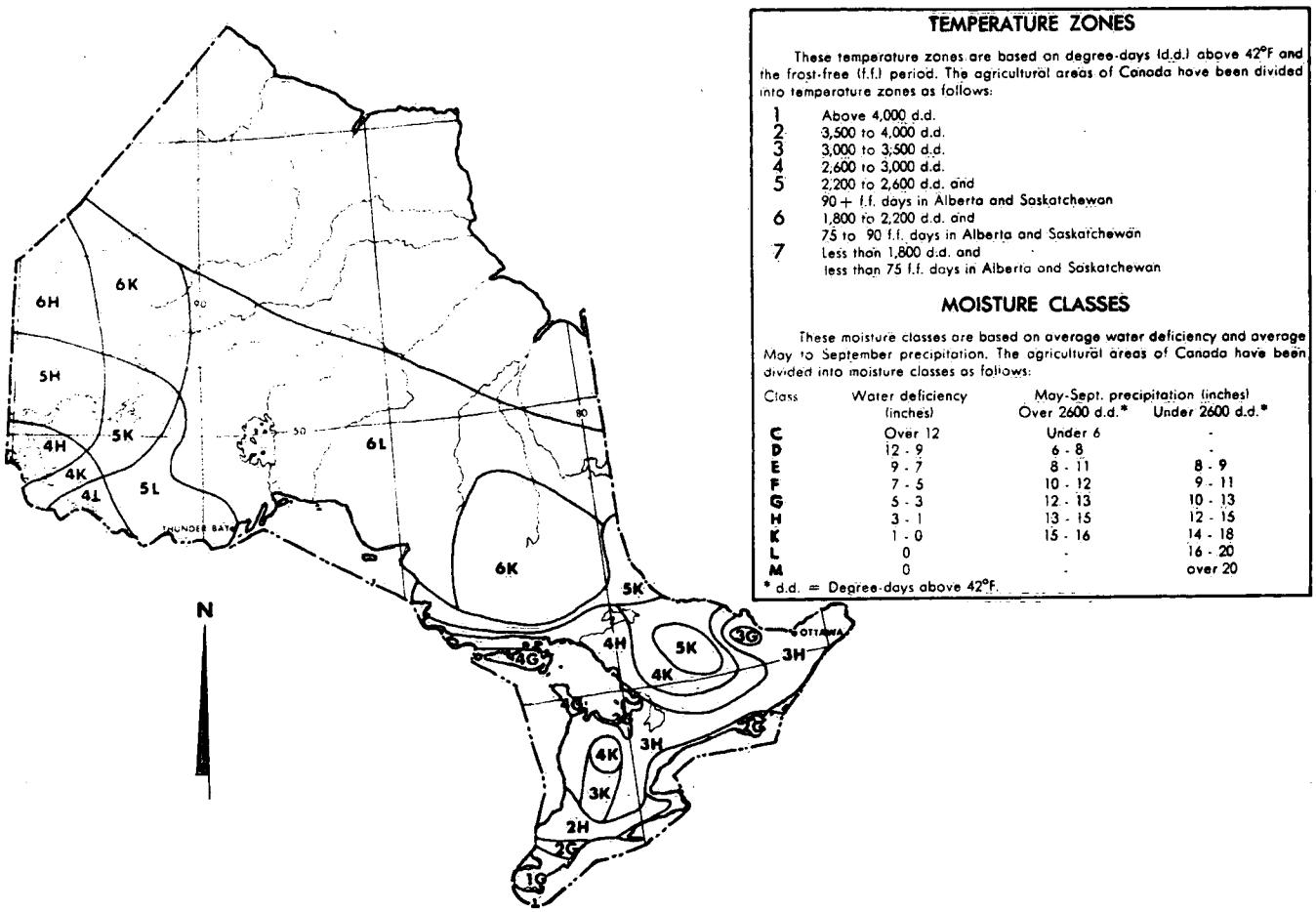
Figure 1: The agricultural climate of Ontario according to temperature and moisture classes (Chapman and Brown, 1966).



This was done by comparing yield statistics for selected crops against growing degree-days, corn heat units, the frost-free period, low winter temperatures, growing season precipitation, and the soil moisture balance. Other meteorological parameters such as sunshine and wind may be introduced subjectively by the analyst. The system is applicable within the provincial scale, but modified techniques have been developed for finer detail. The method is pleasing to the climatologist in that real data have been used, and a *crop calibration* has taken place wherein physiographic and other factors have been considered (Figure 1).

REGIONAL CLI-TYPE CLASSIFICATIONS OF AGRICULTURAL CAPABILITY

The principal difference between national and regional classifications is that in the latter, temperature-moisture indices are ranged to identify seven land classes based on progressive climatic limitations to varieties of agricultural crops. The seven-grade system is a modification of the widely known United States soil capability classification. The classification system as used in British Columbia is illustrated by Figures 2 (British Columbia, 1972) and 3 (Can. Dept. of For., 1965). It may be noted that, in addition to

Figure 2: British Columbia agroclimatic capability classification

Class	Frost-free period (days)	Growing degree-days ≥ 5°C	Annual precip. (mm)	May - Sept. precip. (mm)	Climatic moisture deficit (mm)
1	90-120	1290-1620	<380	<230	Nil or small
2	75-90	1145-1290	<380	<200-250	40-1120
3	60-75	1000-1145	<330	<215	120-190
4	50-60	1000-1145			190-265
5	30-50	735-1000			265-345
6	<30	500-735			345-405
7	<30	<500			

Sub-Classes

A Drought, aridity (climatic not pedological moisture deficit)

E plant injury to dormant trees by low winter temperatures

F plant injury by low temperatures during growing season

G insufficient heat units during the growing season

H low temperatures during growing season which severely lower heat unit accumulation

U wind exposure severe

X combination of low temperatures, low heat accumulations, high snowfall, excess winds

Y excess precipitation during growing season (flooding, poor tractability, poor harvest conditions).

the seven primary divisions, there are a number of subclasses which either identify limitations that might be overcome through technology (e.g. soil moisture deficit overcome by irrigation), or allude to regional peculiarities not expressed by thermal or moisture indices (e.g. severe wind exposure).

The system has been applied with some success in British Columbia where the measuring network has been enhanced in order to document climates on the lower mountain slopes. However, contrasting conditions between the coastal maritime climates and the interior continental climates lead to problems in the use of simple linear thermal indices to suggest crop growth. Long frost-free periods and growing seasons near the ocean give a large accumulation of growing degree-days. However, the relationship of crop growth to temperature is exponential, and accumulations of heat units near the threshold value are of lesser importance to crop development than those associated with temperatures around 20°C and higher.

THE B.C. AGROCLIMATIC CAPABILITY SYSTEM ADAPTED TO THE YUKON AND NORTHWEST TERRITORIES

Erratic agricultural settlement patterns by recent colonists in the North caused governmental bodies in 1974 to cease issuing land permits for three years pending climatic and soil surveys. The Atmospheric Environment Service, in cooperation with the Department of Indian and Northern Affairs, is currently carrying out field studies to enable 1:125,000 climatic capability maps to be produced in areas where soils are considered reasonable. The classification to be used is the British Columbia system. The opportunities for *crop calibration* are limited in the frontier zone, and clearly the longer photo-period during the early growing season, as well as permafrost occurrences, will affect certain crop regimes. For example, vegetables are more reactive to

Figure 3: Selected crops in correspondence with agroclimatic capability classification (B.C.)

CROPS	CLASSES 1	2	3	4	5	6	7
Vegetables							
Corn	X						
Asparagus	X	X	X	X			
Beans	X	X					
Beets	X	X	X	X			
Broccoli	X	X	X	X			
Cabbage	X	X	X				
Cauliflower	X	X	X				
Carrots	X	X	X	X			
Peas	X	X	X	X			
Potatoes	X	X	X				
Turnips	X	X					
Spinach	X	X	X	X			
Fruits							
Tomatoes	X						
Apples	X						
Strawberries	X	X					
Forage Crops							
Alfalfa	X	X					
Red Clover	X	X	X				
Alsike Clover	X	X	X				
Orchard Grass	X						
Brome Grass	X	X					
Timothy		X	X	X	X		
Native Browse					X	X	
Cereal Grains							
Wheat	X	X					
Oats	X	X	X	X			
Barley	X	X	X	X			

light variations than cereals.

The backbone of any classification system is a good data base. For this project, 50 new climatological stations were established in 1975. These were arranged in 15 transects to document elevation, slope aspect, vegetation and water body effects on temperature, humidity and precipitation. To judge the area the transects *represent*, mobile surveys using electrical sensors and recording equipment (mounted on a truck) were carried out in the Yukon Territory. This enables boundaries of influence to be better delineated than by using strictly vegetation and/or physiographic criteria. The details of parameter estimation over the diverse terrain of the Canadian Northwest are beyond the scope of this paper. Procedures adopted have been based on known topoclimatic relationships, and height-dependency curves have been developed for the districts under study.

The research will be published in early 1977 but preliminary results indicate that cultivable lands (classes 1-4) in the Mackenzie District are generally below 950 ft (290 m) a.s.l. Some grazing (class 6) is feasible to 2,500 ft (770 m). Poorly drained areas may be one or two classes lower because of low daytime temperatures and frost dangers. In the Yukon south of 64° latitude, by comparison, useful land extends up to 500 ft (150 m) higher, though in the north and near the St. Elias Mountains, conditions are similar to those of the Mackenzie District. The lower elevations

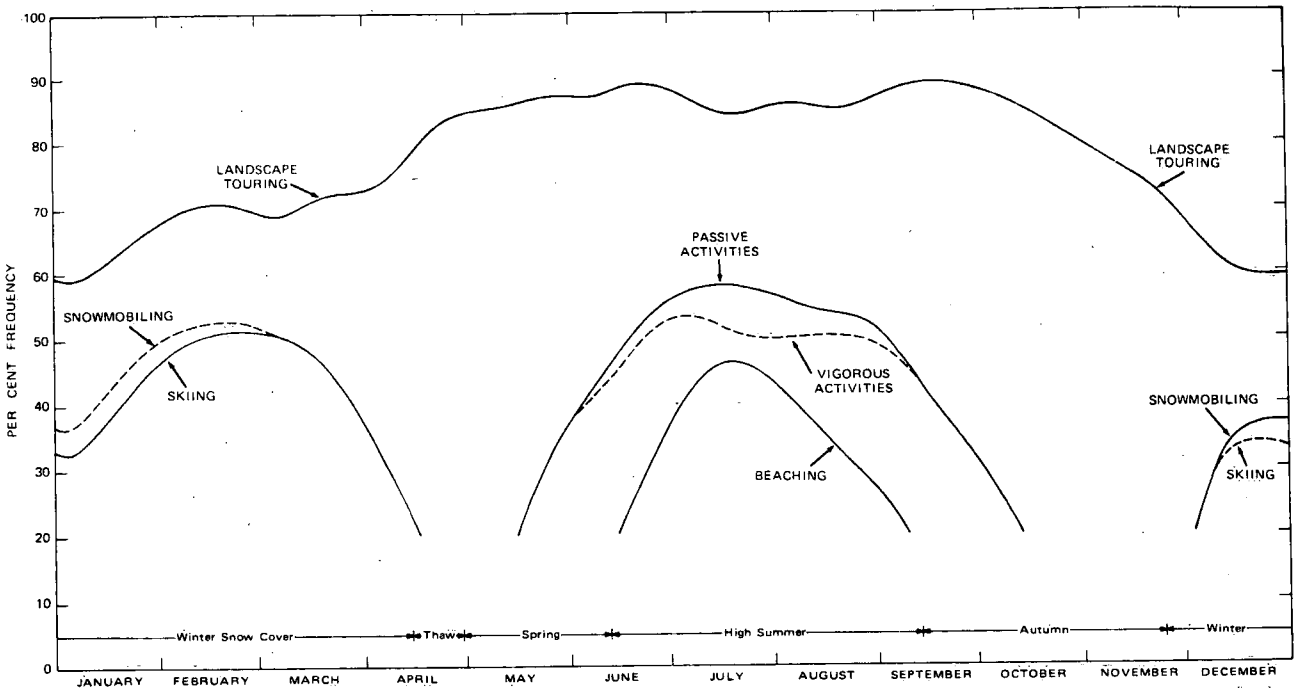
Figure 4: Criteria for recreational classification in the Atlantic Provinces.

Meteorological Factors	Humidex (effective temp.)	Visibility (mi)	Sky Cover (tenths)	Wind Speed m.p.h.	Snow Cover (inches)	Other Weather Contingencies
Landscape Touring	-12 to 89	> 3	n/a	≤ 25	n/a	nil
Passive Activity	> 54	> 1	< 8	≤ 20	n/a	nil
Vigorous Activity	55-89	> 2	< 8	≤ 20	n/a	nil
Beaching	> 64	> 1	< 8	≤ 15	n/a	nil
Skiing	> 6	> ½	n/a	≤ 15	> 1"	nil or S-, SP-, SW-, SG-,
Snowmobiling	> -6	> ½	n/a	≤ 15	> 1"	nil or S-, SP-, SW-SG.

Conditions to be met for 5 hours between 10 a.m. and 6 p.m.

S - light snowfall
SW - light snow showers
SP - light snow pellets (graupel)
SG - light snow grains

Figure 5: Annual variation of "suitable days" - Charlottetown, Prince Edward Island.



of all Yukon valleys experience drought during the summer.

RATIONAL CLASSIFICATION OF CLIMATE FOR RECREATION AND TOURISM AT THE LAND DISTRICT AND LAND REGION SCALE (1:1,000,000)

Based on experience dating from 1970, the Atmospheric Environment Service has recently prepared a climatic overlay for the Canada Land Inventory recreation capability map of the Atlantic Provinces. The latter map was based on landscape amenities and aesthetics (Can. Dept. of Reg. Economic Expansion, 1969). The derivation of the climatic map was based on concepts developed by Crowe *et al.* (1973). A central theme is the *activity-day* which defines the possibility of undertaking with satisfaction certain groups of outdoor activities. Activities are divided into winter and summer varieties and further into passive and vigorous phases. Each activity group has meteorological limits, thresholds of temperature, humidity, wind velocity, snow cover, precipitation, etc. (Figure 4). Following the applications of activity-day criteria to the climatological records, seasonal lengths and seasonal qualities for outdoor activities may be designated.

The climatic capability maps were constructed as follows. A tabulation was generated to indicate the collective ten-day frequency of activity-days for selected recreational pastimes over a ten-year period. The data were plotted as smooth seasonal curves for 48 stations (Figure 5). The area under each curve was measured. The station having the greatest seasonal strength (frequency-duration) was assumed to represent *ideal* conditions and was assigned a value of 100%. Appropriate percentages for the other 47 stations were then calculated. For example, Lake Eon, Québec received the highest regional strength value for skiing (100%) and Fredericton, N.B. was allocated 64%. Percentage values were then mapped for composite seasonal activities. Word descriptors indicating a range from excellent to unsatisfactory conditions were allocated at specific percentage values. The recreation climatic capability maps are shown as Figures 6 and 7.

DISCUSSION

For the purposes of this paper four types of eco-climatic classifications have been recognized from among several possibilities. One of the principal problems encountered in application is that each classification is valid for certain map scales and becomes difficult to transpose to other scales, particularly large scales in land type surveys (1:10,000 - 1:20,000). However, useful work on the district scale has been published by MacIver *et al.* (1972) for Alberta where data from a sparse network were statistically evaluated and allocated to

Figure 6:

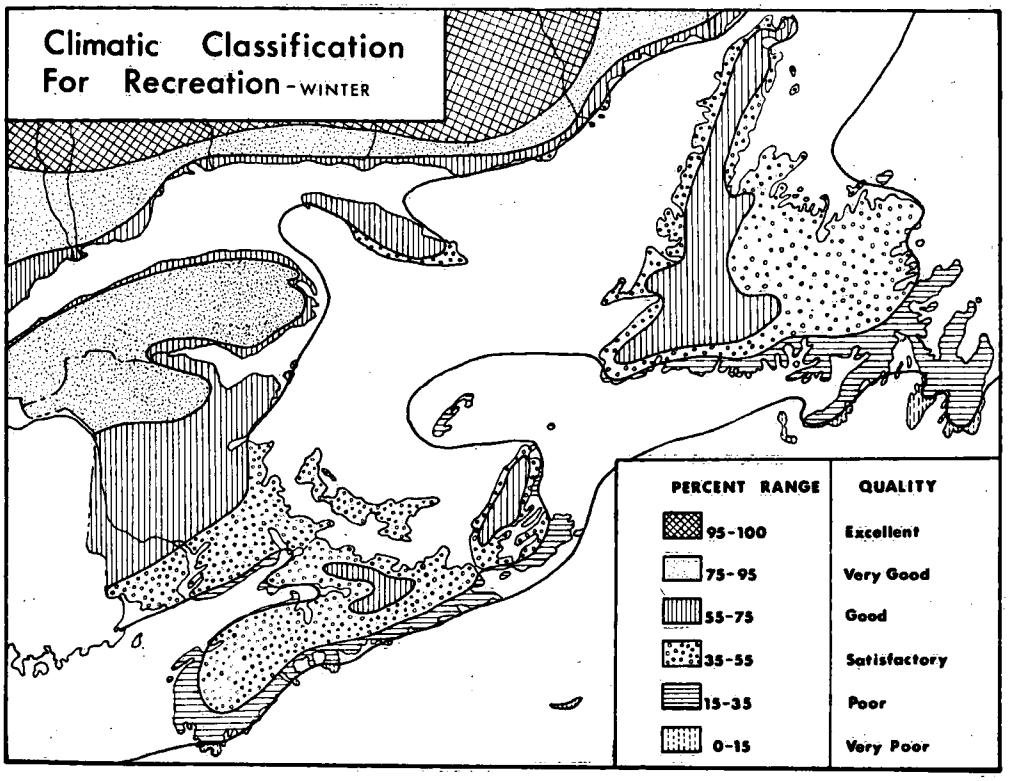
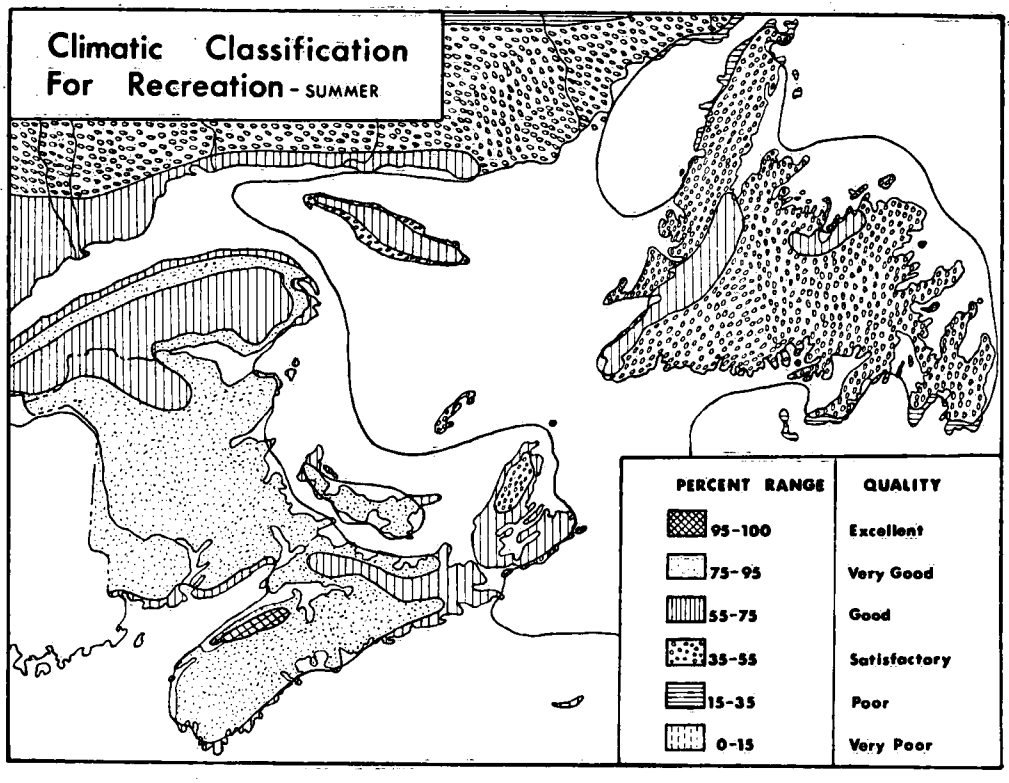


Figure 7:



groupings within homogeneous climatic areas.

The use of elevation transects and mobile surveys to determine representativeness of stations is recommended for biophysical surveys where possible *rational* classifications of the recreation-tourism type could be tested for certain other climatic capability applications such as wildlife. Activity criteria would be substituted by other climatic controls of biological importance such as snow cover, wind chill, and the growing season.

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AN EVALUATION OF REMOTE SENSING TECHNIQUES FOR ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION IN NORTHERN CANADA

J. Thie
Lands Directorate
Environment Canada
Ottawa, Ontario

ABSTRACT

The use of LANDSAT satellite and airborne remote sensing imagery are evaluated in a sub-arctic and northern boreal environment near Churchill, Manitoba. Accuracy and cost-effectiveness of a number of interpretation methods are compared, including visual and automated (supervised and unsupervised) techniques of LANDSAT data and air photo interpretation. Classification results of the different techniques are compared by using the overlay capabilities of the Canada Geographic Information Computer System. Conventional interpretation of aerial photographs enabled classification of about 43 different land types, and proved the best and most practical method for comprehensive biophysical mapping. Satellite-based methods allowed the mapping of about 10 groups of land types, often so broad that their practical value for resource management is limited. At present, visual satellite interpretative methods are more cost-effective than automated approaches for ecological land classification in most parts of Canada.

RÉSUMÉ

L'emploi de satellites de LANDSAT et d'images obtenues par télédétection aérienne est évalué dans un milieu subarctique et boréal près de Churchill, au Manitoba. L'exactitude et le rapport coût-efficacité d'un certain nombre de méthodes d'interprétation, y compris les techniques visuelles et automatisées (avec ou sans surveillance) d'interprétation des données LANDSAT et de photo-interprétation, sont comparées. Les résultats de la classification des diverses techniques sont comparés par l'exploitation des possibilités de recouvrement de l'ordinateur du système d'information géographique du Canada. L'interprétation classique des photographies aériennes a permis de classer environ 43 types de terrains, et s'est avérée la meilleure et la plus pratique des méthodes de cartographie biophysique. Les méthodes utilisant les satellites ont permis de dresser des cartes d'environ 10 groupes de types de terrains, souvent si généraux que leur applicabilité à des fins de gestion des ressources est limitée. A l'heure actuelle, les méthodes visuelles d'interprétation des images prises par satellite sont plus efficaces, relativement au coût, que les méthodes automatisées en ce qui concerne la classification écologique des terres dans la plupart des régions du Canada.

INTRODUCTION

Environmentally sound resource management requires basic biological-physiographical and socioeconomic data that allow an integrated or multidisciplinary approach. In the southern developed part of Canada, the Canada Land Inventory Program has provided a multidisciplinary land capability mapping. One-third of our land area is covered with this nationally consistent information base. For about 3.5 million km^2 of land in the north, there is a serious lack of such base line data (Romaine, 1974).

The National Committee on Forest Land, working under the auspices of the Canada Land Inventory Program, recognized this gap in environmental data and through its subcommittee, started the development of a classification system to provide this biological-physiographical data base for 'wildlands'. The biophysical land classification system evolved. The further development of this system is now supported by the Canada Committee on Ecological (Bio-physical) Land Classification.

The aim of the classification system is to differentiate and classify, at a small scale, ecologically significant segments of the land surface (Lacate *et al.*, 1969). It was recognized that this system should be ecolog-

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ically based, and that mapping and the description of land surfaces, and assessments related to forestry, wildlife, recreation, agriculture, etc., could be made rapidly and with little additional effort. The system has four levels in its classification hierarchy. *Land region*, the first level, is defined as an area of land characterized by a distinctive regional climate as expressed by vegetation. The second level, *Land district*, is basically a sub-division of the land region based primarily on the separation of major physiographic and/or geologic patterns that characterize the region as a whole. *Land system*, the third level, is defined as land areas throughout which there is a similar recurring pattern of landforms, soils and vegetation. The fourth level, *Land type*, could also be called a land ecosystem. It has a fairly homogeneous combination of soil and chronosequence of vegetation. Mapping scales suggested are as follows:

Land Region	1:1,000,000 - 1:3,000,000
Land District	1:500,000 - 1:1,000,000
Land System	1:125,000 - 1:250,000
Land Type	1:10,000 - 1:20,000

The objective of this paper is to report on the usefulness of airborne and satellite remote sensing for biological-physiographical data gathering in northern areas. As low cost and rapidity are considered critical, most attention is given to the evaluation of LANDSAT data. Different interpretation methods are tested in an area near Churchill, Manitoba, where boreal and arctic elements are present.

Air photo interpretation has played a significant role in the development of environmental survey systems related to vegetation, surficial geology, soils, forestry and agriculture including biophysical land classification. In the early 1950's, Hills recognized the value of aerial photographs for his forest site (physiographic site) classification. He stressed landform and surface geology as the integrating framework for vegetation, soils, local climate and 'site'. The value of landforms in delineating and describing site conditions was supported by Gimbarzevsky (1966) and Lacate (1966). Stereoscopic viewing of aerial photographs provides a three-dimensional image of terrain features. Relief and slope are important indicators of ecosystem parameters such as drainage, parent material, soil formation and vegetation succession (Thie, 1972). Good perception of depth in a stereo model and quick analysis of shapes and textures enable the human interpreter to readily separate significantly different units. Following field descriptions of selected sample areas, results can be extrapolated to non-sampled similar areas by means of photo-interpretation. With this approach, the total number of field investigations is considerably less than in conventional surveys. The value of each field observation is much greater; therefore, both its choice location, and its description and classification are more critical (Vink, 1964).

As a result of the development of new remote sensors, the interpretation methodology is changing rapidly. Much of the 'imagery' generated by airborne and satellite sensors is now stored in an analogue or digital fashion on magnetic tape. Transforming these into visible images for human interpretation usually significantly reduces spectral information and spatial resolution. Computer interpretation of images should not entail loss of information.

The introduction of the airborne program of the Canada Centre for Remote Sensing (CCRS) and the launch of the Earth Resources Technology Satellites (ERTS, presently called LANDSAT) pushed the research in application of remote sensing in Canada rapidly ahead. Much of the work, at one time carried out in the U.S., now came within reach of Canadian researchers. These Canadian experimenters in remote sensing-assisted soil mapping, terrain studies and biophysical inventories (Beke, 1972; Boydell, 1974; Desloges, personal communication; Gimbarzevsky, 1974; Howarth, 1976; Mills, 1972; Oswald, 1975; Tarnocai, 1972; Tarnocai and Thie, 1974; Thie, 1972, 1976; and Thie *et al.*, 1974) used visual and automated methods of analysis.

STUDY AREA

To evaluate airborne and satellite remote sensing for northern land classification, an area was chosen in that part of northern Manitoba where arctic and boreal elements meet (Figure 1). Two main physiographic regions also meet in this area - the Canadian Shield and the Hudson Bay Lowland. In this area, the disturbance of natural vegetation by man and fires is insignificant; surface vegetation can be considered as a good indicator of subsurface conditions, and therefore also of the geographic distribution of land types or ecosystems.

Using LANDSAT imagery, the area was subdivided into two land regions and five land districts (Figure 1). Although the boundary of the land regions is actually based on a physiographic divide, the difference in the first place is climatic. This climatic difference is expressed in the distribution of

Figure 1: Land districts in the Churchill map-sheet (54L). The square area outlined in heavy lines represents the 54L sheet. Background is an image taken 14 Aug. 1973 (1387-17021-band 7). Continuous lines delineate the land districts; broken, the 'transition' zones.

vegetation and permafrost occurence.

LAND REGION (1) has continuous and widespread discontinuous permafrost (Brown, 1967), a prevalent forest-tundra type of vegetation (Ritchie, 1962), and an arctic climate.

The *Seal River District* (1A) is characterized by a relatively thin layer of stony till over bedrock, partly overlain by extensive peat deposits. Water-modified glaciofluvial deposits, till ridges, and beaches occur throughout the area. Till covers about 35% of the area. In wet to moist areas, strong frost heaving of stones and rocks in the till has resulted in rock and stone fields. In the peatlands, peat polygons occur, as well as sedge wetlands.

The *Lofthouse-Lovett Lake District* (1B) consists of 99% organic deposits over marine sediments and till. Glaciofluvial deposits provide the only areas of dry land. In the peatlands, peat polygons occur more frequently (40%), associated with patterned sedge fens (30%).

The *Coastal District* (1C) is the most complex district in the study. This narrow strip along the coastline consists of extensive marine flats, alluvial deposits, numerous beach ridges, and a thin layer of relatively recent organic deposits. Occasional bedrock and glaciofluvial deposits are found. Wetland types are sedge fens, peat plateaus, palsas and salt marshes.

LAND REGION (2) is marked by widespread discontinuous permafrost, open coniferous forest

and a north boreal and arctic climatic.

In the *Mack Lake District* (2A), more than 95% of the surface material is peat. Peat plateaus form the dominant landforms reflecting the gently undulating topography controlled by a thick overburden of till over Precambrian bedrock.

In the *Knife River District* (2B), till is the dominant surface material. It has a vegetation cover of open to semi-open black spruce. Local fires may have introduced jack pine. Only about 20% of the area is covered with peat (peat plateaus and sedge fens).

METHODS

Fieldwork, carried out during the summers of 1973 and 1974, entailed an aircraft survey and the sampling of landform-soil-vegetation-permafrost complex in about 100 locations.

Remote sensing photography, including high altitude coverage for the complete study area and low altitude and radar coverage for selected parts of the area, was obtained on different dates during the spring and summer of 1973. The standard sensor package included colour infrared, colour, and black and white photography combined with various filters, and thermal infrared scanning (Figure 2). Moreover, various LANDSAT images in the form of prints, transparencies and digital tapes were used in the satellite evaluation

To compare the effectiveness of various visual and automated satellite interpretative techniques, three different ecological land classification maps were prepared:

MAP I - based on the visual interpretation of 1:1,000,000 multidate LANDSAT imagery.

MAP II - based on the visual interpretation of a LANDSAT colour composite, digitally enlarged to 1:250,000 scale.

MAP III - based on a supervised automated interpretation using the Multispectral Analyser Display (MAD) of the CCRS.

In addition, parts of the study area were mapped using unsupervised automated classification techniques and supervised and unsupervised multidate (summer-winter combination) interpretation techniques as implemented on CCRS Image 100 and MAD systems.

To measure the success of each map, it was compared with a detailed ecological base map. This map is based on field sampling and visual interpretation of 1:100,000 scale black and white aerial photographs.

Based on field work, about 50 representative land types were recognized. They formed the legend for classification of map units (or pixels) for any of the interpretative methods. For convenience, these are called *classes*. Grouping of classes into *class groups* was done when the land types were not spectrally separable, or were cartographically or resolution-wise unmappable. A simple alphameric system was used to identify the classes.

To allow easy comparison of the interpretative results, all ecological land classification maps were stored in the Canadian Geographic Information System (CGIS) of the Lands Directorate, Department of the Environment, Ottawa. This system is designed to read, store, analyse, manipulate, and overlay maps. Using this system, Maps I and II were overlaid on the detailed ecological base map. For each mapping on both maps, a new classification was generated using the detailed base, and the results were compared with the original classification of the units. The amount of misclassification was calculated as the difference from the base map for each class and class group on a land system (Table 1), land district and total map sheet basis. The individual performance of mapping units and classification generated by the different methods are measured on a land system basis; the relation of classification performance and physiographic and ecological characteristics are obtained through the land district analysis. Because of geometric distortions, Map III was visually compared with Map IV and detailed aerial photographs.

RESULTS

The maps generated by the visual interpretation methods are partly displayed in Figure 3. The results of the supervised automated classification are displayed in Figure 5. To compare the various maps, at least four aspects have to be considered.

1. The number and size (detail) of the units on the map.
2. The number of land types (ecosystems) that are used in the legend.
3. The classification accuracy of the mapping units.
4. The accuracy or significance of the land system (mapping unit) boundaries.

On the ecological base map, 700 land systems were mapped, each covering about 1800 ha. Map II, resulting from the visual interpretation of 1:250,000 satellite imagery, has 167 land systems for three areas covering about 25% of

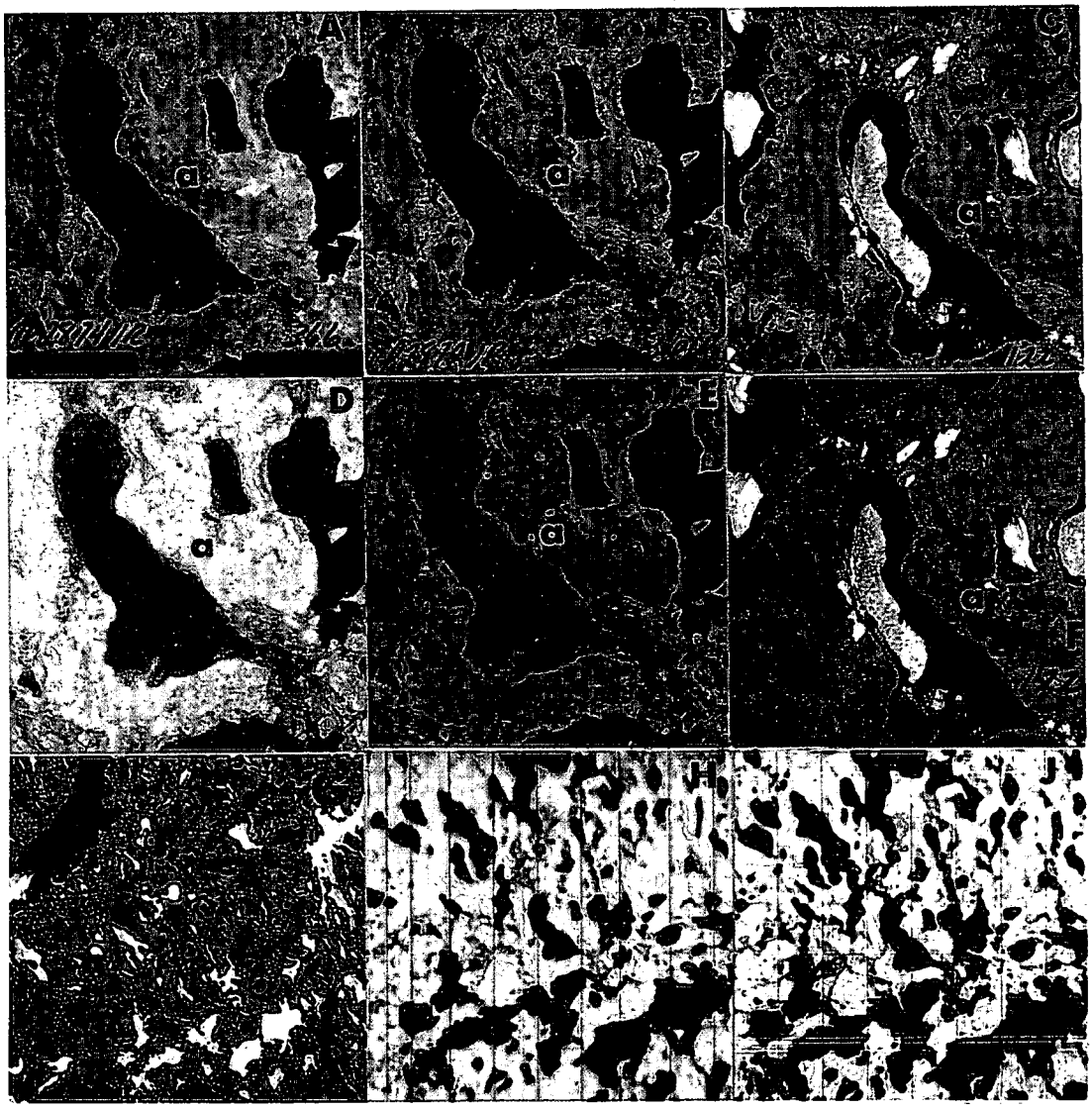


Figure 2: Airborne multiband coverage of the Long Lake area. Two flights took place at an altitude of 3,050 m ASL. A, B, D, E *and* H *were taken 22 July 1973;* C, F, G *(at 10,700 m ASL) and* I *were taken 1 June 1973.* A *(CP28741R-366) was taken with a 2443 film with CC20M filter;* B *(CP28721R-366) with a CC20B filter;* D *(BN2873-366) with a 2405 film combined with a W12 filter ('Red Band') and* E *(CP2875-366) a colour photo.* H *and* I *are thermal scanning images taking simultaneously with the 70 mm Vinten camera imagery.* G *(RSPA-306651R) is part of a 9" by 9" small scale colour infrared photo.*

Table 1: Computer-Generated Overlay Results. In this example of computer-generated overlay results, Maps I and IV, the land system (no. 543300003) is described by two columns with classes. The left column shows the method to be tested (Map I); the right column shows the 'true' classification based on (Map IV).

	MAP I			MAP IV			difference			
LANDSYSTEM 543300003	CLASS	AREA	%	CLASS	AREA	%	AREA	%		%
	A3	31593	60	A1	3888	7	3888	7	A	3.0
				A3	16629	32	-14964	-28		
				A31	12670	24	12670	24		
				B1	600	1	600	1		
	B2	10531	20				-10531	-20	B	-18.9
				C2	4007	8	4007	8	C	7.6
				D1	104	0	104	0	D	6.3
				D2	174	0	174	0		
				D3	791	2	791	2		
				D5	2225	4	2225	4		
	E1	10531	20	E1	7354	14	-3176	-6	E	-6.0
				G1	1501	3	1501	3	G	6.0
				G12	523	1	523	1		
				G2	1133	2	1133	2		
				O2	214	0	214	0	O	1.6
				O3	644	1	644	1		
				P1	196	0	196	0	P	0.4
				TOTAL	52655	100		53.5		24.9

the total map area; coverage size is 2370 ha. Map I, based on 1:100,000 LANDSAT imagery, has 149 land systems averaging about 9100 ha. Thus, the levels of mapping detail of Maps II and IV are similar; Map I, however, displays significantly larger units.

1:1,000,000 Visual Satellite Interpretation

Figure 4 shows the classification results for each land system as mapped on 1:100,000 multi-date satellite images (Map I) as compared with the base map (Map IV). The percentages in the map units identify the amount of misclassification for each land system. The lower number gives the weighted sum (based on averages) of the misclassification for individual classes or land types (A_1, A_2, A_3, B_1, B_2, etc.). The upper number gives this weighted sum of misclassification for groupings of the individual classes (A, B, C, D, etc.) for that land system. Misclassification for each class group of classes is based on the areas of omission per class or per class group by land system as a percentage of land area. For example:

$$100 \times \frac{\text{CLASS Y acreage (Map IV)} - \text{CLASS Y acreage (Map I)}}{\text{land system acreage}} = \text{\% omission of Y}$$

and

$$\text{Land system misclassification} = \frac{\Sigma[\text{\% of omission (A), (B), (C),...(Z)}]}{Z}$$

As shown by the lower numbers on Map V (Figure 4), the amount of misclassification arising from visual interpretation of individual land types is excessive in most areas. The best system has 21% misclassification. Only 11 of the 149 land systems have better than 35% misclassification. This indicates that the land type legend used for visual interpretation is too complicated for this method as it causes excessive classification errors. Simplifying the legend by joining land types into groups of classes (A, B, C, etc.) increases classification accuracy significantly (upper number, Figure 4) to the extent that 58 of the 149 units have acceptable classification results.

Figure 4 shows that relatively large amounts of misclassification occur in the smaller and more complex land systems. It illustrates a relationship between physiographic complexity and the amount of misclassification. The greatest amount of misclassification is found in areas where mineral deposits occur. While peat-dominated areas, such as the peat plateaus in the SW part of the map area, have relatively good classification results (5%-20% misclassification), till-dominated areas nearby in land region 2 are misclassified by as much as 90%. However, mineral soils in land region 1 are significantly better-classified (about 30% misclassification). This possibly arises from the relative lack of vegetation and the lack of vegetation disturbance in the area, which results in less confusion during interpretation. Figure 4 also shows that higher amounts of misclassification are associated with the coastal

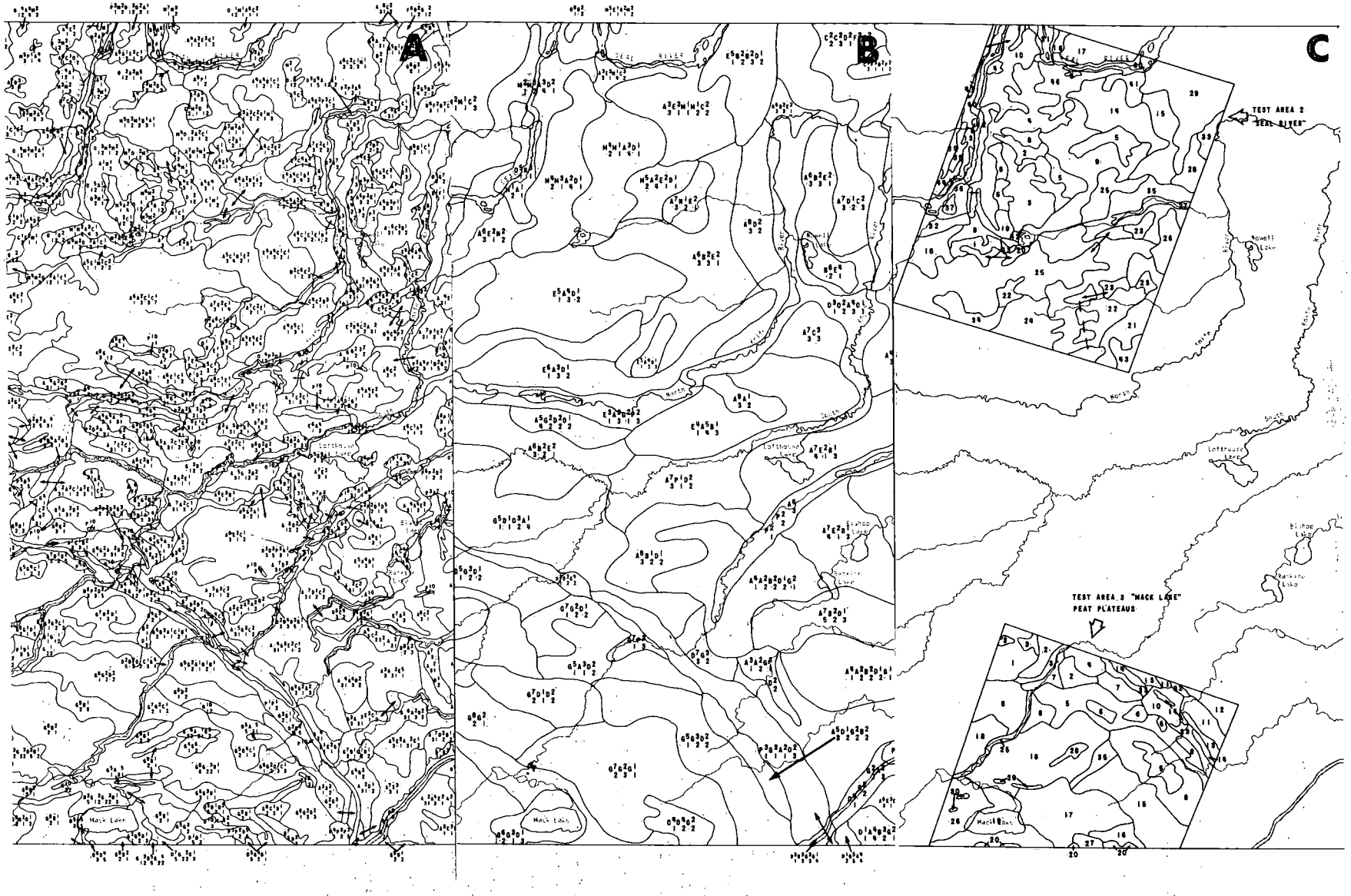


Figure 3: Visual interpretative methods. A *shows part of the detailed ecological base map;* B *is the same area interpreted from 1:1,000,000 LANDSAT imagery; and* C *shows parts interpreted from 1:250,000 scale enlarged LANDSAT images.*

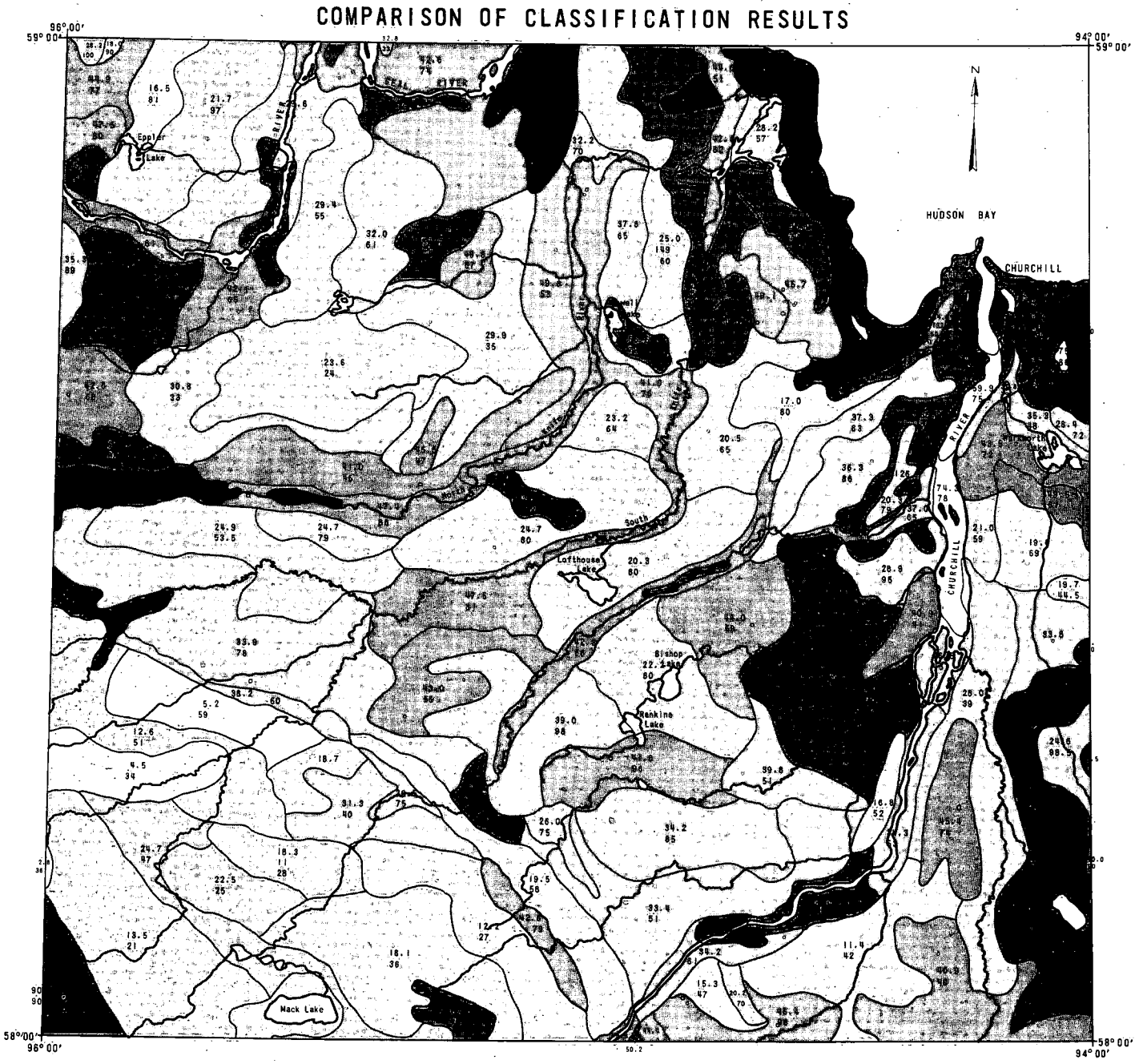


Figure 4: Map V - a comparison of classification results. Map I was overlaid on the biophysical base map (Map IV) and misclassification of Map I was calculated for each land system using the Canadian Geographic Information Computer System. The upper number gives the misclassification per land system when the various land types are grouped into broader class groups (A, B, C.....Z), while the lower number lists the misclassification per land system when individual land types are compared (A_1, A_2, A_3,.....B_1, B_2,.....C_1, etc.). Scale - 1:750,000.

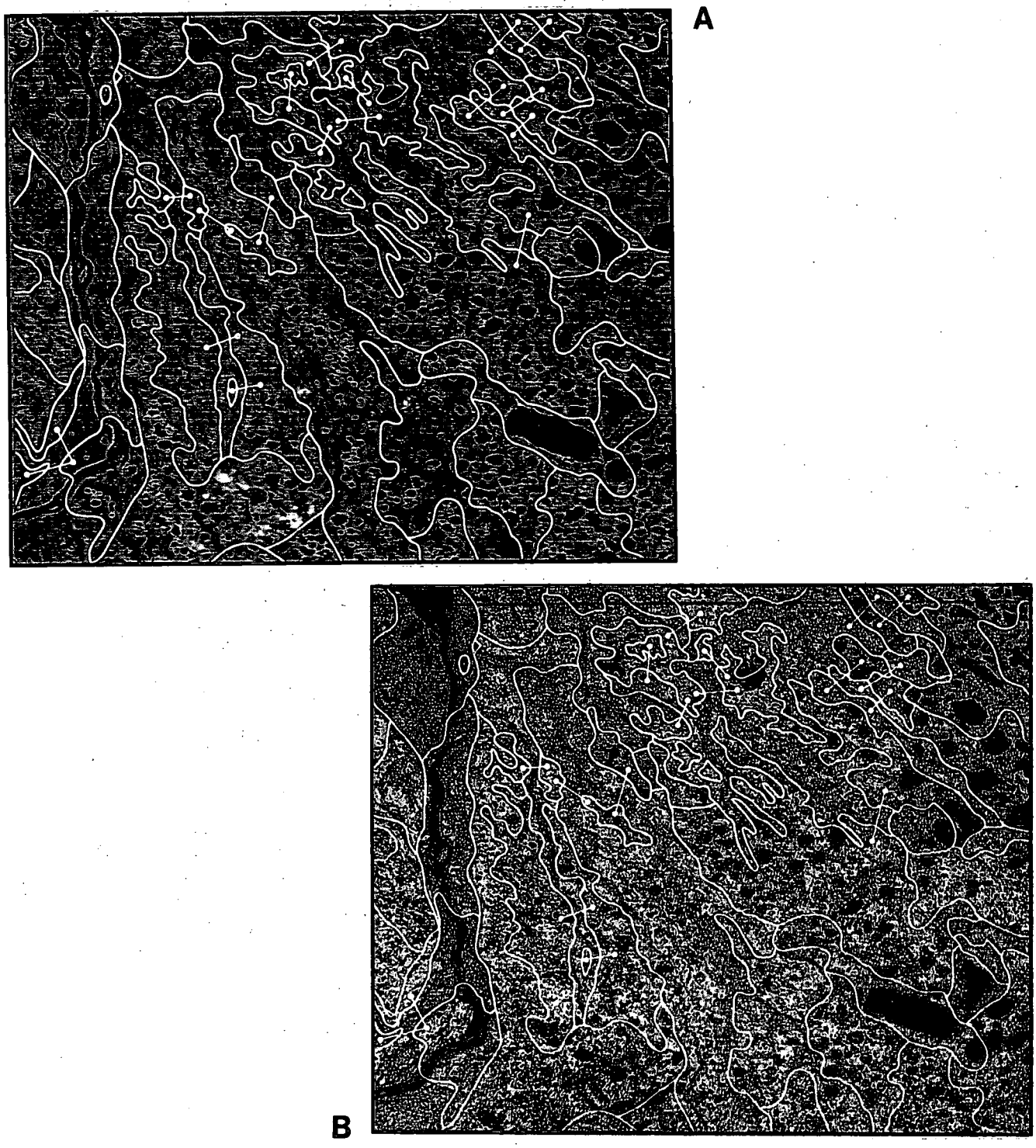


Figure 5: The Lovett Lake test area. A *is the digitally enlarged satellite colour composite, with delineation of land system by visual interpretation.* B *is the result of supervised automated classification. For comparison, the land system lines of* A *are superimposed on* B*. While there is a good general relationship between the two sets of information, there are some discrepancies in areas where cloud cover or slight haze interferes (arrows). Such interference is difficult to eliminate with automated techniques.*

CLASS	TOTAL MAPSHEET: omission as % of class	TOTAL MAPSHEET: omission as % of area	TOTAL MAPSHEET: total of class as % of map	BY DISTRICTS: MACK LAKE DISTRICT (2A): omission % of class	MACK LAKE DISTRICT (2A): omission % of district	MACK LAKE DISTRICT (2A): % of district	MACK LAKE DISTRICT (2A): % of map	KNIFE RIVERS DISTRICT (2B): omission % of class	KNIFE RIVERS DISTRICT (2B): omission % of district	KNIFE RIVERS DISTRICT (2B): % of district	KNIFE RIVERS DISTRICT (2B): % of map	TRANSITION DISTRICTS 2 and I: omission % of class	TRANSITION DISTRICTS 2 and I: omission % of district	TRANSITION DISTRICTS 2 and I: % of district	TRANSITION DISTRICTS 2 and I: % of map	SEAL RIVER DISTRICT: omission % of class	SEAL RIVER DISTRICT: omission % of district	SEAL RIVER DISTRICT: % of district	SEAL RIVER DISTRICT: % of map	LOFTHOUSE – LOVETT LAKES DISTRICT, TRANSITION IB and 2A&B: omission % of class	TRANSITION IB and 2A&B: omission % of district	TRANSITION IB and 2A&B: % of district	TRANSITION IB and 2A&B: % of map	DISTRICT IB: omission % of class	DISTRICT IB: omission % of district	DISTRICT IB: % of district	DISTRICT IB: % of map	TRANSITION (2) and IC: omission % of class	TRANSITION (2) and IC: omission % of district	TRANSITION (2) and IC: % of district	TRANSITION (2) and IC: % of map	COASTAL DISTRICTS: omission % of class	COASTAL DISTRICTS: omission % of district	COASTAL DISTRICTS: % of district	COASTAL DISTRICTS: % of map
A	1.4	0.4	29.0	-6	0.0	1	0.1	23	2.6	11	0.3	19	5.4	28	0.8	19	7.7	40	3.4	11	3.4	30	3.6	-4	-2.0	49	18.2	-6	-1.5	27	2.6	22	0.3	1	0.1
B	-78	-3.3	4.2	98	8.3	8	1.0	69	1.2	3	0.1	100	0.0	0	0.0	75	0.9	1	0.1	-188	-3.0	2	0.2	-336	-8.5	2	0.9	-21	-1.8	8	0.8	-59	-6.9	12	1.2
C	46	3.2	6.9	100	0.8	1	0.1	100	1.9	2	0.0	59	4.7	8	0.2	-74	-4.7	6	0.5	100	4.3	4	0.5	61	5.2	8	3.2	30	+3.5	11	1.1	41	5.3	13	1.3
D	-13	-1.0	8.0	10	1.3	13	1.6	84	26.6	32	0.7	48	5.4	11	0.3	-144	-5.3	4	0.3	-63	-8.3	13	1.6	0	0.0	7	2.5	-25	-1.2	5	0.5	-57	-3.3	6	0.6
E	33	4.4	13.0	5	0.0	0	0.0	-51	-0.7	1	0.0	7	0.4	5	0.1	-34	-2.2	6	0.5	85	5.1	6	0.7	26	6.5	25	9.7	65	11.6	18	1.7	91	4.0	4	0.5
F	-60	-0.9	1.5	-	-	-	-	-	-	-	-	100	0.4	0	0.0	+100	0.1	0	0.0	-	-	-	-	75	0.1	0	0.0	-123	-2.1	2	0.2	-57	-7.1	12	1.3
G	-5	-1.1	20.7	-11	-8.4	74	8.6	8	2.3	29	0.6	-1685	-3.2	2	0.0	-	-	-	-	-0.6	-0.3	39	4.7	-3	-0.1	4	1.7	-40	-9.8	24	2.3	35	9.5	27	2.7
H	-261	-0.6	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	0.3	0	0.0	94	0.0	0	0.0	-109	-0.9	1	0.1	-548	-5.6	1	0.1
I	-551	-1.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	493	-10.6	2	0.2
M	-22	-0.6	2.7	-	-	-	-	-42	-0.6	1	0.0	26	5.1	20	0.6	-34	-8.0	23	2.0	-	-	-	-	-100	-0.2	0	0.1	-100	0.3	0	0.0	100	0.0	0	0
N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O	-17	-6	3.6	-9	-0.3	2	0.3	-119	-22.2	19	0.4	-98	-21.7	22	0.6	49	7.8	16	1.3	85	1.0	1	0.1	+5	0.1	2	0.7	30	-0.3	1	0.1	-110	-1.1	1	0.1
P	-29	-0.5	1.8	-199	-1.0	1	0.1	-427	-7.8	2	0.0	100	2.1	2	0.0	100	2.9	3	0.3	-55	-2.4	4	0.5	-81	-1.3	2	0.6	100	0.9	1	0.1	70	1.5	2	0.2
R	66	0.2	0.3	-	-	-	-	100	0.1	-	-	100	1.3	1	0.0	100	0.7	1	0.1	-	-	-	-	100	0.0	0	0.0	100	0	0	0.0	5.6	1.5	2	0.2
Z	21	1.5	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	1.3	1	0.1	81	13.0	16	1.6
TOTALS			99.7			100	11.8			100	2.1			100	2.6			100	8.5			100	11.9			100	37.2			100	9.5			100	10.2
% misclass. A		9.8			-10.1				35.3				24.9				20.2				14.1				12.0				18.2				36.1		
% misclass. B		29.9			14.7				47.6				42.1				28.1				27.7				33.3				35.1				55.0		

L 84-9

*Table 2: Summary of misclassification per land district and for the total map area based on the results of the visual interpretation of 1:1,000,000 LANDSAT imagery. The class groups can be described as follows: A - Peat polygonal areas; B - **Carex** fens; C - **Larix** fens; D - **Picea**-dominated peatlands; E - Patterned fen areas; F - Marshes and swamps; G - Peat Plateaus; H - Palsas; I - Mud flats; M - Stone fields; N and O - Glacial till; P - Sandy beach and glaciofluvial deposits; R - Bedrock outcrop; Z - Water.*

zone and with some drainage and beach systems.

To study these physiographic aspects in more detail, the computer comparison of Maps I and IV for the land districts and the total map area is summarized in Table 2. Listed are:

(i) The omission per class group (A, B, C,.....Z) as a percentage of the class group.
(ii) The omission per class group as a percentage of the district or map sheet.
(iii) The actual area of the class group as a percentage of the district.
(iv) The actual area of the class group as a percentage of the map sheet.

The percentage of *misclassification A* is calculated by adding the absolute values of (ii) and dividing by two.

The classification results per land district and map area in this summary table are significantly lower than those identified for the separate land systems (Figure 3). Apparently, errors are cancelled out in the summation process. For example, in the Mack Lake District, misclassification A is 10.1% while Figure 3 shows that most land systems in this district have significantly higher amounts. To obtain a more accurate indicator, the classification performance for each land system was weighted according to acreage and summarized; it is called *misclassification B*.

$$\textit{misclassification B} = \frac{\Sigma[\textit{misclass. (A) for each land system} \times \textit{acreage}]}{\textit{Land district acreage}}$$

Table 1 shows that the Coastal and Knife Rivers districts have the poorest classification results, followed by the transition zones of districts (1B-1A) and (1B-1C). All three areas are physiographically complex. The relatively simple 'Mack Lake' district has the best classification performance: misclassification A is 10.1% and misclassification B is 14.7%. About 74% of this district is composed of peat plateaus. These are only 3.4% overclassified, mainly at the cost of sedge-dominated areas (class B) which as a result of generalization are consistently underclassified.

The Lofthouse-Lovett Lakes district and the Seal River district perform equally well on a land system basis, in spite of the fact that the Seal River area contains a significant proportion of mineral deposits (39% M and O). In both districts, peat polgons represent a large part of the unit (between 30% and 50%) and are consistently well-classified. In the Seal River district, the classification of patterned fens and stone fields is reasonably satisfactory (34% omission). In the latter, it is thought that the lack of vegetation on M (stone fields) has helped to identify the land types. Considerable confusion with O (till areas) is expected, as classes M_2 and M_3 include parts of O.

1:250,000 Scale LANDSAT Visual Interpretation

Table 3, showing the classification results for the Mack Lake, Seal River and Lovett Lake test areas, is similar to Table 2. From the results of misclassifications A and B, the detailed interpretation clearly does not compare well with the results of Map I based on 1:1,000,000 LANDSAT interpretation. The Map I results are clearly equal to or better than Map II results. Although delineation of a land system at the detailed scale is more accurate, it is not matched by a similar increase in classification accuracy. The interpretation time involved for Map II is only slightly less than that required for interpretation of aerial photographs.

	MACK LAKE			SEAL RIVER			LOVETT LAKE		
CLASS	omission as % of class	omission as % of area	total of class as % of area	omission as % of class	omission as % of area	total of class as % of area	omission as % of class	omission as % of area	total of class as % of area
A	-408	-16.0	3.9	25	9.5	38.0	16	6.6	41.8
B	-29	-1.7	5.8	-54	-12.5	23.1	-5	-1.9	41.1
C	-371	-5.4	1.4	19	2.0	10.7	-157	-4.4	2.8
D	54	6.2	11.5	7	0.2	3.4	9	0.1	8.5
E	-	-	-	-	-	-	-	-	-
F	-	-	-	-292	0.2	0.1	31	0.3	0.9
G	+20	14.8	73	-8756	-2.8	0.0	-14	-0.5	3.8
H	-	-	-	-	-	-	-	-	-
I	-	-	-	-	-	-	-	-0.2	-
M	-	-	-	-11.0	-1.6	15.0	-	-	-
N	-	-	-	-	-	-	-	-	-
O	70	1.1	1.5	49	4.1	8.3	100	0.5	0.5
P	3.5	1.0	2.9	100	0.7	0.7	100	0.0	0.0
R	-	-	-	100	0.5	0.5	-	-	-
Z	-	-	-	-	-	-	100	0.3	0.3
Total	na		100	na		99.8	na		100.0
% misclass A		23.1			16.9			7.1	
% misclass B		38.2			33.4			26.2	

Table 3: Summary of classification results for the three tests areas based on the results of 1:250,000 scale visual satellite interpretation.

AUTOMATED SATELLITE CLASSIFICATION

There are two different approaches to automated classification: supervised and unsupervised. Each was applied to single- as well as multidate satellite imagery. LANDSAT I tapes RSØ198 and RSØ35 were used; moreover, summer and winter data are combined using band 7 of RS2863 (30 October 1972) and bands 5, 6 and 7 of RS2940 (27 July 1972).

Supervised Automated Classification

In supervised classification, the interpreter selects the objects to classify and identifies training areas for the computer. Training areas were selected across the whole image by available ground control and photo-interpretation. This procedure allows the selection of relatively large, pure and representative sites for the respective land types. Classification was carried out using the CCRS computer, MAD (Multispectral Analyser Display) and the MICA interpretation package, developed by scientists at the CCRS. For the classification, the Maximum Likelihood Decision Rule was used in all evaluations, as implemented on the CCRS computer. After about 15 iterations of training, displaying, classifying and analyzing training statistics, a final training set evolved. This set, including water, represents 10 different class groups.

Table 4 shows the divergence and confusion matrix for the class statistics, and the final set. An increase in the number of classes was found to increase confusion and to give less satisfactory results. Initially, in the training process, an attempt to show land types (A_1, B_1, B_2, C_3, etc.) was tested, but confusion between spectral signatures of land types made it impossible at this level and quite broad class groups were used.

Using the final training set, the complete satellite image was classified (Figure 6). This result was subjectively evaluated on a land district basis by comparison with the ecological base map, detailed aerial photographs, and ground sampling. Figure 6 demonstrates the differences and relationships between the unclassified images, automated classification and visual interpretation.

Table 5 shows the results of this evaluation. The ratings only identify the classification accuracy of the different classes in the training set. Whether the particular class itself is satisfactory from an ecological viewpoint is not considered. Table 5 shows that the overall performance of the classifier is satisfactory. Best results (70%) are achieved in the Mack Lake, Knife Rivers and

DIVERGENCE MATRIX

CLASS	1	2	3	4	5	6	7	8	9
1	0.00								
2	15.78	0.00							
3	29.71	80.78	0.00						
4	69.29	24.64	105.96	0.00					
5	255.62	343.49	305.87	776.03	0.00				
6	51.28	77.46	30.56	130.40	612.99	0.00			
7	64.68	90.33	45.13	160.84	809.39	18.54	0.00		
8	54.83	130.89	32.09	267.86	531.33	8.68	37.20	0.00	
9	6.56	42.06	17.60	122.87	311.42	32.30	33.39	38.17	0.00

CONFUSION MATRIX

Chosen Class \ True Class	1	2	3	4	5	6	7	8	9
0	0	0	0	0	0	0	0	1	0
1	89	3	0	0	0	0	0	0	10
2	1	96	0	0	0	0	0	0	0
3	0	0	94	0	0	0	0	5	2
4	0	1	0	100	0	0	0	0	0
5	0	0	0	0	100	0	0	0	0
6	0	0	0	0	0	89	5	5	0
7	0	0	0	0	0	3	95	2	1
8	0	0	1	0	0	8	0	86	0
9	10	0	5	0	0	0	0	1	87

MEAN SPECTRAL INTENSITIES

Class \ Band	4	5	6	7
1 - sedge-bs/th	15.4	13.0	19.6	11.7
2 - open black spruce	14.8	11.1	21.9	12.9
3 - stonefields	18.3	16.2	21.1	11.1
4 - willow - alder-birch	14.9	10.5	27.5	18.3
5 - water	13.2	9.2	7.1	0.9
6 - peat plateaus	19.1	18.4	27.9	17.7
7 - peat polygons	17.5	17.4	25.7	17.3
8 - lichen/sand-till	20.5	19.5	27.7	16.8
9 - patterned fens	16.7	14.7	21.2	12.6

Table 4: Divergence and Confusion matrix and means statistics for the 'final' training set.

Seal River districts, possibly because these districts have seven or fewer classes. The Lofthouse-Lake district and its transition zones perform uniformly with about 65% classification accuracy. The Coastal Zone has the poorest showing: none of the classes except 'water' and 'willow/alder/birch' perform well.

Although the classification results can be described as satisfactory for the total map area, they do not indicate that the automated classification can generate useful results. The nine-class final legend is too broad and too sinple to be of much value. As a vegetation classification, the results could be considered successful; however, as a biophysical classification, the method performs poorly. As there is a relation between classification results of land districts and distribution of classes, automated classification may be improved by classifying on a land district basis. This procedure implies that training takes place within a district and is repeated for each district, and that legends

Figure 6: Map III - A supervised automated classification of the Churchill area. Map-sheet 54L is identified by thick line. Colour themes were generated through the use of the CCRS Multispectral Analyser Display (MAD).

dark blue	- water	brown	- peat plateaus
light blue	- sedge-bs/tl	yellow	- peat polygons
green	- open spruce	pink	- lichen/sand-till
red	- stone fields	grey	- patterned fens
orange	- willow-alder	black	- unclassified.

*Table 5: Evaluation of supervised automated classification results for total map-area and for each land district: 1 - very poor; 2 - poor; 3 - imperfect; 4 - satisfactory; 5 - good; and 6 - very good. *Indicates that the particular class does not occur in appreciable quantity.*

CLASS	KNIFE RIVERS DISTRICT (2B)	MACK LAKE DISTR. (2A)	SEAL RIVER DISTR. 1A	LOFTHOUSE-LOVETT LAKES DISTR			COASTAL DISTR. 1C	TOTAL MAPSHEET
				TRANSITION 1B-2B	1B	TRANSITION 1B-1C		
1 Sedge-bs-tl	1	3	2	3	2	3	1	3-
2 Open black spruce	4*	5	4-	4-	4-	3	3	4-
3 Stonefields	5*	6*	4+	5*	6*	5*	4*	4+
4 Willow/ald/birch	6*	6*	6*	6*	6*	6*	4+	4+
5 Water	5	5	6	5	5	5	5	5+
6 Peat plateaus	4	4+	5*	4	3-4	4+	1	4
7 Peat polygones	5*	2	4	3	4	2-3	2	4-
8 Lichen-sand-till	4-	4	4+	4-	3	2	3	3+
9 Patterned fens	6*	6*	2	3	2	3	1	3-
10 Unclassified	5	3	5	2	3	5	4	4
All Classes	4	4+	4	4	4	4	2	4

would vary according to districts. Confusion would be reduced considerably. However, it would also increase the reuired time for training and classification of a satellite frame 5 to 20 times, assuming that about 5 to 20 land districts are likely to occur in one satellite frame. Although this procedure would not drastically increase computer time, it would require a number of days of interactive supervised training, with the probable result of a 20- or fewer class legend, varying according to land district and heavily biased toward vegetation.

Unsupervised Automated Classification

In the three test areas (Seal River, Mack Lake and Lovett Lake), supervised classification was carried out using a multidimensional histogram approach (Goldberg and Shlien, 1975). In this method, the image to be classified is scanned and a four-dimensional histogram of intensity vectors is created. By choosing a threshold, the intensity vectors can be grouped into clusters. The interpreter chooses the threshold value. This procedure makes the approach interactive; the interpreter can break up a specific cluster by raising the threshold value and treating only the vectors belonging to that cluster (Goldberg and Shlien, 1975). Figure 7, showing the Long Island area and part of the Lovett Lake test area, permits the comparison of an unsupervised clustering (A), a supervised classification (B), and interpretation (C) of 1:100,000 scale black and white photographs. (C) shows typical biophysical land systems as complexes of land types, with each primary land type identified by a class and percentage of occurrence. The unsupervised classification provides the most detailed map themes. (A) is the result of about 16 clusters, only 10 of which occur in considerable quantity. (B) maps only 9 class groups.

The unsupervised clusters are not better classes or land types than the ones derived from supervised classification. In fact, the results of the supervised classification closer to an ecologically desirable map than are the results of the unsupervised classification.

The advantage then of the unsupervised technique is that the computer, with little user interaction and time, gives an impression of which objects are separable. However, relating clusters of practical classes and themes and grouping them is usually not a simple task. It can be time-consuming and still not provide the most desirable classification. In addition, such 'editing' requires at least as much ground control as is needed for supervised classification.

Use of Multidate Imagery for Automated Classification

The visual interpretation of satellite images has demonstrated the value of using multidate satellite imagery for classification purposes (Thie *et al.*, 1974; see Figure 8). Kalensky (1974) also reported improved classification accuracy for vegetation mapping using multidate information. Winter imagery, especially, contains information that is complementary to summer date. Figure 9 demonstrates the considerable difference between the spectral characteristics of a summer and a winter channel As a result of the very special associations among vegetation, soils and permafrost in this subarctic area, winter imagery enhances, for example, the distribution of well-drained glaciofluvial and beach deposits. The Seal River test area was used for the multidate evaluation as it has suitable representation of mineral and organic soils, and vegetation is not visibly disturbed. Both supervised and unsupervised classifications were applied to a tape composed of three summer channels and one winter channel. The addition of the snow covered image was mainly beneficial for areas covered with vegetation (trees and shrubs) that is sufficiently high enough to penetrate the snow layer and dense enough to lower reflectance values of

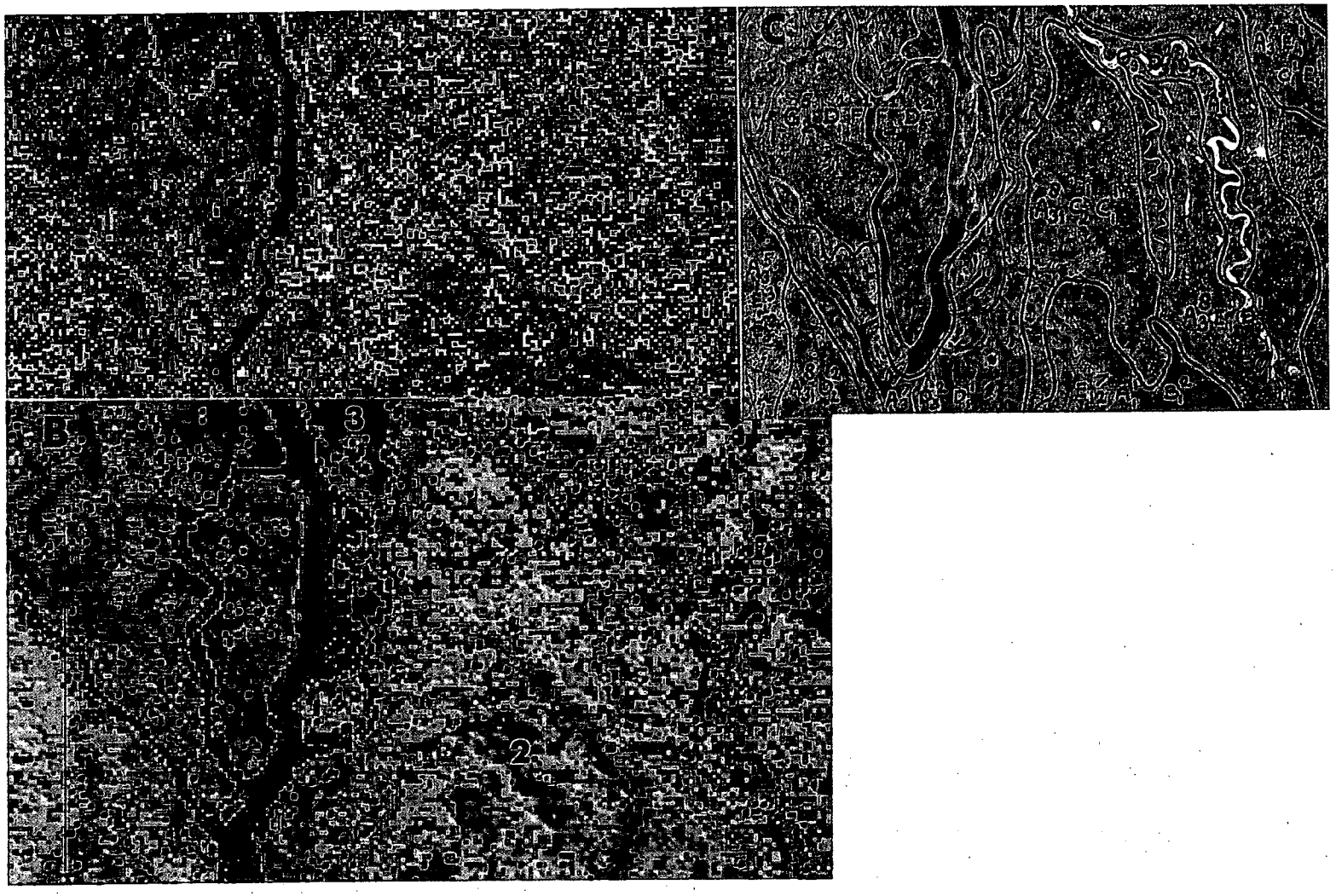
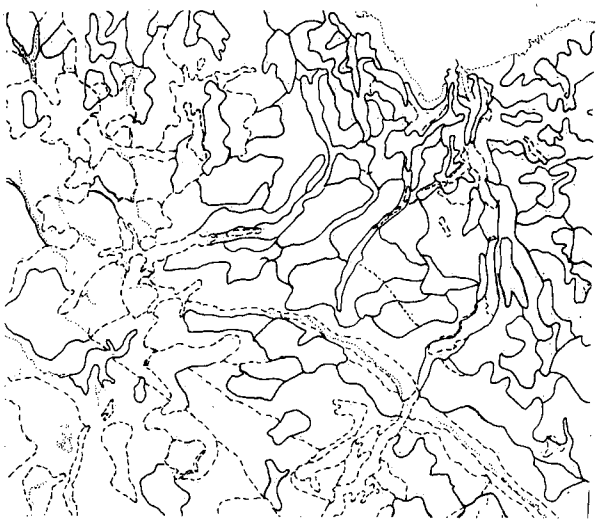


Figure 7: Comparison of unsupervised A, *supervised* B *and interpretation of B&W aerial photographs. Colour scheme of* A *is explained in Figure 4.* C *shows land system with percentage of land types.*

Figure 8: Land system boundaries derived from summer (closed lines) and winter (broken lines) satellite imagery through visual interpretation.



snow. However, in areas either devoid of vegetation or with the vegetation completely covered by a snow mantle, the addition of the winter channel was not beneficial, and occasionally lowered classification accuracy. Such was the case with the stone field theme.

COMPARISON OF INTERPRETATIVE METHODS — DISCUSSION

Table 6 compares the time and cost requirements for the various interpretative methods, including those for the ecological base map. In addition, the information value of each of the maps for resource management was subjectively estimated, based on the requirements for *regional* resource planning. Out of a possible value of 100 (i.e. satisfying most biophysical information requirements for regional resource planning though not necessarily local requirements), the satellite-based techniques do not score higher than about 15 (1:250,000 visual satellite interpretation). The ecological base map, made through conventional photo-interpretation, has a value of about 75.

Taking into account the time and cost considerations, Table 6 shows that visual interpretation of 1:1,000,000 LANDSAT imagery is the most cost-effective satellite interpretation method.

Of the 50 representative land types for the area, only a few can be mapped satisfactorily using the satellite techniques. This means that spectral signatures are inadequate to map land types using automated techniques and that the addition of shape information using visual techniques does not change this significantly. The success of the photo-interpretation in mapping and describing 43 of the 50 land types is likely the result of the relief information available in the three-dimensional model, and the shape information of landforms and micro-landforms, rather than signatures.

To obtain a reasonable classification with the tested interpretative methods, the 50 land types (classes) had to be joined into broader class groups. In this way, 15 class groups were separable with the visual satellite interpretation and about 10 with the automated techniques. These class groups are so broad

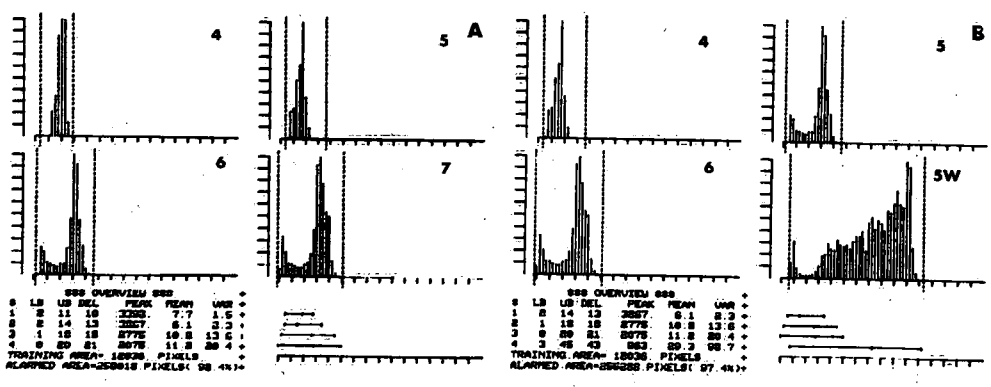


Figure 9: One-dimensional histogram displays of the intensities of the composite summer-winter image B *(summer channels 4, 5 and 6; winter channel 5W) and the summer image* A *(summer channels 4, 5, 6 and 7) for the same clustering training area. The horizontal axis displays the reflectance values (from 1-63) and the vertical axis, the frequency of pixels with those values. Note the wide range of distribution and the skew towards light reflectance values of (5W).*

Table 6: Time and Cost Considerations

TIME AND COST CONSIDERATIONS*

Per 13,000 Km^2

		Time	Mat.	Labor	Information Value
1:1,000,000	LANDSAT (VISUAL)	15-20 hrs	$ 100	$ 600	8-10
1:250,000	LANDSAT (VISUAL)	80-100 hrs	$ 100	$3000	15
AUTOMATED	LANDSAT	15-20 hrs	$2000	$ 600	5-10
1:100,000	Ecological Base Map	120-160 hrs	$ 200	$4800	75

* Only listed is the time and cost for interpretation of imagery. Cost of fieldwork is not included. Fieldwork cost can be considered the same for all methods. It constitutes up to 80% of the total survey cost for conventional type surveys, depending on the accessibility of the area. (Thie et al, 1974).

that their value to resource managers is very restricted, hence the low rating (5-15) in Table 6. The study indicates that an increase in the physiographic or ecological complexity of the land area causes an increase in misclassification with all satellite interpretative techniques. The more complex areas have a greater variety of surficial materials, vegetation and relief. The present resolution as well as the lack of detailed relief information appears to be the main limiting factor to apply satellite interpretative methods.

This study demonstrates that classification methods based only on spectral signatures did not map enough land types. The relative success of the visual analysis as compared with automated methods might be due to the use of shapes and spatial patterns in the interpretative process, as well as the use of multidate images. This apparently more than compensates for the loss in spectral information. It can be argued that present automated interpretative techniques allow geometric corrections, multidate overlays, and simple spatial feature analysis. While they should improve classification results, they also require additional computer and training time. Costs involved *at present* make it unattractive for operational use.

This study was unusually simple for Canadian circumstances with regards to ecology and physiography. The land surface is flat or at most lightly sloping. Surficial materials cover extensive areas and are not mixed. Most important, due to a lack of distrubing agents, vegetation and therefore its signatures can be considered a good indicator of ecosystem or land type conditions. Thus, changes in relief, soil, drainage, landform, habitat, etc. are reflected in vegetation gradients or boundaries. However, this exceptional situation does not hold for most of Canada. Vegetation has been disturbed through land use, and in northern areas, forest fires and disease are even more important. In those situations, changes in vegetative cover are not usually related to changes in land types. Figure 10 gives a striking example of the impact of forest fires on the vegetation pattern of the boreal zone in Canada. Satellite imagery classification, expecially automated performance, can be expected to drop considerably in such areas. While mapping of vegetative cover type can be reasonably successful with digital techniques, soil, landform, and land type classifications appear doomed to fail for large areas, except large wetlands.

The above mentioned limitations do not apply to air photo interpretation techniques. Through the use of relief and shape information, fire boundaries can be identified, and only those vegetation boundaries are used that are considered to reflect land type conditions.

CONCLUSIONS

Taking into consideration the usefulness of data resulting from the various interpretative methods for resource management purposes, photo-interpretation of small scale aerial photographs *presently* provide the best cost- and data-effective method for ecological land classification in Canada. Satellite data should be used in a complementary way; that is, to assess and delineate environmental dynamic phenomena,

Figure 10: Forest fire patterns in the boreal zone near Black Lake, Saskatchewan. The snow cover on this 7 March, 1974 LANDSAT image enhances the complex forest fire pattern. Some areas (A) *were burned more than 100 years ago, others very recently* (B)*; most of the area is burned repeatedly. This image shows forest fires to be an integral part of the boreal ecosystem.*

and to delineate land districts.

Visual interpretation of 1:1,000,000 multidate satellite imagery provides an operational alternative only if more than 20,000 km^2 per man-year has to be mapped, and then only in ecologically and physiographically simple areas: arctic, subarctic, and large wetlands in the boreal zone. Automated classification appears, *at present*, unsuitable for ecological land classification in Canada. While certain simple maps can be made for arctic and subarctic areas and boreal wetlands, the practical usefulness of this information is somewhat in doubt. It is expected that this assessment will change when a significant breakthrough occurs in the automated analysis of shapes and textures.

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ECOLOGICAL (BIOPHYSICAL) LAND CLASSIFICATION PROJECT

REPORTS

RAPPORTS DES PROJETS DE LA CLASSIFICATION ÉCOLOGIQUE (BIOPHYSIQUE) DU TERRITOIRE

BIOPHYSICAL MAPPING IN THE MACKENZIE VALLEY

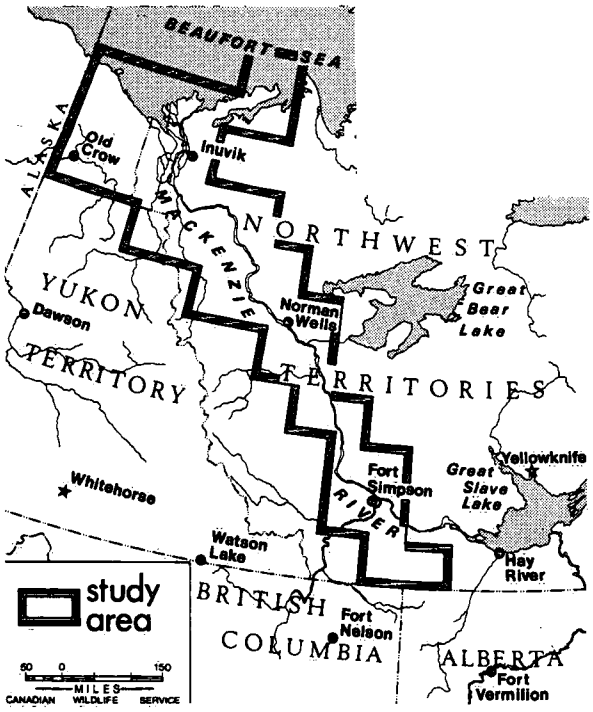
S.C. Zoltai
Canadian Forestry Service
Environment Canada
Edmonton, Alberta

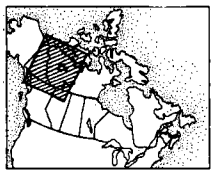
In 1970, the Geological Survey of Canada (GSC) undertook a three-year program of mapping the surficial deposits in the Mackenzie Valley and northern Yukon. As environmental concerns relating to a possible energy transportation corridor became evident, the survey was expanded to include such terrain sensitivity indicators as vegetation and soils. In 1971, the Canadian Forestry Service was invited to provide the vegetation input, and the Soil Research Institute was invited to provide pedological information.

The resulting survey was clearly a surficial geology study, with vegetation and soils added on. Thus, it was never intended nor organized to be a biophysical study. The investigators of the vegetation-soils aspect had two viable choices: 1. to use the mapping units identified by the GSC to characterize the vegetation and soils of the area; and 2. to map biophysical characteristics of the area. The size of the area (120,000 mi^2) and time constraints (two field seasons) were important constraints, as each of the two teams were to cover about 30,000 mi^2 a year.

The northern team chose to use the mapping units prepared by the GSC at a scale of 1:125,000. The mapping units, as conceived by the GSC, were to be based strictly on the genesis of the surface materials. The vegetation-soils team was successful in persuading the surficial geologists to add such features as texture and slope to their mapping criteria. This made the resulting units more suitable to vegetation-soil interpretation and paved the way to a modified biophysical classification. The modification was necessary, as the main thrust of the project was not productivity of the terrain, but sensitivity to disturbance.

The southern team chose to map the area, applying a biophysical classification, as interpreted by the investigator. This study





Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

very rapidly became a nightmarish exercise in mapping and air photo interpretation of the huge area at the detriment of field studies, as both the surficial geology mapping and the biophysical mapping were proceeding concurrently, without effective interchange of ideas or maps. In 1972, the Soil Research Institute became involved with the southern team and produced an integrated report with the Geological Survey (Tarnocai, 1973).

The northern team, free of the burden of duplicating the mapping effort of the GSC, concentrated on studying and understanding the relationships between landforms (identified by the GSC), vegetation, and soil (active layer). Two avenues were taken in the reporting: one presented the findings of the vegetation-soils team only (Zoltai and Pettapiece, 1973), and the second avenue was to integrate the vegetation-soil-active layer results into the legend of the map by GSC. In the legend, the Land Zones (e.g. Land or Site Regions) were established on the basis of vegetation chronosequence and permafrost characteristics. Within each Land Zone (Region), the mapping units were characterized as to vegetation and soils. The stable and fire-originated vegetation were indicated for the major moisture regimes (drainage classes) of each landform. Likewise, the soil texture, depth of active layer and frost-induced microrelief were given for each major drainage class of each mapping unit in the different Land Zones (Regions).

This study and subsequent field work in 1973 (Zoltai and Tarnocai, 1974) enables us to develop a terrain sensitivity classification (Van Eyk and Zoltai, 1975). In this scheme, each drainage class of all mapping units was rated as to the expected reaction to specified surface disturbances. The resulting ratings were generalized and portrayed on a 1:1,000,000 map. This map, while too generalized to be of value at the local level, shows the regional picture and puts southern (boreal forest) features on the same scale as the northern (tundra) features.

The cost of the survey in relation to a biophysical survey cannot be determined. The GSC, being the lead agency, decided the various aspects of the field investigations. Thus, much effort may be spent on an area of complex glacial history, while other areas of simple depositional history may receive little attention, although this may be an area sensitive to disturbances.

The northern team consisted of two or three professional Pleistocene geologists, a geophysicist, a vegetation man and a soils man. With support staff (technicians, pilots, students, labourers and cook) the whole crew numbered about 16 persons. A helicopter and a Beaver aircraft supplied full-time transportation. A biophysical survey, yielding comparable results, could have been completed by about half the crew in the field, with comparable savings.

My estimate is that such a survey could be conducted for $175,000 to cover 30,000 mi^2, or about $6/$mi^2$.

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EASTERN MELVILLE ISLAND: BIOPHYSICAL ASPECTS OF A GEOLOGICAL SURVEY RECONNAISSANCE MAPPING PROGRAM

D.M. Barnett
Terrain Sciences Division
Geological Survey of Canada
Ottawa, Ontario

ABSTRACT

This paper is a summary of a fuller treatment being released as GSC Paper 76-23. It highlights some of the concepts developed on Melville Island in integrating the data of geomorphologists, geologists, botanists and wildlife biologists resulting in 1:125,000 scale photomosaic maps, expanded legends and an encyclopedic text.

RÉSUMÉ

Le présent article constitue un résumé d'un communiqué plus élaboré de la Commission géologique du Canada publié sous le numéro 76-23. Il met en lumière quelques-uns des concepts élaborés dans l'île Melville concernant l'intégration des données recueillies par des géomorphologistes, des géologues, des botanistes et des biologistes de la faune en vue de la production de cartes photomosaïques au 1:125,000e, de légendes détaillées et d'un texte d'information.

INTRODUCTION

The biophysical aspects of the Eastern Melville Island project were experimental and the methodology was evolutionary, particularly in the data presentation phase. Several progress reports have appeared (Barnett and Dredge, 1974; Barnett *et al.*, 1975a), a general approach advocated (Barnett *et al.*, 1975b) and a detailed encyclopedic text with the maps released as Geological Survey Open File 252 (Barnett *et al.*, 1975c). A formal methodological paper outlining the basis for the mapping system is in press and will appear as GSC Paper 76-23 (Barnett *et al.*, 1976). This paper is an attempt to précis the most important points of particular interest to those concerned with Ecological Land Classification.

CONCEPTS

1. A single map was to depict units which had common boundaries formulated by geologist-geomorphologists, botanists and wildlife biologists, all of whom were anticipated to recognize various natural subdivisions of the terrain. Not all boundaries were anticipated to be significant to all disciplines. This single map concept was philosophically in contrast to the Mackenzie Valley studies which were carried out largely independently. In the latter case, the data then had to be recompiled, not without difficulty, for the pipeline evaluation process.

2. In spite of the high latitude of Melville Island, glacial deposits and related erosional features are not common attributes of the landscape which is dominated by sedimentary strata (Figure 1) and their weathering products.

3. Despite the relative lack of glacial features, the island was depressed by an ice load and the coasts were inundated by the sea up to as much as 110 m above present sea level. This inundation led to the admixture of marine silts with whatever surface materials occur, and also led to richer plant communities below marine limit by both amount and species.

4. As pipelining is one of the more probable major undertakings for which environmental data will be useful, it was decided that the top three m of material was our target for evaluation. This policy must be borne in mind when evaluating the maps, for on occasion, below the marine limit, a major boundary occurs for which there is little or no evidence on the imagery. In such localities (perhaps one m below the surface), a major change in materials is predicted but it is covered by a suite of beach materials, marine silts or colluvium.

5. Although geological, geomorphological, botanical and wildlife habitat data were combined in determining the location of boundaries, this was not done in such a way that

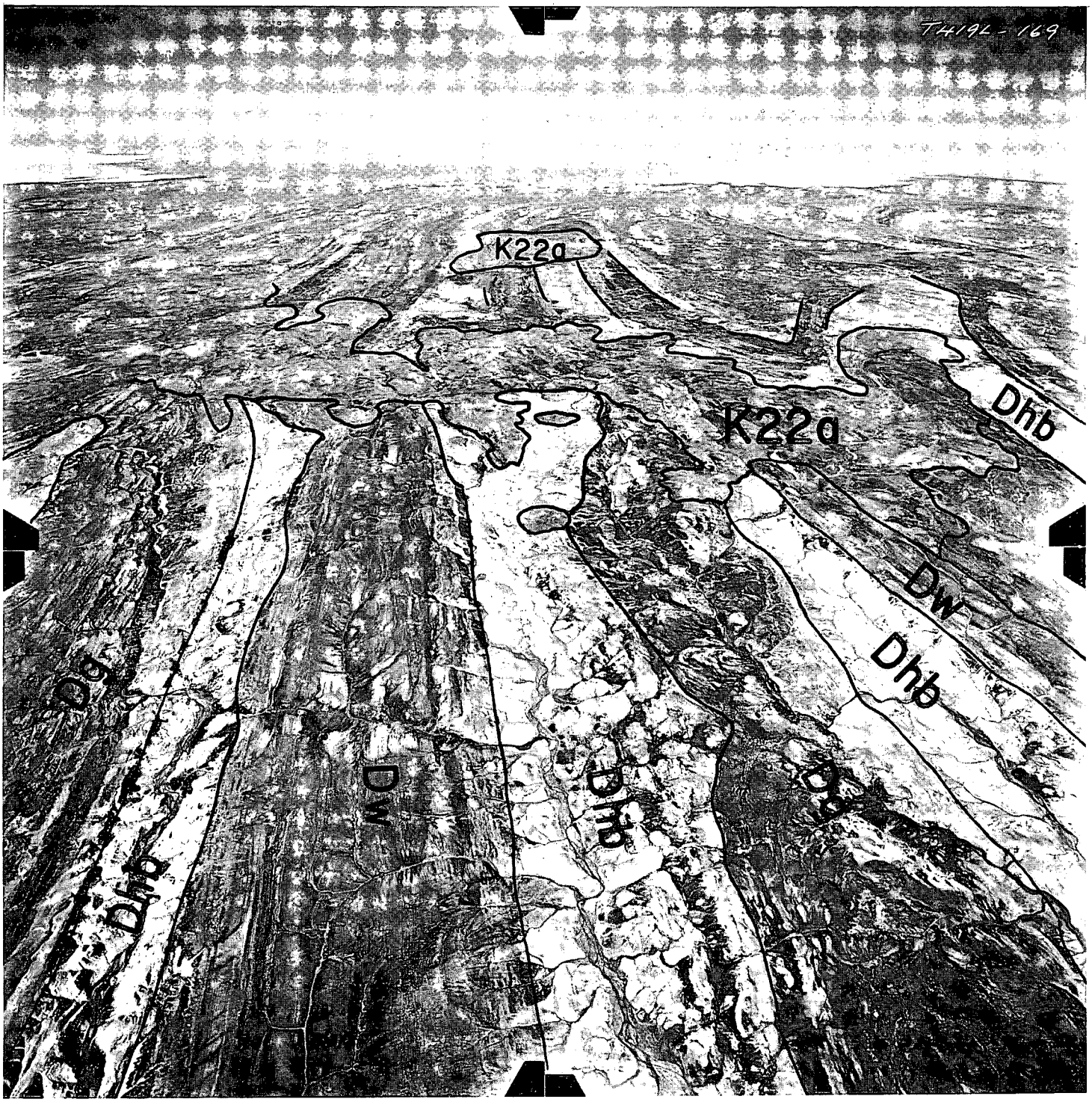

Figure 1: Aerial oblique photograph looking west across the Devonian sandstone upland west of Rea Point, eastern Melville Island. In the middle ground a belt of unconsolidated Cretaceous deposits (K22a) is visible resting on the Griper (Dg) Hecla Bay (Dhb) and Weatherall (Dw) sandstones. Landscape type boundaries are shown.

Trb

Attribute	Level	1.002	1.003	1.005	1.040	2.008	2.020	2.040	2.043	2.101	2.102	2.103	2.107	2.108	3.007	3.209	4.109	4.202	4.206
GEOBOTANICAL FACIES sq. km. % area	LT	BJORNE SANDSTONE (Trb) 694.5 sq. km.																	
	Gbf	1.BJORNE ALLUVIUM 28.7 sq. km. (4% Trb)				2. BJORNE SANDSTONE BML 306.5 sq. km.									3. VEGETATED BJORNE SANDSTONE AML 79 sq. km. (11% Trb)		4. UNVEGETATED BJORNE SANDSTONE AML 283.4 sq. km. (41% Trb)		
TERRAIN UNIT % area	TU	1.002 Alluvial terraces partially vegetated 7.2 sq. km. 25%	1.003 Alluvial terraces well vegetated 11.7 sq. km. 41%	1.005 Braided channel 7.0 sq. km. 24%	1.040 Tundra ponds 2.8 sq. km. 10%	2.008 Lake 0.5 sq. km. (-)	2.020 Beach ridges 43 sq km. 14%	2.040 Tundra ponds 10 sq. km. 3%	2.043 High center polygons 2.9 sq. km. 10%	2.101 Discontinuous marine veneer, poorly vegetated 22 sq. km. 7%	2.102 Discontinuous marine veneer, partially vegetated. 29 sq. km. 10%	2.103 Discontinuous marine veneer, well vegetated 159 sq. km. 51%	2.107 Clay veneer 6 sq. km. 2%	2.108 Fluvial veneer 8 sq. km. 3%	3.007 Gorge/ravine 7.3 sq. km. 10%	3.209 Well vegetated, moderately dissected bedrock 68.6 sq. km. 90%	4.109 Rubble veneer 92.3 sq. km. 33%	4.202 Poorly vegetated, moderately dissected bedrock 87.4 sq. km. 31%	4.206 Partially vegetated, moderately dissected bedrock 103.7 sq. km. 36%
SUMMARY EVALUATION / ENVIRONMENTAL VARIABLES: MORPHOLOGY & RELIEF	LT	Ridge former with northerly dip; generally rounded topography: open terrain at higher levels; some incision in lower reaches. Vegetated facies more angular in morphology. Ranges from sea level to 210 m. Generally an east-west grain to the structures.																	
	Gbf	Terraces, river channels and between terrace depressions. Relief 60 m.				Undulating terrain, gentle slopes, moderately dissected, 70 m. relief.									Scarp & dipslope angular in section. 60 m - 150 m.		Rounded topography, open valley scarp slopes. 60-210 m a.s.l.		
	TU	elongate fluvial terr. adjacent to channels. Unit relief 20 m. Local relief 3 m.	elongate fluv. terraces highest terraces most stable. Unit relief 60 m.	anastomosing channels and bars. Unit relief 60 m. Local relief 2 m.	low relief surface; small ponds on oldest terraces. Local relief 2 m.	shallow oblong shape 3 m. deep (est.)	linear, quasi-parallel ridges & troughs on intermediate slope. Unit relief 30 m. Local relief 2 m.	grouped shallow ponds on flat surface. Polygons sometimes present. Local relief 2 m.	group of polygons, 10-30 m. diam. with thaw troughs. Unit relief 15 m. Local relief 2 m.	moderate dissection, close spacing; steeper than 2.103. 20° slopes. Unit relief 20 m.	moderately dissected; closely spaced. 15-20° slopes. Unit relief 40 m.	lightly dissected, 8-15° slopes Unit relief 50 m.	uniform slopes moderately dissected Unit relief 20 m.	along river channels in narrow terraces Unit relief 60 m. Local relief 2 m.	steep sided, V-shaped valleys Unit relief 30-40 m.	hilly, moderately to deeply dissected escarpment. Unit relief 100 m. Local relief 15 m.	convexo-concave hilly topography, haematite rich rubble cap; mod. dissected, close spaced Unit relief 180 m.	convexo-concave, open rounded hilly terrain Unit relief 100 m.	moderately dissected low hills Unit relief 75 m.
DRAINAGE	LT	Rectangular pattern; well drained with sand and gravel stream bottoms. One 4th order stream plus several 3rd order streams. Stream will fluctuate very rapidly during snowmelt & following heavy summer rain.																	
	Gbf	3rd order, broad, shallow channels.				Dendritic, in well defined channels, generally well drained; small units with poor internal drainage. Tends to conform to structure.									Channelled. no standing water. well drained.		Several dry valleys; drains rapidly, rapid fluctuation of flow.		
	TU	1st order channels. Well drained. Moderate to low soil moisture	moderate soil moisture	3rd order linear streams. Rapidly fluctuating flow	internal, non-integrated poorly drained.	3rd order stream drains lake.	1st order channels; internal in swales--ponds.	internal drainage saturated soil	internal drainage around polygons. centres drier. troughs-high soil moisture	well drained, channeled flow with short, steep tributaries. Soil moisture low	channeled; short steep streams. well drained	rectilinear and conforming to structure; 4th order streams; moderate to well drained	channelled 1st order streams. soil moisture high on clay, moderate at depth.	found along 3rd and 4th order segments. channels well defined	2nd order streams in deep channels. well drained.	2nd order streams. generally low soil moisture.	rectangular, with short dendritic tributaries soil moisture low	2nd order flow in open channels. well drained very low moisture content	1st order channelled flow; dendritic, low to moderate soil moisture.
SURFACE MATERIALS (includes SSC)	LT	Medium quartzose sand with occasional conglomerates. Predominantly reddish sands, locally grey. A very resistant haematite lag gravel, which is a distinctive dark red, occurs locally. This is a frequent lining of stream beds.																	
	Gbf	Unlithified sand and gravelly sand. Generally orange-red in colour.				Unlithified graded sands with excess fines. Materials locally gravelly. All materials a characteristic red-orange colour.									Medium quartzose sand. grey in colour		Well sorted, unlithified sand with gravels; clay-silt binder.		
	TU	uniform medium grained sand, sometimes with gravelly veneer. SSC 90-5-5	sand, with surface fines. SSC 98-1-1 (at 50 cm.)	sand with gravel locally. SSC 95-2-3	sand between ponds. fines at bottom of ponds. SSC 90-5-5	lake water	red orange sand or gravelly sand. Some fines in swales. occasional boulders. SSC 90-5-5 (est.)	sand. fines at base of ponds SSC 90-5-5 (est.)	gravelly sand-30% above 2 m diameter. SSC 95-2-3	sand with excess fines (20%) SSC 80-10-10 (est.)	sand with excess fines in topographic lows SSC 80-10-10 (est.)	unlithified orange sands with admixture of marine silts. SSC 63-21-15 (4) surface 73-14-12 (4) 1 m.	sandy with high silt-clay component (60%) at surface SSC 40-25-35 (est.)	river bed cobbles & pebbles. terraces of gravel with fine sand and fines. unlithified	sand, moderate lithification of gorge walls SSC 85-10-5 (est.)	mostly sand but with 22% fines at depth. unlithified. SSC 87-7-7 (3) surface 78-11-11 (3) subsf	unlithified uniform, ochre-red sand underlying gravel veneer. SSC 94-4-2 +14% gravel.	med. quartzose sand with a binder of fines; red gravel on surface. unlithified. SSC 86-6-8 (4) surface 95-2-3 (2) 55 cm.	medium sand with a silt-clay binder SSC 80-10-10
VEGETATION	LT	BML, vegetation cover is primarily based on Luzula associations; only in localized areas do graminae, willow and saxifrage become significant. Bjorne Sandstone AML is characterized by saxifrage based communities; 2/3 of area is poorly vegetated saxifrage barrens; the other 1/3 has well vegetated saxifrage communities with various cryptogamic understories																	
	Gbf	Stabilized alluvium-well vegetated by Luzula/patina commimities; areas with ponds have monocot associations. Stabilizing alluvium has scattered monocots and herbs which sometimes form substantial tussocks.				Mesic areas have a Luzula based upper strata. Lower strata components (moss & patina) vary with moisture availability.									Almost total (>70%) vegetation cover- saxifrage based communities. Variation in % cover related to moisture availability.		Mostly saxifrage barrens (less than 5% cover); some areas nearly vegetation free. Localized areas of patina sub-strata occur on one unit.		
	TU	10% rush-herb 50% patina occasional tussocks	20% Luzula 70% patina	Nil	pond edge: 25% sedge-grass 75% moss *inter-pond areas: 10% Luzula (Salix) 70% moss-patina	*5% Puccinellia-Stellaria humifusa barrens.	crest: 5% Luzula-lichen barrens *slope: 10% Luzula 70% patina swale: 15% grass-sedge 80% moss	pond edge: 20% monocots 70% moss slopes: 10% mixed monocots 60% moss *between ponds: 20% Luzula 70% patina	*centres: <10% saxifrage barrens slopes: 10% Luzula-grass 40% patina troughs: 15% luzula-grass 70% moss-patina	<5% saxifrage-Luzula barrens	*topog. highs(60%area): <5% Saxifrage barrens lower slopes (40%area): 10% Luzula-saxifrage 50% patina	12% Luzula 70% moss-patina (1:1)	*slopes: (90% area) 15% Salix arctica 70% patina impeded drainage:(10%) 20% Salix-monocot 70% moss	terraces: 10% luzula 60% patina river bed: nil	*slopes: <2% saxifrage-lichen barrens valley bottom: 10% saxifrage 70% moss-patina	crest: <8% saxifrage-lichen barrens *midslope: 10% saxifrage 70% patina lower slope: 10% saxifrage 85% moss-patina	<5% saxifrage barrens	<1% saxifrage barrens	*highs and upper slopes <5% saxifrage barrens colluvial slopes: 7% saxifrage 50% patina
ZOOLOGICAL COMPONENT: MAMMALS	LT	Survey densities / 100 sq. km.:(1) muskoxen, all five surveys 6.6, winter (two) 7.3, summer 6.2. (2) caribou, all surveys 2.9, winter 7.3, summer 0. Muskoxen occur almost exclusively in lowland regions within 13 km. (8 mi.) of the coast. Those coastal strips constitute important range. The unit is important to caribou in winter, especially if snow conditions are severe. Poorly vegetated hilltops in the western half of the unit are important or critical to caribou in some winters e.g. 1972 and 1974.																	
	Gbf	Densities: (1) muskoxen, all surveys 25.5, winter 0, summer 42.4. (2) caribou,all survey 0. Summer use by muskoxen is indicated.				Densities: (1) muskoxen, all surveys 10.5, winter 16.3,summer 6.7. (2) caribou, all surveys 2.0, winter 5.0, summer 0. Portions of Trb 2 are important to muskoxen and caribou.									Survey densities zero for muskoxen & caribou, but 3.209 of some importance to the latter.		Densities: 1) muskoxen, all surveys 0.9, winter 0, summer 1.5. 2) Caribou, all surveys 5.5,winter 13.8, summer 0.		
	TU	M3 C3	M2 C2	M4 C4	M1 C3	M4 C4	M4 C1	M3 C3	M4 C3	M4 C3	M4 C3	M2 C2 (M1) (C1)	M4 C4	M2 C4	M4 C4	M4 C3 (C2)	M4 C2	M4 C2	M4 C2
BIRDS	LT	Most of the birds recorded were on the west side of Sabine Peninsula.																	
	Gbf	Low value to birds.				Units 2.020 and 2.107 are important as moulting areas for 3 species of non-breeding waterfowl in July and August.									Unit 3.209 may have some importance to Snowy Owls and Raptors when lemming activity is high.		Little use by birds.		
	TU	W3	A4	A4	(A4)	W2 R3	W1 S3	W2r	W3 S3	W3 S3	A4	Wp	W1	A4	A4	(Rb)	(A4)	(A4)	(A4)
GROUND ICE & ENGINEERING PROPERTIES	LT	Little excess ground ice; high bearing strength generally. A generally favourable environment from the view of engineering properties.																	
	Gbf	Low amounts of ground ice, little if any excess ice; top soil is well drained. good subgrade				Moderate amounts of excess ice; soil is fairly well drained. Good to excellent as subgrade; materials non-plastic.									Low ice content; well drained; good subgrade.		Low ice content; well drained; good subgrade.		
	TU	stratified ice. WE 50%	stratified ice. WE 28%	stratified & massive ice along margins	segregated ice in polygons & excess ice	excess ice may occur beneath lake margin	segreg. ice present moderate excess ice	segregated excess ice in polygons	ice wedges in troughs; excess ice, loc. high	ice variable but gen. low; good subgrade	moderate excess ice	19% water in active layer;64% frozen layer	mod. amt. excess ice moderate plasticity	no data on ice. good subgrade	low ice content WE about 35%	low ice content WE 35%	non-visible to stratif. ice. WE 37%	non-visible ground ice WE 22%	non-visible to stratif. ice. little excess ice.
TRAFFICABILITY (rated 0-1-2)	LT	0; occasionally 2 north to south across escarpments																	
	Gbf	Good except where steep slopes occur. 0, occasionally 1.				1									0; occasional 2 north-south		1		
	TU	0; at bank edge 1	0; at bank edge 1	0 except at snowmelt (floods)	1, but easily avoid	2 in summer 0 in winter	along ridges-0 across ridges-1	0 to 1	1	1	1	0	1 when wet; 0 dry	0,except at snowmelt 2	0; occnl. 2 n-s	0; occnl. 2 n-s	1; loc. 2; occnl. steep gradients.	1	1; loc. 2; occnl. steep gradients.
SENSITIVITY TO TRAVEL / TO TRENCHING (rated 1-5)	LT	1/1 Rated least sensitive of the larger Landscape Types.																	
	Gbf	1/1				2/2; summer 1/1									1/1		1/1		
	TU	1/1	1/1	1/2	3/5	1/5	2 wet/1	3 wet /5	2/4 wet /4	1/1	1/1	1/1	3wet/1	3 wet/1	1/1	1/1	1/1	1/1	1/1

Figure 2: Sample of the expanded legend for the Bjorne sandstone (Trb). Note the three levels of detail and the distinction between Environmental Variables (data) and Summary Evaluation (qualitative appraisal). (After Barnett et al., 1976).

individual (disciplinary) terrain attributes could no longer be abstracted from the data in either the legend or the map. The collaboration refined the location of boundaries rather than compromised them as some critics have surmised.

MAPPING

Costs

The area mapped was approximately 6000 mi^2 (15,500 km^2) at a cost to GSC of $137,000 including salaries, or nearly $23/$mi^2$. This figure lacks overhead and non-GSC salaries plus valuable input from the Polar Continental Shelf Project. It also does not include two prior field seasons on Melville Island when the work was not specifically oriented toward a biophysical product. Adding those earlier seasons costs in boosts the rate to $28/$mi^2$. However, products other than biophysical maps are in preparation.

Scale and Format

Mapping was at a scale of 1:125,000 on a 20% magenta screened mosaic base from an interpretation at 1:60,000. The format of the legend evolved during the project and it was decided that a three-tier hierarchical legend was desirable (Figure 2). In this way, regional (general), detailed (local), and intermediate level appraisals were possible. The differences were therefore not of scale but of degree of generalization. At the regional level, it was concluded that each of the rock types - bearing in mind that they are gently flexed, sedimentary strata, with little glacial modification and rarely far from the surface - gave rise to a distinctive landscape, hence these units formed the basic regional unit.

At the most detailed level (terrain unit), a total of 49 recurring units were identified. This number, although relatively large, was necessary to identify the changes in the landscape which are or may be significant for some aspect of the disciplines involved, and therefore for potential land uses. At the intermediate level, the marine limit was adopted as one of the boundaries. In some localities it is marked morphologically, in materials composition and by strong vegetation contrast, and in others it is much more subtle. The data on ground ice are not sufficient to conclude a significant difference across the boundary, but circumstantial evidence and inconclusive quantitative evidence suggest that such a difference may well occur, with more ground ice below marine limit than above.

The expanded legend (Figure 2) which may appear formidable at first, is organized from top to bottom from geologic to vegetation to wildlife data to one of the more interesting parts of the project, that of summary evaluation. This part of the legend involves value judgements based on non-quantitative criteria encompassing field experience. A simple numerical rating for sensitivity was derived from the field data. A broad range of probable responses of the terrain to various tracked vehicle uses is listed in Barnett *et al.* (1975c, 1976). As they are relative ratings, experience with either a particular technique or a particular vehicle type may require an adjustment to the rating, but it is believed that any such changes would be all in the same direction and by a similar amount.

The problem of depicting a variety of data on a photo mosaic and have it both readable and meaningful is a continuing problem. In this case, a simple alpha-numeric system was used which has the following merits: 1) The alphabetic prefix follows the geological convention for the formation name (to all intents and purposes - rock type). 2) The numerical format allows almost unlimited additions of new units occurring in areas not already mapped. 3) The simple designation of a digit and three places of decimals allows the reader to easily carry the information to the legend which is where the bulk of the information is. 4) Cartographic economies are achieved by this method when compared with manuscripts requiring sub- and superscripts.

An attempt to summarize the whole scheme is shown as a characterization matrix with the Landscape Types along one margin and the various attributes and evaluations along the other (Figure 3).

CONCLUSIONS

Interdisciplinary mapping projects can heighten the perception of natural subdivisions of the landscape and refine the precision of boundary locations.

For environmental impact assessment, a study involving several related disciplines is beneficial in that the data are set out in a compatible fashion, thus eliminating a reconciliation phase in data compilation.

CHARACTERIZATION MATRIX OF LANDSCAPE TYPES OF EASTERN MELVILLE ISLAND

LT	Morphology	Relief (relative absolute)	Surface drainage	Surface materials	Vegetation*	Ground-ice contents (Engineering soil classification)	Trafficability rating** (0-1-2)	Sensitivity rating*** (1-5)	Degree of lithification	Relative effect of marine inundation (Per cent affected)	Weathering products
Qa	Terraced	Low 70 m	Well	Silt-sand (alluvial-deltaic)	1 monocot/ 3 monocot (± *Salix*)	Moderate; ML, SU, SW/SF Sands, or silts of low plasticity	1	2/5	Unlithified	High 100%	Sands, locally silts
Qm	Upland residual	Low 15 m	Well	Gravel	1 saxifrage	Low; GP Gravel-sand mixture	0/2	1	Unlithified	Nil 0%	Dirty gravel
Te	Lowland	Low 80 m	Moderate/ well	Sand-silt (nonmarine)	1 grass/ 3 grass	Low; Variable Uniform sand to silty clay	0	2/3	Unlithified to poorly lithified	Low, locally moderate 80%	Medium sands, locally silts
Kk	Upland	High 150 m	Well	Silt	1 lichens/ 1 monocot	High; ML, CL Silt and clay of low plasticity	1	4	Poorly lithified	Moderate to high 50%	Tinkling shale platelets and pebble rubble
Kh	Benchland	Medium 55 m	Moderate	Sand (nonmarine)	1 saxifrage	Low; SF Silty sand	0	3	Moderately lithified	Moderate 48%	Angular hematite pebble rubble
Kc	Lowland	Low 150 m	Poor	Silt	3 grass (+ saxifrage)	High; MI/CI Silts and clays of intermediate plasticity	1/2	5	Poorly, locally moderately lithified	High 71%	Silty clay, sticky when wet
K22a	Flat upland residual	Low 35 m	Well / poor	Sand / silt	1 saxifrage/ 1 grass	Low; SF/MI Silty sands or silt	0/1	3	Poorly lithified	Nil 0%	Sands / silts
Ki	Lowland	Low 60 m	Well	Sand (nonmarine)	1 monocot-saxifrage	Low; SU Uniform sand	0	2	Moderately lithified	Moderate to high 95%	Medium sand
Jmb	Minor escarpment	Medium 105 m	Moderate	Sand (marine)	3 *Carex-Luzula*	Low; SF Silty sand	0	2	Moderately lithified	High 90%	Fine sand
Jwp	Lowland	Low 124 m	Poor	Fine sand (marine-nonmarine)	3 *Carex-Luzula*	Low; SF Silty sand	0	2	Moderately lithified	High 88%	Fine sand
Trb	Scarp and vale	High 240 m	Well	Medium sand (nonmarine ?)	1 saxifrage	Low; SF/SU Sand, some silty sand	0	1	Lithified	High 49%	Angular hematite rubble to medium sand
Pma	Escarpment	High 220 m	Well / moderate	Calcareous sand (marine)	1 saxifrage/ 2 saxifrage	Moderate; M/SF Sand with fines	1	3	Lithified	High 25%	Angular bioclastic rubble
Pmsb	Minor escarpment	Medium 90 m	Well	Sand (nonmarine)	1 saxifrage	Low; SF/ML Silty sands, and silts of low plasticity	0/1	2	Lithified	Moderate 32%	Angular pebbles
Pmbc	Minor escarpment	Medium 190 m	Well	Sandy limestone (marine)	1 saxifrage-grass	Low; GW/GC Well graded gravels, locally with clay	0/1	2	Lithified	Very low 42%	Angular rubble
Cpcf	Diverse	Medium 235 m	Moderate	Silt-fine sand	1 *Puccinellia*-saxifrage	Moderate; SF/CL Silty sand, and clay of low plasticity	0/1	3	Variable	Low to moderate 56%	Sandy fines
Pe	Diapir	High 255 m	Well	Gypsum, limestone, shale, gabbro	nil	Low?; GC Sand and gravelly sand	2	3	Variable	Low 2%	Gypsum rubble
Dg	Plateau	High 225 m	Moderate/ poor	Sand (largely nonmarine)	1 *Rhacomitrium-Alectoria*/ 3 *Carex-Luzula*	Low; Variable Sands and gravels containing fines	1	2/3	Lithified	Moderate 22%	Felsenmeer and fine sand
Dhb	Dissected plateau	High 215 m	Well	Sand (nonmarine)	1 saxifrage-*Luzula*	Moderate GC/SW Graded sands with gravels	1	1/2	Lithified	Low to moderate 28%	Felsenmeer and sand
Dw	Plateau	High 255 m	Variable	Sand (marine-nonmarine)	1 *Rhacomitrium-Alectoria*/ 3 *Luzula*	Low; BC/SF Silty sands or boulders and cobbles	1	3	Lithified	Moderate Locally high 23%	Felsenmeer and fine sand
Dbf	Dissected upland	High 385 m	Well/ poor	Limestone	nil	Low; BC Boulders and cobbles	1/2	1	Lithified	Very low 13%	Angular rubble
S	Hill	High 215 m	Well	Dolomite	nil	Low; BC Boulders and cobbles	2	1	Lithified	Very low 13%	Rubble

The matrix portrays the variables characterized by ratings. A horizontal line is used to separate attributes which differ topographically, and an oblique line denotes an areal separation.

* Ratings for vegetation cover are: 1 - sparse, 0-20%; 2 - moderate, 20-70%; and 3 - dense, 70-100%. The dominant or co-dominant vascular component is shown.

** Ratings for trafficability increase in difficulty from 0 to 2.

*** Ratings for sensitivity increase from 1 to 5.

Figure 3: The characterization matrix, which portrays variables by ratings or in few words. Ratings for vegetation cover are: 1) sparsely, 0-20%; 2) moderately, 20-70%, and 3) well, 70-100%. The dominant or co-dominant vascular component is shown. Ratings for trafficability increase in difficulty from 0-2. Ratings for sensitivity increase from 1-5. A horizontal line is used to separate attributes which differ topographically, and where an oblique line is used, the separation is an areal one.

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BIOPHYSICAL LAND CLASSIFICATION IN BOOTHIA PENINSULA AND NORTHEAST KEEWATIN, N.W.T.*

C. Tarnocai
Canada Soil Survey
University of Manitoba
Winnipeg, Manitoba

J.A. Netterville
Geological Survey of Canada
Terrain Sciences Division
Ottawa, Ontario

ABSTRACT

Boothia Peninsula and northeast Keewatin, an area of approximately 64,000 km², were surveyed as part of a biophysical study. The main objective of the survey was to classify, describe and map the artic terrestrial environment in terms of landforms, unconsolidated deposits, soils, vegetation, permafrost and eco-climate. The information was presented on three levels: the ecoregion, ecodistrict and ecoarea. The definitions of these three levels are given, as are the roles of the major ecosystem components.

A portion of the Pelly Bay West biophysical map is used to illustrate the system. For this area the ecoregion, ecodistrict and ecoareas are described in detail. Field data, analyses and cost estimate of the project are also given.

RÉSUMÉ

La presqu'île de Boothia et le nord-est du district de Keewatin, une région de quelques 64,000 km², ont fait l'objet de relevés dans le cadre d'une étude biophysique. L'objectif principal du programme était la description, la classification et la mise en carte du milieu terrestre arctique, compte tenu des reliefs, des dépôts non consolidés, des sols, de la végétation, du pergélisol et de l'éco-climat. Les données ont été présentées sur trois plans: l'éco-région, l'éco-district et l'éco-zone. Les définitions de ces trois plans sont données ainsi que les rôles des principaux éléments des écosystèmes.

Une partie de la carte biophysique de la Baie Pelly ouest sert pour illustrer le système. Pour ce secteur, l'éco-région, l'éco-district et l'éco-zone sont décrits en détail. Le document présente en outre des données recueillies sur le terrain, des analyses du projet et des évaluations des coûts du projet.

INTRODUCTION

Boothia Peninsula and the northeast portion of the District of Keewatin (north of latitude 68°N), an area of approximately 64,000 km² (25,000 mi²), were surveyed as part of a biophysical study (see Figure 1).

Initial planning and logistical support for the field operation was provided by the Geological Survey of Canada, Energy, Mines and Resources, Canada (A.N. Boydell, project leader, now with Environment and Land Use Committee Secretariat, Victoria, British Columbia). This agency also provided the geological and geomorphological information for the project. The soil Research Institute (Canada Soil Survey), Agriculture Canada, as a cooperating agency, provided the soil and vegetation information and the delineation of ecoregions and ecodistricts.

In this paper the objectives and methodology are given, an example of the land classification is discussed, and cost estimates and manpower requirements are outlined. Short definitions of the geological, geomorphological, soil and vegetation terms employed in the classification are included in the appendices.

OBJECTIVES

The main objective of this biophysical study was to classify, describe and map the arctic terrestrial environment in terms of landforms, unconsolidated deposits, soils, vegetation, permafrost and eco-climate. This was done

* Contribution No. S.R.I. 602

Study Area

Northern limit of trees

Southern limit of continuous permafrost

Southern limit of discontinuous permafrost

Figure 1. Map indicating the location of the Boothia Peninsula-Northeast Keewatin biophysical study area in the Central Canadian Artic.

to provide a real knowledge of the physical and biological components of the terrain as background information relevant to land use planning and various aspects of engineering construction, especially to pipeline construction in the area.

METHODOLOGY

Basic Concept - The basic methodology of this biophysical classification is similar to that of previous land classification systems, especially that described by Lacate (1969), and some of the biophysical work carried out in the Mackenzie River area. All of these previous biophysical studies were carried out in the forested regions of Canada, hence some of the terms and definitions used in the Boothia-Northeast Keewatin biophysical mapping project have been modified to fit the arctic environment.

The biophysical information in this project was presented on three levels: the ecoregion, ecodistrict and ecoarea. All three are interconnected (hierarchical) and ecologically oriented. The landforms and surficial materials provided the basis for mapping on the ecoarea level since they are probably the most stable components of the environment and provide the parent material upon which soils and vegetation develop. Vegetation played an important role in the delineation of climate on the ecoregion level but, since part of the area is sparsely vegetated or unvegetated, other components of the ecosystem, e.g. soils and permafrost (degree of cryoturbation and sorting), provided most of the information. The definitions of ecoregion, ecodistrict and ecoarea, the three basic levels of the system

used in this study, are as follows:

Ecoregion - The ecoregion represents similarities of climate as determined by vegetation, soils and, to some degree, the permafrost condition, which then produce specific ecosystems on material having similar properties (Tarnocai and Boydell, 1975). Ecoregion boundaries were identified through field work and were subsequently mapped using 1:1,000,000 scale LANDSAT imagery.

Ecodistrict - The ecodistrict is a subdivision of the ecoregion and represents similarities of geological, physiographical and geomorphological patterns, soil parent materials and associated ground ice conditions. The ecodistricts in this project were mapped at a 1:250,000 scale and the boundaries were subsequently transferred to the 1:125,000 scale biophysical maps.

Ecoarea - The ecoarea or mapping unit is a recurring pattern of landforms, soils and vegetation. Most of the units mapped in this project are a single landform type, soil association and vegetation cover class with the remainder being composite units developed of two or more landform types. Ecoarea boundaries were mapped on 1:60,000 scale panchromatic aerial photographs and were subsequently transferred to 1:125,000 scale photomosaics and contour maps.

MAJOR ECOSYSTEM COMPONENTS

Eco-climate - An ecologically sound land classification must include the regional variation in climate. The detailed and long-term meteorological information needed to classify the climate in northern areas of Canada does not exist. Even if this information were available we do not now have the information necessary to establish which climatic parameters determine the critical ecological thresholds. This critical ecological threshold value can be estimated, however, through knowledge of the climate-vegetation-soil-permafrost relationships. A degree of climatic uniformity exists in an area (ecoregion) when similar ecosystems (with similar vegetation, genetic soil, cryoturbation, sorting and active layer) develop on similar materials and landform.

Climate is placed at the highest (ecoregion) level in this biophysical land classification. All other levels are arranged according to this climatic framework. For example, a particular soil association occurs only under similar climatic conditions and therefore does not cross ecoregion boundaries.

Surficial Geology and Geomorphology - The system used to map the surficial geology and geomorphology of the Boothia Peninsula and northeast Keewatin is basically the same as that used by the Geological Survey in the forested areas of Labrador, British Columbia, the Mackenzie Valley, central Manitoba, and most recently, in the tundra and 'polar desert' areas of Somerset and Prince of Wales Islands. It has been modified each time as new workers trimmed or expanded certain features within it, attempting to accommodate new problems as they arose. Essentially, the system remains a compromise between the complex landform symbolling done in Europe and the systems which utilize simply names or numbers for their units outlining areas of homogeneous terrain or areas exhibiting a characteristic recurring pattern of two or more terrain types. The Australian CSIRO system is an example of the latter.

The Boothia system employs a basic five-part symbol for identification of geologic/geomorphic units. In order of appearance on the interpreted photos, these parts, or descriptors as they are called, are 1) material, 2) origin, 3) morphology, 4) relief and 5) slope. All parts are considered equally important; for ease of interpretation and symbol balance, *material* and *morphology* descriptors are written as lower case letters, *origin* as upper case; arabic numbers indicate *slope* and relief classes, the latter being included as a subscript.

The system is highly flexible. Where necessary, stratigraphic information may be mapped; multiple material and morphologic descriptors may be appended to indicate the presence and relative amounts of each type wherever it is necessary to group them together. If secondary, perhaps relatively recent, perhaps very old, processes have markedly influenced or modified a primary landform, this can be indicated by one or more *morphologic modifiers*. Where a process such as stream aggradation, degradation, or delta deposition is observed to be active, this can be indicated by a map symbol. Where two or more landform units occur in a meaningful, mappable pattern within an area, they may be mapped as a *composite unit* whose constituent relative abundances are indicated on a percentage basis. The system also provides for the mapping of relative abundances of two or more veneer types when they occur in one or both units of a composite unit. Unfortunately, to do all this, the system employs what to some appears to be a rather bulky language base. We feel that the glossary is not unwieldy for a system which apparently can be applied successfully to a

wide variety of terrain conditions, such as those encountered during past programs in which it has been used and developed upon. A listing of the terms used in the Boothia work, or in some cases, the modified terms employed on Somerset and Prince of Wales Islands, is included as a glossary Appendix I, Sections A.1 to A.4.

In addition to the letter and numeric symbols used on the map to denote certain terrain conditions, a small number of schematic symbols are used to indicate the occurrence of specific features whose presence, size, or distribution it is felt necessary to show separately. These special symbols, and their meanings, are also described and illustrated in Appendix I, Section A.5.

To illustrate the system employed during the geologic/geomorphic mapping stage, Figure 2 is included. It consists of a stereopair of a portion of a 1:60,000 panchromatic aerial photograph showing unit boundaries as determined by the geomorphologist. A complete decoding of the unit symbols is given in Table 1. Note that terrain with complex morphological relationships can be visualized from the symbols alone by a person familiar with the system. We feel that by using, where possible, the first letter of each descriptor term as part of the unit symbol, unfamiliar users stand a good chance of successfully utilizing the final maps with very little practice.

Soils - Soils were mapped as soil associations. The soil association is a sequence of soils of about the same age which have developed on parent material of similar origin and physical and chemical characteristics, but having unlike genetic characteristics because of variation in relief and drainage. The soil associations are named after local geographic names. The numbers after the name indicate the change in genetic profile types (subgroups) or lithological changes within a 1.5 m depth (veneer). Soil associations occur under similar climatic (ecoregion) conditions. Thus, soil association names do not cross ecoregion boundaries. They could occur, however, on similar parent materials in several different ecodistricts within the same ecoregion.

The soil classification used is included in Appendix I, Section B1. The soil parent materials were described on the basis of the origin, texture and $CaCO_3$ equivalent (see Appendix I, Section B2). Soil drainage classes were also indicated and their description is included in Appendix I, Section B3.

Vegetation - Vegetation communities are named according to the dominant species (see Table 2 and abbreviations in Appendix I, Section C1). In the map legend, the dominant vegetation communities are listed according to the increasing moisture condition within a soil association. On the biophysical map, the vegetation cover class (see Figure 4) is given for each ecoarea.

DATA COLLECTION AND COMPILATION

Field Data Collection - Field data collection was carried out with full helicopter support and also utilized light, all-terrain vehicles and foot traverses. Fixed-wing aircraft (Twin Otter) provided transportation for people, equipment and supplies between the base camp and fly camps.

The study area was covered by helicopter traverses using a Jet Ranger helicopter. Selected stops were made along these traverses and data was collected relating to surficial deposits, geomorphology, soils and vegetation. Soil samples and plant specimens were also collected during these stops. Information, especially that relating to landforms, materials and soils, was also continuously collected from the air during these traverses and this was immediately checked on the previously interpreted 1:60,000 scale panchromatic photographs. Light, all-terrain vehicles were used and foot traverses were conducted in areas where more detailed information was needed. In addition, drilling was carried out at 8 locations (for a total of approximately 14 days) and detailed soil and vegetation studies were carried out on 8 sites (approximately 1 day per site). During the helicopter traverses (approximately 250 hours flying time) 350 stops were made. The foot and all-terrain vehicle traverses covered 60 miles (100 km) and 100 miles (160 km) respectively. These field activities resulted in the collection of 401 soil samples, 68 soil moisture and ice content core samples, 27 carbon dating samples and 150 plant specimens.

Data Analysis and Compilation - Ecoregions and ecodistricts were delineated during the field season and finalized the following winter. Detailed photointerpretation of surficial materials and landforms was also finalized during the winter. Later, the photographs were interpreted for soils and vegetation and changes or modifications in map unit boundaries were made if necessary. The final map unit (ecoarea) symbols were then produced. These symbols included the soil association descriptor

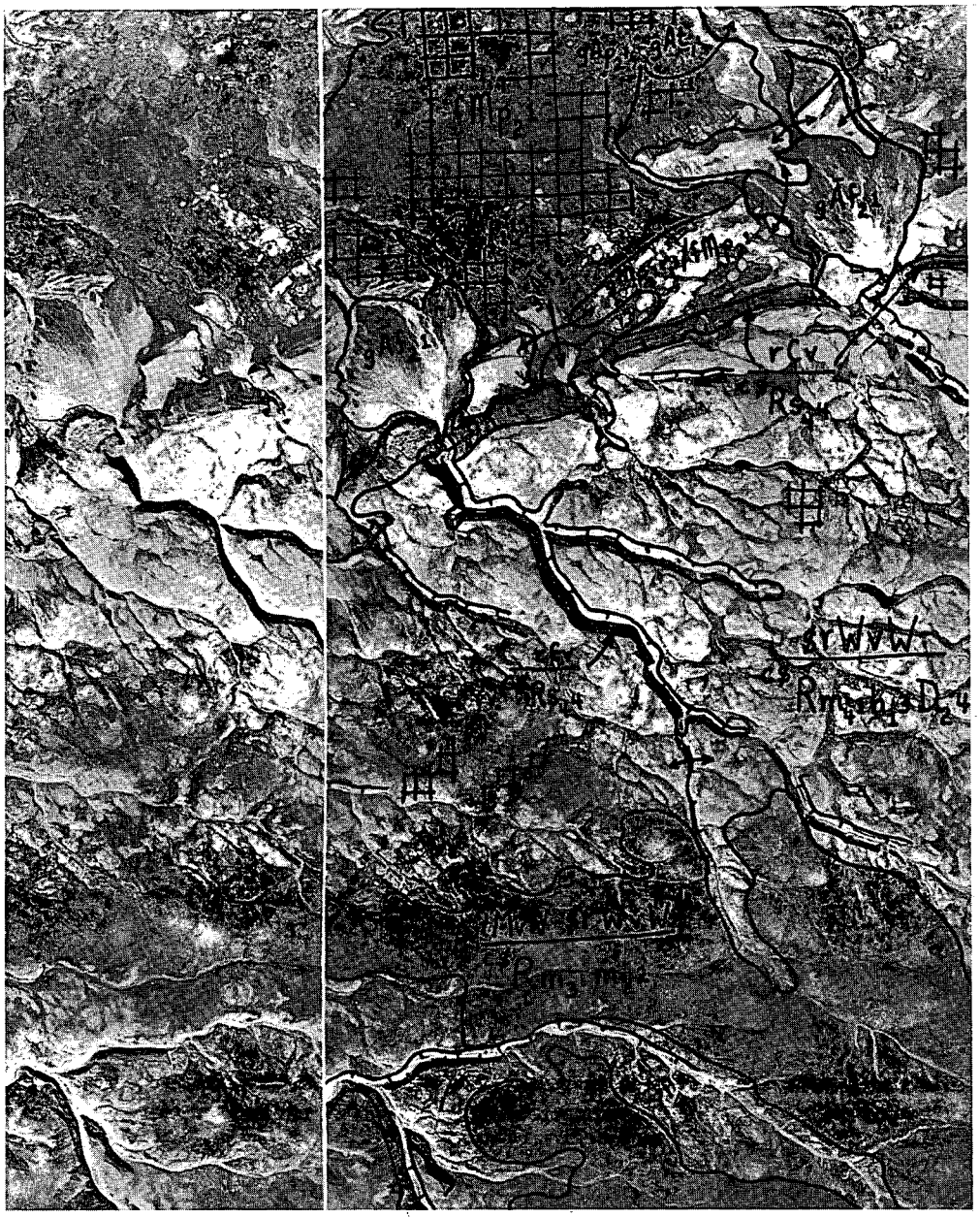


Figure 2: Stereopair illustrating some examples of geologic/geomorphic units. Soil and vegetation data are subsequently integrated into the unit symbols. See Table 1 for a decoding of terrain data contained on this image.

and vegetation cover class in the numerator and the genetic landform, relief and slope designators in the denominator. This information was transferred first to 1:125,000 scale photo mosaics and then to 1:125,000 scale contour maps.

The major changes were made in the original geologic/geomorphic symbols during integration of soil and vegetation data. Firstly, since geomorphologists tend to map texture in terms of grain size classes rather than in soil terms, their textural descriptors were translated into soil terms to become part of the 'soil association' descriptor. This change is made by the pedologist as he integrates his data into the map. By doing this, repetition of descriptors is eliminated. Unfortunately, the engineer (or even another pedologist who is not familiar with the area) probably will not be able to obtain textural information as readily after this change, unless he or she becomes completely familiar with the different soil association descriptors which, since they are based on geographic names, would surely become numerous as large areas are mapped. The engineer would probably benefit most if the original grain size descriptors were retained on the biophysical map as part of the geoglogy/geomorphology symbol. Doing so would not create additional cartographic size problems.

The second major change involves the transfer of stratigraphic information from the surficial geology/geomorphology symbols into the soils legend. The information is keyed to the map through the soil association descriptors which appear in their respective positions in the unit symbols. This move significantly reduces the bulk of the final symbol, thus avoiding creation of a major cartographical size problem. Once again though, unless the engineer is completely familiar with the rather numerous soil association descriptors, he or she must search the soil legend thoroughly to obtain information about covered units in the area, rather than simply read it at a glance from the map. It appears, however, that retention of the original geomorphological descriptors for landforms with an overlying veneer would create major drafting problems at scales involving cartographically small units.

The soil laboratory analysis completed during the winter following field work provided the basis for the separation and description of soil parent materials and for establishing and describing soil associations. The collected plant specimens were identified or the identifications were verified by the Department of Botany, University of Manitoba Herbarium. Vegetation data were compiled and the major vegetation communities were established according to the soil associations and moisture conditions.

DESCRIPTION OF THE BIOPHYSICAL UNITS

A portion of the Pelly Bay West area (see Figures 3 and 4) was chosen to illustrate this biophysical classification and all detailed information pertains to this area.

Description of Ecoregions - Two ecoregions, the Low-Artic and the Mid-Arctic, were delineated in the Boothia Peninsula and northeast Keewatin area (see Figure 3). A description is given only for the Low-Arctic ecoregion since the chosen portion of the Pelly Bay West lies within this unit.

Low-Arctic Ecoregion - This ecoregion covers the southern quarter of the study area and is designated by the ecoregion symbol L on Figure 3. There is continuous vegetation cover except on bedrock and eroding surfaces. Its northern limit coincides with the northern limit of some ericaceous species (*Ledum decumbens*, *Vaccinium Vitis-idaea* and *V. uliginosum*) and also with that of the tussock-forming *Eriophorum* species. Some willows up to 30 cm high are also present along the river valleys. The soils in this region are dominantly Turbic Cryosols developed on marine silt and clay and sandy loan textured till materials. Minor amounts of Static Cryosols (soils not affected by cryoturbation) which have developed on coarse textured fluvial outwash and marine sand and beach deposits are present. The most common patterned ground types in this ecoregion are the non-sorted circles, ice-wedge polygons and earth hummocks. There is some active peat development in this region but these peat deposits cover only small areas and are relatively shallow.

The thickness of the active layer under various drainage conditions and soil materials is as follows: well to imperfectly drained till, 80 - 90 cm; poorly drained till 40 - 70 cm; well drained sand and gravels, 70 - 80 cm; poorly drained sands and gravels, 40 - 60 cm; imperfectly drained marine silts and clays, 40 - 60 cm; poorly drained marine silts and clays, 30 - 40 cm; well to imperfectly drained alluvium, 60 - 80 cm; and poorly drained alluvium, 30 - 50 cm.

Description of Ecodistricts - The various ecodistricts delineated in the Boothia Peninsula and northeast Keewatin area are designated by an arabic number following

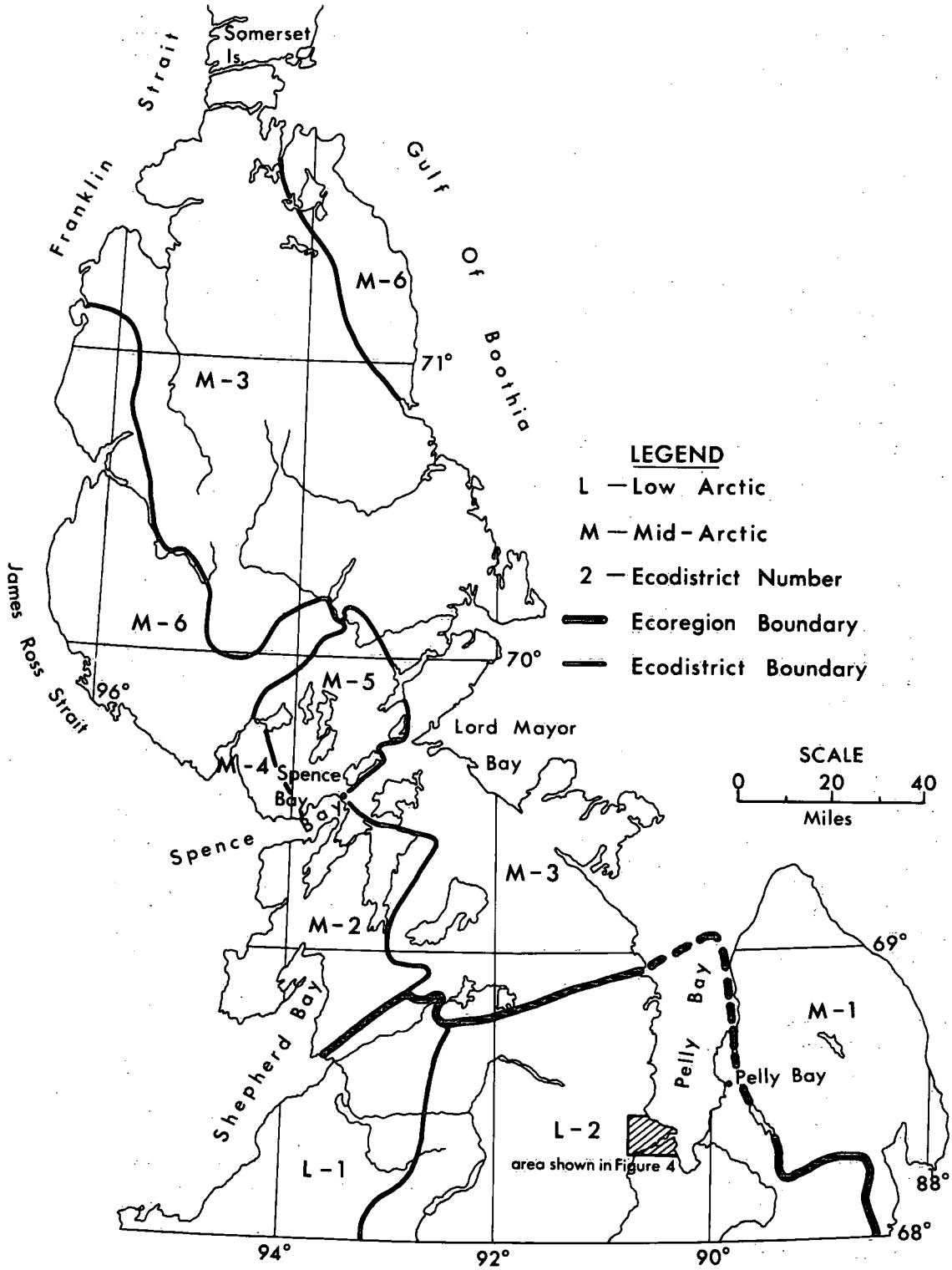
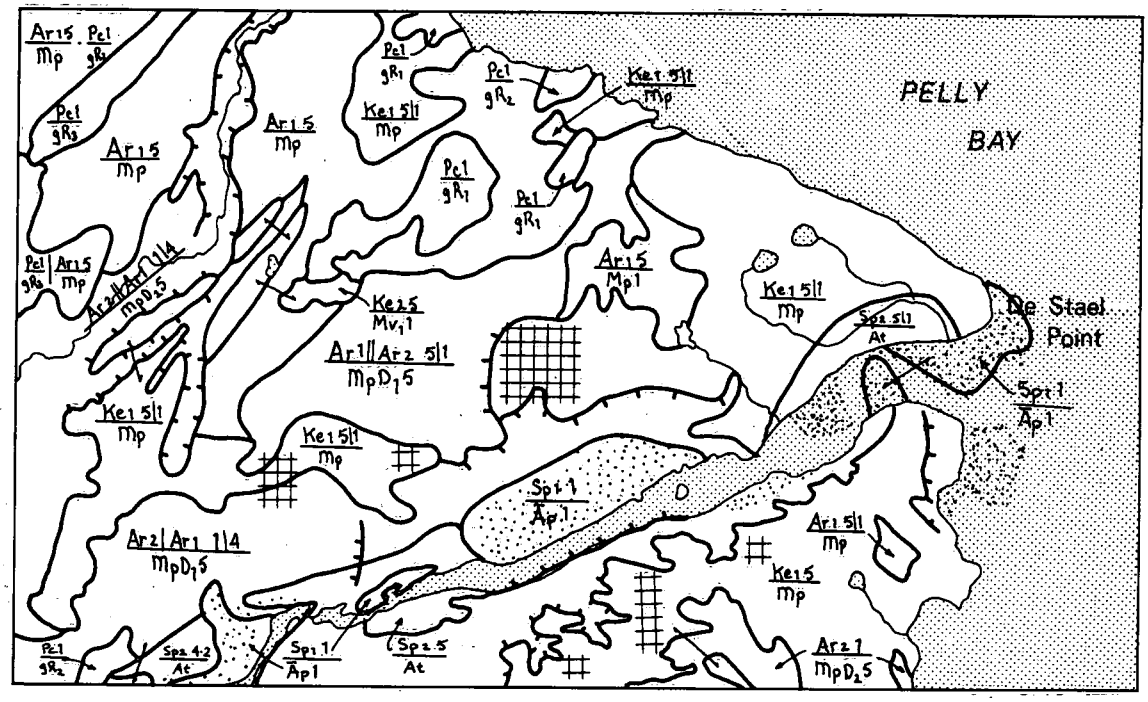


Figure 3. Ecoregions and ecodistricts in the study area. Location of area discussed in text is shown.



LEGEND

TERRAIN

(Map Symbol)

GENETIC LANDFORM CLASS

- m marine
- A alluvial
- Ā modern alluvial floodplain
- gR bedrock (granitic)

MORPHOLOGY AND SURFACE FORM

(lower case) p plain = flat*
v veneer
t terraced

*but may have unit tilt

MORPHOLOGIC MODIFIER (upper case)

D dissected

RELIEF CLASS (numerical subscript)

1 less than 6 meters
2 6 - 20 meters
3 21 - 50 meters
4 greater than 50 meters

SLOPE CLASS (numerical, on line)

1 1 - 5 degrees
2 6 - 15 degrees
3 16 - 35 degrees
4 greater than 35 degrees
5 complex slopes

VEGETATION COVER CLASSES

(Map Symbol)

1 - Unvegetated	(less than 10%)
2 - Sparse	(10 - 40%)
3 - Moderate	(41 - 70%)
4 - Abundant	(71 - 90%)
5 - Continuous	(91 - 100%)

MAP SYMBOLS

Break of slope (scarp)

Ice wedge polygon

COMPOSITE UNITS

| first of units is more than 80% of total unit area

|| first of units is more than 60% of total unit area

• units are of roughly equal proportions

EXPLANATION OF MAP SYMBOL

Soil Association — Vegetation Cover Class

Ar1 5

mpD1 5

Landform — Slope Class

Relief Class

For Soil and Vegetation description, see Table 1.

Figure 4. An example of the 1:125,000 scale Pelly Bay West biophysical map.

Table 1: Explanation of geologic/geomorphic data encoded in Figure 2.

Unit Symbol	Explanation	Unit Symbol	Explanation	Unit Symbol	Explanation
$f\bar{M}p_2l$	marine plain consisting predominantly of silt and fine sand; regional slope less than 5°, total relief from lowest to highest point 5-20 m.	$g\bar{A}f_2l$	These fan-shaped areas consist of alluvial gravel which is in large part subject to annual flooding during the period of snowmelt. The fans are quite low, with slopes less than 5° and total relief 5-20 m.	$\frac{tMvW\text{-}grWvW}{c\#Rm_3lm_2 2}$	this area consists of gently rolling carbonate and shale bedrock with macroscopic relief of 21-50 m and slopes commonly less than 5°. Superimposed on this gently rolling landscape occur lower bedrock hills (relief 5-20m) with steeper slopes of 6-15°. About 60-80% of the area is covered by a veneer (less than 1.5 m) of till; the remainder (20-40% of the area) is covered by a veneer of silty rubble produced by weathering of bedrock. The entire area was once below water. This has to some extent modified the original materials through sorting and/or redeposition.
$g\bar{M}p_2lr_1l/f\bar{M}p_2l$	at least 80% of the area consists of a gravelly marine plain with regional slope less than 5° and a total relief of 5-20 m. The plain contains a significant number of marine gravel beach ridges less than 5 m in height and with local slopes less than 5°. The remainder of the area (less than 20%) consists of plainar areas of marine silt and fine sand. These areas possess a regional slope not greater than 5° and a total relief of 5-20 m.	$g\bar{A}f_2 2$	As above, but the fan surface is steeper, possessing a slope of 6-15°.		
		$\frac{grWvW}{c\#Rm_4lh_1 3D_2 4}$	This area consists of gently rolling carbonate and shale bedrock (average slope less than 5°, total relief more than 50 m). In places the bedrock is hummocky, the hummocks being less than 5 m in height but with steep slopes of 16-35°. The bedrock has been dissected by water erosion at some time in the past. The dissection produced generally does not exceed 20 m in relief but the slopes are very steep (more than 35°). Most of the bedrock surface is covered by a thin veneer (less than 1.5 m thick) of silt and rock rubble derived through the action of mechanical and/or chemical weathering. The entire area has been inundated at some time by a standing body of water, resulting in a certain amount of sorting of the surface materials. Fine grained deposits may be expected to occur in depressions, scattered gravel beaches or lag concentrate may occur on the rises.	$\frac{rCv}{c\#Rs_4 4}$	these areas of carbonate and shale bedrock consist of steeply sloping (greater than 35°) scarp faces with maximum relief greater than 50 m. The scarps are in part covered by a veneer of rubbly colluvial debris moved to its present position predominantly through the action of gravity.
gAp_1l	this area is a gravelly alluvial plain above the apparent limit of annual spring floods. The plain slopes at an angle less than 5° and possesses not more than 5 m of relief.				
$g\bar{A}p_2l\text{-}gAt_1l$	this area consists of gravelly alluvial deposits; 60-80% of the unit is a plain subject to annual flooding. The plain possesses slopes less than 5° and a total relief of 5-20 m. The remainder of the area consists of terrace gravels above the apparent limit of the spring flood. The terraces are very low, with slopes less than 5° and relief less than 5 m.				

Table 2: Soil and vegetation portion of the biophysical map legend.

Map Symbol	Ecoregion and Ecodistrict	Parent Material	Ground Ice and Ice Content	SOIL: Soil Association	SOIL: Gen. Name and Drainage	Depth of Thaw (cm)	Vegetation
Ar1	L-2	Noncalcareous to weakly calcareous silty clay to clay marine deposit.	Massive ground ice in near surface permafrost (0.5 m or more thick). Ice lenses, segregated ice crystals and vein ice are also common. High ice content.	Arrowsmith River 1	Brunisolic Turbic Cryosol (I 7) Gleysolic Turbic Cryosol (P 3)	40-50 35-60	Ner, Et-Mo-L, Mo-L-Eo, Mo-Cx Et
Ar2		Noncalcareous to weakly calcareous silty clay to clay marine deposit.	Ice lenses, segregated ice crystals and vein ice. Medium ice content.	Arrowsmith River 2	Regosolic Static Cryosol (W)	70	Ner
Ke1		Noncalcareous marine sand.	Massive ice wedges and segregated ice crystals. High to low ice content.	Kellet River 1	Brunisolic Static Cryosol (W 8) Regosolic Static Cryosol (W 2)	35-70 80-90	L-Er, Cr-Mo-Dr, Mo-L Ner
Ke2		Less than 1.5 m of noncalcareous marine sand over marine clay.	Massive ice wedges and segregated ice crystals. High to low ice content.	Kellet River 2	Brunisolic Static Cryosol (W)	35-70	L-Er, Cr-Mo-Dr, Mo-L
Sp1		Weakly calcareous to noncalcareous recent sandy alluvium.	Ice lenses and segregated ice crystals. Low to medium ice content.	Stael Point 1	Regosolic Static Cryosol (P)	90	N
Sp2		Weakly calcareous to noncalcareous sandy alluvium.	Ice wedges, ice lenses and segregated ice crystals. Medium to high ice content.	Stael Point 2	Regosolic Static Cryosol (W,I 6) Brunisolic Static Cryosol (W,I 4)	60-80	L-Er, Ca-Mo-Dr, Mo-L
Pc		Coarse-grained igneous or metamorphic rock containing quartz as an essential component, along with feldspar and mafic minerals; mainly refers to granite and granite gneiss.	----	Precambrian Granitic Bedrock	----	--	N

NOTES:

Bedrock slope classes are assumed to be complex unless otherwise shown.
Stratigraphy: deposits less than 1.5 m thick are indicated as a veneer (v).
Drainage Distribution: The percentage of each drainage class is indicated by a decile number following the drainage symbol.
Soil Classification: See Proc. of the Ninth Meeting of the Canada Soil Survey Committee, Univ. of Sask., Saskatoon, May 16-18, 1973, p. 346-358.
Depth of Thaw: measured in August, 1974.
For abbreviations of plant species, see Appendix I, Section C1.

the ecoregion symbol (see Figure 3). A description of this ecodistrict, L-2, in which the Pelly Bay West example lies, is as follows:

Ecodistrict L-2 - The western and central portion of this district (area between Pelly Bay, Arrowsmith River and L-1 district boundary) is a Precambrian upland with moderate relief. A discontinuous veneer of Pelly Bay till occurs mainly in valleys and depressions. The surface material of the eastern central part of this district, which lies in the Arrowsmith River area, is dominantly marine clay (Arrowsmith clay) while to the east, the terrain is dominated by low granitic hills with various amounts of Pelly Bay till and Arrowsmith clay. Kellet River sand commonly occurs in the southern part of this district. Massive ground ice, ice lenses and vein ice in the near surface permafrost are commonly associated with the Arrowsmith clay. Massive ice wedges associated with polygons are common in Kellet River sand and Stael Point sand. The ice wedges are especially well-developed where Kellet River sand overlays marine clay (mapped as Kellet River 2 soil association). Pelly Bay till is associated with only segregated ice crystals and small ice lenses.

Description of Ecoareas - The ecoareas are presented on the 1:125,000 biophysical maps (Tarnocai *et al.*, in preparation), and are classified and described according to their characteristic pattern of landform, soils and vegetation. The map symbols contain the soil association and vegetation cover class descriptors in the numerator and the genetic landform, relief and slope descriptors in the denominator (see Figure 4). The soil parent materials, ground ice, ice content, genetic soil name, depth of thaw and the dominant vegetation communities are found in the soil-vegetation portion of the map legend (see example in Table 2).

Most of the map units represent a single landform type, soil association and vegetation cover class on the biophysical map (e.g. $\frac{\text{Arl 5}}{\text{Mp}}$). Composite map units, however, occur where these components are not separable at the 1:25,000 scale. In this case, the components are labeled separately and their percentage distribution is identified by a symbol (e.g. $\frac{\text{Arl 5}}{\text{Mp}}$ $\frac{\text{Pc 1}}{\text{g}^{\text{R}}\ 1}$).

ANTICIPATED USES

The interpretation of data presented in this biophysical study was used for determining terrain sensitivity and trafficability ratings of the terrain and for estimating the granular resources of the area. These interpretations were carried out because of their importance for pipeline construction.

This information can also provide a basis for determining the capability of the terrain to support wildlife and also forestry and agriculture if a similar system is used in more southern areas.

COST ESTIMATE OF THE PROJECT

In total, 5.5 man-years (4 professional and 1.5 technical man-years) were spent on this project. This includes both the field work and the office and laboratory work portions. The estimated unit cost of the project was $8±1/mi^2. This figure covers the field expenses, including the helicopter and fixed-wing flying, salaries, materials, equipment and shipping cots.

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of Canada, Open File (in preparation).

APPENDIX I

A. Description of Landforms - The genetic landform terms used in the Boothia biophysical maps, or modified terms based on subsequent work, are defined and briefly described below.

1. Origin

Morainal - Relating to accumulations of unsorted, unstratified glacial drift (till) deposited chiefly by the direct action of glacier ice in a variety of landforms that are primarily independent of control by the surface on which the drift lies.

Ice-Contact Outwash - Landforms consisting of stratified deposits formed in contact with melting glacier ice, such as an esker or kame.

Proglacial Outwash - Pertaining to the landforms and stratified deposits produced by meltwater flowing from wasting glacier ice.

Marine - Pertaining to materials deposited in marine environments. These may form a blanket of offshore silts and clays, or may occur as a series of marine nearshore features, largely composed of gravel and sand, such as spits, bars and beaches.

Deltaic - Refers to alluvial sediments deposited where rivers or streams enter (entered) standing bodies of water, forming broad, nearly horizontal tracts of land, large or small, which extend (extended) into the present (former) water body.

Alluvial - Sorted sediments of wide particle size range, transported and deposited by running water in postglacial time. Units are subjectively mapped as active or inactive. Active floodplains are those immediately adjacent to and below the assumed or apparent maximum annual flood level of the river or stream which deposited them. They commonly support only scant vegetation due to yearly flooding and deposition of fresh sediment. The surfaces of inactive floodplains are generally at an elevation of 1 to 3 m above the assumed or apparent maximum annual flood level.

Colluvial - A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity; may include soliflucted material on gentle or strong slopes.

Eolian - Pertains to deposits such as loess or dune sand whose constituents were transported, and deposited by wind.

Weathered Product - A general term referring to any significant occurence of essentially *in situ* or cryoturbated unconsolidated or partially consolidated material derived from an underlying bedrock source through the action of mechanical and/or chemical weathering.

Bedrock - A general term for the rock, usually solid, that underlies unconsolidated surficial material, or is exposed.

2. Bedrock Type

Granitic - A term broadly applied to identify coarse-grained igneous or metamorphic rock containing quartz as an essential component, along with feldspar and mafic minerals; mainly refers to granite and granite gneiss; may include minor outcrops of other igneous, volcanic, or metamorphic rocks.

Carbonate - A term intended to identify rocks with consist primarily of carbonate minerals; mainly refers to limestones or dolomites; may include minor occurrences of conglomerate, breccia, sandstone, or shale.

Shale - A laminated sedimentary rock in which the constituent particles are predominantly of the clay or silt grades; may include minor outcrops of sandstone or carbonates.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of sand-sized quartz grains; may include minor outcrops of conglomerate, carbonates, or shale.

Conglomerate - A cemented clastic rock containing rounded fragments corresponding in their grade sizes to gravel or pebbles; may include minor outcrops of sandstone.

3. Morphology

Plain - An area of terrain, large or small, with little or no surface undulation; total relief and average slope indicated by appropriate numeric symbols.

Rolling - A gently to strongly defined succession of hills or broad undulations that impart a wave effect to the surface.

Hummocky - A term referring to the presence of moderately to strongly defined mounds, knolls, hillocks, or tors which may occur

in closely spaced groups mappable as a single terrain unit, or as individuals superimposed upon a rolling, ridged, or planar landscape.

Ridged - A term referring to the presence of gently to strongly defined linear hills or smaller surface undulations which may occur as large individuals or in closely spaced groups mappable as a single terrain unit, or as individuals or closely spaced groups of individuals superimposed upon a rolling or planar landscape.

Terraced - Refers to the presence of one or more, relatively level or gently inclined surfaces, bounded along one edge by a steep ascending slope and along the other by a steep descending slope. Terraces commonly occur along the margin and above the level of an ocean, lake or river, marking former water levels.

Kettled - An area characterized by numerous steep-sided, bowl- or basin-shaped depressions often containing a small lake or pond; primarily occurs only in ice-contact, or near-glacial, outwash deposits.

Fan - A gently to strongly sloping mass of alluvial or colluvial material forming a segment of a cone, commonly at a place where there is a noticeable change in gradient. Colluvial fans, deposited chiefly by mass wasting, are generally too small to map at a scale of 1:125,000. They are a common landform situated at the base of most scarps in bedrock-dominated terrain.

Scarped - An area containing one or more escarpments, cliffs or very steep slopes of some extent along the margin of a plateau, mesa, terrace, bench, or forming the sides of a valley.

4. Morphologic Modifier

Dissected - A term referring to a pattern of closely spaced gullies, ravines, valleys, or other linear depressions, and the remnant interfluve ridges, formed by water erosion acting upon a gently undulating or planar topographic surface.

Washed - A general term referring to landforms which have been modified in some manner by wave action. The process has resulted in the sorting of surface materials, such that fine-grained sediment has been moved from high ground to adjacent depressions, or in the formation of scattered minor beaches.

Note: The term 'boulder covered', a morphologic modifier used in the Boothia mapping project to indicate areas of felsenmeer, has been deleted from the updated version of the legend based on classification problems encountered on Somerset and Prince of Wales Islands. Classic felsenmeer is now being mapped as rsWv - rubble and sand weathered veneer. It is probable that much of the silty rubble overlying Paleozoic rocks of the high Arctic is also felsenmeer-like in its origin.

5. Special Symbols

Drumlin, drumlinoid (ice direction indicated, not indicated)

Crag-and-tail (ice movement in direction of arrow)

Fluting (ice direction indicated, not indicated)

Moraine ridge

Esker (direction of flow assumed, uncertain)

Pingo

Meltwater channel (large, small)

Abandoned beach ridge

Escarpment

Slump

Retrogressive thaw-flow slide

Frost-cracked terrain (including ice wedges)

B. Soil

1. Soil Classification of Cryosols

Order	Great Group	Subgroup
Cryosolic	Turbic Cryosol	Brunisolic Turbic Cryosol
		Regosolic Turbic
		Gleysolic Turbic Cryosol
	Static Cryosol	Brunisolic Static Cryosol
		Regosolic Static
		Gleysolic Static Cryosol

For a more detailed description of Cryosols see: Proc. of the Ninth Meeting of the Canada Soil Survey Committee, Univ. of Sask., Saskatoon, May 16-18, 1973, p. 346-358

2. Calcareous Classes - The classes are determined on the basis of the $CaCO_3$ equivalent. The classes are as follows:

a)	Weakly calcareous	2-5%	$CaCO_3$ equivalent
b)	Moderately calcareous	6-15%	" "
c)	Strongly calcareous	16-25%	" "
d)	Very strongly calcareous	26-40%	" "

3. Soil Drainage Classes - The three soil drainage classes used are described below:

Well drained - Water is removed from the soil readily but not rapidly. Well drained soils are commonly coarse to intermediate in texture, although soils of other textural classes may also be well drained. Well drained soils, especially coarse textured materials, have the deepest active layer.

Imperfectly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions.

Poorly drained - Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a very shallow active layer, to seepage or to some combination of these conditions.

In Table 2 drainage classes are abbreviated as follows: W - well drained; I - imperfectly drained; and P - poorly drained.

C. Vegetation

Vegetation communities are named according to the dominant species and listed (see Table 2) in order of increasing moisture condition of the site. The species abbreviations used in Table 2 are shown below.

Ca - *Carex rupestris, Carex scirpoidea*
Cs - *Cassiope tetragona*
Cr - *Carex misandra, Carex saxatilis*
Cx - *Carex stans*
Dr - *Dryas integrifolia*
Er - Ericaceae *(Ledum decumbens, Vaccinium uliginosum, V. Vitis-idaea* var. *minus)*
Eo - *Eriophorum angustifolium*
Et - *Eriophorum* Tussock *(Eriophorum vaginatum)*
L - Lichens
Mo - Mosses
N - Unvegetated *(Nudum)*
Sa - *Saxifraga oppositifolia*
Sx - *Salix arctica*

(Modifier abbreviations)
cb - Cryoturbated
er - Eroded

LA CARTOGRAPHIE ECOLOGIQUE INTEGREE DU TERRITOIRE DE LA BAIE JAMES

M. Jurdant, J.L. Bélair, J.P. Ducruc et V. Gerardin
Service des Etudes Ecologiques Régionales
Direction des Terres
Environnement Canada
Ste-Foy, Québec

RÉSUMÉ

La gestion des ressources naturelles d'un territoire aussi vaste que celui de la Baie James (410,000 km²) doit être basée sur une planification écologique intégrée à long terme. Une telle planification présuppose la connaissance dynamique des écosystèmes obtenus par un inventaire écologique intégré de l'espace. Depuis 1973, une équipe multidisciplinaire de 29 personnes a entrepris la cartographie écologique systématique du territoire. Nous exposons les concepts méthodologiques de base et définissons les divers niveaux de perception (Région Ecologique, District Ecologique, Système Ecologique, Type Ecologique et Phase Ecologique) utilisés dans la réalisation d'une telle cartographie.

ABSTRACT

Natural resource management in a vast area such as the James Bay Territory (410,000 km²) must be based on long-term integrated ecological planning, which presupposes a dynamic knowledge of the ecosystems involved obtained through an integrated ecological space inventory. Since 1973, a 29-man multidisciplinary team has been carrying out a systematic ecological mapping of the area. The basic methodology is outlined and the various levels of perception used in ecological mapping (Ecological Region, Ecological District, Ecological System, Ecological Type, and Ecological Phase) are defined.

INTRODUCTION

La gestion rationnelle d'un territoire doit être basée sur une planification intégrée à long terme. Cette planification doit, en outre, être écologique, c'est-à-dire basée sur le respect des équilibres naturels.

Dans le but de fournir au planificateur et à l'aménagiste les informations concernant les ressources, leur potentiel et leur susceptibilité à la dégradation, il est nécessaire de procéder à un inventaire écologique de l'espace en unités identifiées, caractérisées et nommées par les composantes biophysiques de l'environnement qui reflètent le mieux les perspectives d'utilisation du milieu naturel.

La carte écologique représente l'inventaire du 'Capital-Nature' (1) d'une région. Elle permet de déterminer les alternatives de développement les plus conformes au maintien des équilibres écologiques. Trop souvent, les études écologiques ne sont incorporées au processus de planification que dans les dernières phases, alors que les décisions sont déjà prises. C'est ainsi que l'écologie est devenue pour beaucoup une science contestataire, centrée sur les analyses d'impact alors qu'elle peut et qu'elle doit être une science permettant d'orienter le développement pour optimiser le 'Capital-Nature'.

Lors de sa création en 1971, la Société de Développement de la Baie James a reçu pour mandat de procéder à l'aménagement intégré des ressources de cet immense territoire de 410,000 km² (figure 1) tout en veillant à la qualité de l'environnement. Pour beaucoup, ce territoire étant totalement inconnu et, à part les richesses hydro-électriques, il ne représentait qu'une immense étendue de tourbières et de forêts rabougries improductives. La première tâche consistait donc à évaluer ces ressources et leur potentiel.

A ce moment, un groupe de chercheurs d'Environnement Canada venait de mettre au point une méthodologie d'inventaire écologique du territoire grâce à la réalisation d'un projet-pilote dans la région du Saguenay-Lac-St-Jean (Jurdant *et al.*, 1972). Cette recherche faisait partie d'un effort déployé à l'échelle nationale visant à mettre au point une méthode d'inventaire intégré des ressources naturelles applicable aux territoires nordiques du pays

(1) Expression mise de l'avant par Saint-Marc (1971).

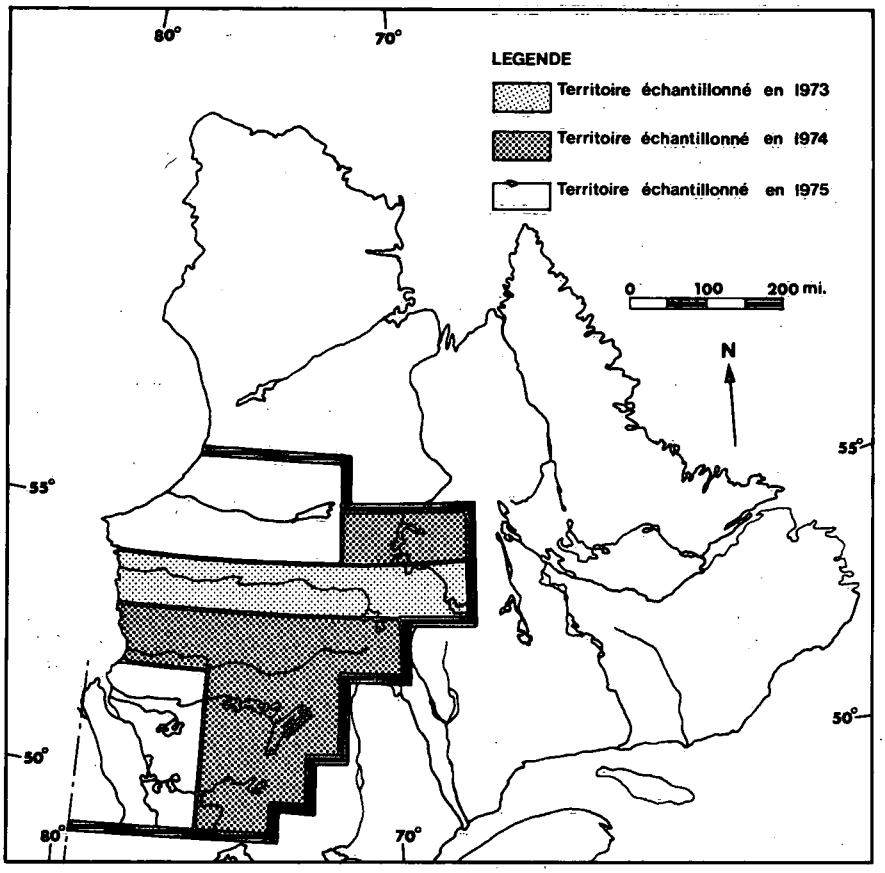


Figure 1: Localisation du territoire étudié

(Lacate, 1969; Jurdant *et al.*, 1975). Grâce à une entente entre la Société de Développement de la Baie James et Environnement Canada, le SEER (Service des Etudes Ecologiques Régionale des Terres à Québec) fut donc chargé de réaliser, en trois ans, la classification et la cartographie écologique de tout le territoire de la municipalité de la Baie James.

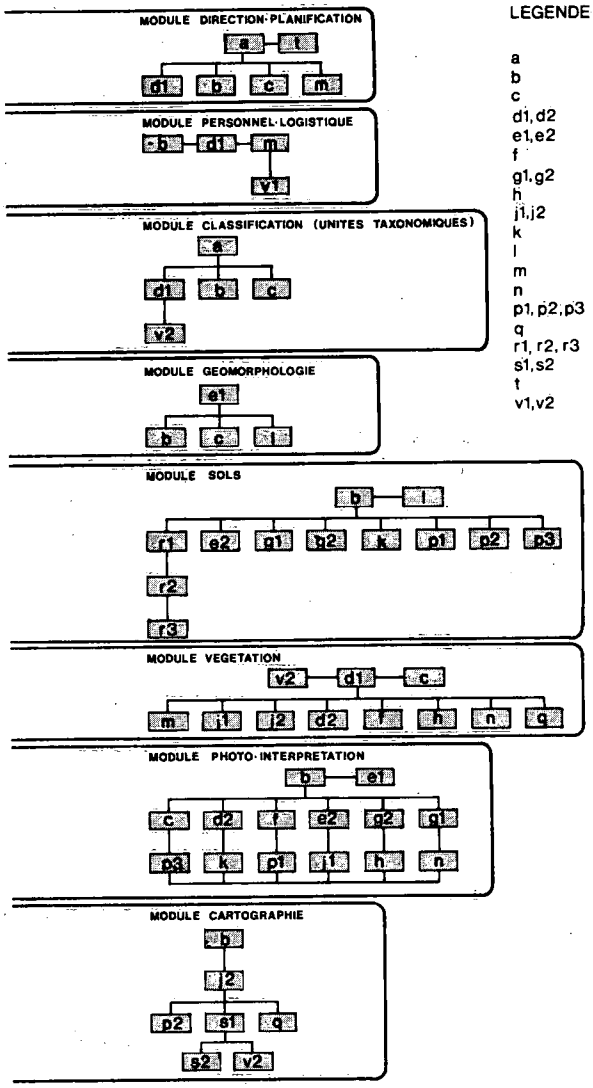
CONCEPTS MÉTHODOLOGIQUES ET BUT DE L'INVENTAIRE ÉCOLOGIQUE

Subdiviser le territoire en unités 'iso-écologiques', tel est, en essence, l'objet même de l'inventaire écologique. Par 'iso-écologique', nous entendons semblable quant à la distribution des processus écologiques opérant dans l'écosystème. Ces processus doivent être analysés, classifiés et interprétés quant à leur signification par rapport au fonctionnement global de l'écosystème. L'inventaire écologique est, avant tout, un inventaire de processus très divers devant faire appel à l'intervention aussi intégrée que possible de plusieurs disciplines parmi lesquelles la pédologie, la phytosociologie et la géomorphologie jouent un rôle prépondérant.

La méthode utilisée est basée sur une intégration *a priori* par laquelle le travail interdisciplinaire est une réalité fonctionnelle à toutes les phases du travail: la définition des objectifs, la description des écosystèmes, l'échantillonnage, l'expression des hypothèses, la détermination des critères de classification, la cartographie et l'interprétation des écosystèmes.

Pour développer cette méthodologie, nous nous sommes inspirés de divers travaux d'écologie appliquée à l'aménagement du territoire, tout particulièrement, des méthodes fondées sur un travail multidisciplinaire et une intégration *a priori*. Citons, entre autres, l'approche de l'école australienne du C.S.I.R.O. (Commonwealth Scientific and Industrial Research Organization) (Christian, 1952; Christian et Stewart, 1952 et 1968; Christian *et al.*, 1968); les travaux du C.E.P.E. (Centre d'Etudes Phytosociologiques et Ecologiques) de Montpellier (Gounot, 1958; Long, 1969 et 1974); ceux de Hills (1961) en Ontario; les études effectuées

Figure 2. Organisation en modules d'une équipe multidisciplinaire d'inventaire écologique.



LEGENDE

a	forestier, éco-pédologue
b	agronome, éco-pédologue
c	biologiste, phyto-écologiste
d1, d2	forestiers, phyto-écologistes
e1, e2	géographes, géomorphologues
f	géographe, phytosociologue
g1, g2	biologistes, éco-pédologues
h	biologiste, phytosociologue
j1, j2	forestiers, phytosociologues
k	forestier, pédologue
l	géographe, pédologue
m	technicien, taxonomie végétale
n	technicien, phytosociologue
p1, p2, p3	techniciens, pédologues
q	technicien forestier
r1, r2, r3	techniciens de laboratoire
s1, s2	dessinateurs
t	secrétaire
v1, v2	techniciens

Cet organigramme est celui du Service des Etudes Ecologiques Régionales, Direction régionale des Terres à Québec, Environnement Canada, pour la réalisation du programme d'étude écologique du territoire de la Baie James (1973-1976).

sous l'égide de la Commission Canadienne de Pédologie (CCP, 1972) et finalement plusieurs travaux de l'auteur principal de cette publication (Jurdant, 1968).

Dès le début de nos travaux d'inventaire, nous fûmes conscients du danger inhérent à tout travail scientifique: celui de produire des documents uniquement compréhensibles par les scientifiques, cités dans des revues un peu partout dans le monde et inutilisés dans la région même pour laquelle ils ont été bâtis. Pour éviter cela, nous avons clairement défini les thèmes interprétatifs à être développés à partir du document écologique de base. La carte écologique doit permettre de lever, dans les mêmes contours cartographiques, les cartes interprétatives suivantes:

- la vocation agricole,
- la vocation forestière,
- la vocation récréative,
- la vocation faunique,
- la vocation récréative des écosystèmes aquatiques,
- l'attrait du paysage,
- les chronoséquences végétales après feu, coupe ou tout autre type d'intervention,
- les possibilités d'utilisation des sols pour l'ingéniérie,
- la traficabilité,
- le potentiel de régénération naturelle,

- les risques de chablis,
- les risques d'érosion du sol,
- la capacité de rétention en eau des sols,
- les risques de destruction ou de dégradation de la végétation et des sols,
- la production potentielle pour diverses espèces végétales utiles pour l'agriculture, la foresterie, la faune ou l'amélioration de la qualité des paysages,
- les niveaux de complémentarité et de compatibilité des diverses ressources naturelles renouvelables.

LES CRITÈRES DE LA CLASSIFICATION ÉCOLOGIQUE

Les critères ont été choisis en fonction des objectifs poursuivis, de leurs possibilités d'interprétation par télédétection et de leur permanence. Les critères retenus sont les suivants:

Ecosystèmes terrestres:

- le climat régional,
- la physiographie,
- la géologie du substratum,
- la géomorphologie,
- le relief,
- la pédogenèse (type de développement du sol),
- la chronoséquence végétale,
- la texture, l'épaisseur et la pétrographie du sol,
- le régime hydrique du sol,
- la nature des horizons organiques de surface,
- la physionomie et la structure de la végétation,
- la composition de la végétation,
- la texture et la pierrosité du sol,
- la pente.

Ecosystèmes aquatiques:

- l'étendue,
- la profondeur,
- la géomorphologie des berges,
- le découpage du périmètre aquatique,
- la pente de la berme,
- le relief des rives,
- le système de drainage.

LES NIVEAUX DE PERCEPTION ÉCOLOGIQUE DE L'ESPACE

La perception d'un phénomène naturel est fonction de l'échelle à laquelle on peut et ou on veut l'exprimer. Nous avons ainsi été amenés à considérer cinq niveaux de perception écologique de l'espace:

1er niveau: la *REGION ECOLOGIQUE* (échelle d'expression 1:1,000,000): portion de territoire caractérisée par un climat régional distinctif, tel qu'exprimé par la végétation.

2e niveau: le *DISTRICT ECOLOGIQUE* (échelle d'expression 1:500,000): portion du territoire caractérisée par un pattern propre du relief, de la géologie, de la géomorphologie et de la végétation régionale.

3e niveau: le *SYSTEME ECOLOGIQUE* (échelle d'expression 1:125,000): portion du territoire caractérisée par un pattern propre du relief, des matériaux géologiques de surface, des sols, des chronoséquences végétales et des plans d'eau.

4e niveau: le *TYPE ECOLOGIQUE* (échelle d'expression 1:20,000): portion de territoire caractérisée par une combinaison relativement uniforme du sol et de la chronoséquence végétale.

5e niveau: la *PHASE ECOLOGIQUE* (échelle d'expression 1:10,000): portion de territoire caractérisée par une combinaison relativement uniforme du sol et de la végétation.

La cartographie écologique du territoire de la Baie James se situe principalement au 3e niveau, bien que Districts et Régions Ecologiques soient également cartographiés. Par contre, la classification écologique du territoire est réalisée à chacun de ces cinq niveaux de perception.

RÉALISATION PRATIQUE DE L'INVENTAIRE ÉCOLOGIQUE

Le programme de classification et de cartographie du territoire de la Baie James a été réalisé par une équipe multidisciplinaire de 29 personnes dont la composition et l'organisation sont illustrées à la figure 2.

Un plan de reconnaissance sur le terrain est établi à partir d'une photointerprétation préliminaire des Districts Ecologiques. L'objectif de ces reconnaissances est de découvrir, pour ensuite les définir, les principales séquences existant entre la végétation et les principaux gradients écologiques du milieu naturel: les climoséquences, les toposéquences, les lithoséquences et les chronoséquences. Les travaux de terrain répartis sur les trois étés du projet se sont étalés sur une période totale de 35 semaines. Huit équipes, constituées chacune d'un pédologue et d'un phytosociologue effectuèrent un total de 963 reconnaissances écologiques.

Chaque reconnaissance consiste en une description détaillée des écosystèmes rencontrés en parcourant un transect de trois à huit km de longueur. Au cours de ces reconnaissances, un total de 2,088 stations écologiques de référence furent échantillonnées et décrites à l'aide de relevés complets du sol, de la végétation et de divers paramètres du milieu. A la fin de chaque journée de reconnaissance, chaque équipe consigne, sous la forme d'un rapport, ses principales observations et cartographie les Systèmes Ecologiques parcourus. L'équipe soumet ainsi ses hypothèses à la critique des autres équipes. Une décision est alors prise quant à la classification de ces unités qui deviennent des Systèmes Ecologiques de référence pour la photointerprétation finale. Chaque Système Ecologique cartographié est décrit en pourcentage des Types Ecologiques le constituant. Ces derniers sont définis à partir des stations écologiques de référence.

RÉSULTATS

1. Cartographie des Systèmes Ecologiques.

Cette cartographie réalisée à l'échelle de 1:125,000 représente l'essence même du projet. Les cartes terminées recouvrent actuellement une superficie de 350,000 km^2. La cartographie finale des 60,000 km^2 restant est en cours. Les unités cartographiques sont identifiées à l'aide de symboles (SEER, 1974, Ducruc *et al.*, 1976) par lesquels sont caractérisés:

- la Région Ecologique,
- le relief,
- l'épaisseur des matériaux meubles,
- la nature et la forme des matériaux géologiques de surface,
- la catégorie d'écosystème aquatique, ainsi que certaines de leurs caractéristiques morpholométriques: découpage du périmètre aquatique, pente de la berme, pente des rives, profondeur, système de drainage, matériaux géologiques de surface des rives,
- l'abondance de ruisseaux et de stations ripariennes,
- la répartition (en %) des Types Ecologiques permettant de connaître la superficie couverte par les types de sol et les chronoséquences végétales pour chaque unité.

2. Cartographie des Régions Ecologiques.

Les Régions Ecologiques du Territoire de la Baie James ont été décrites et cartographiées par l'équipe du SEER (Gerardin *et al.*, 1976). La carte des Régions Ecologiques constitue le cadre écoclimatique à l'intérieur duquel l'équipe étudie actuellement les chronoséquences végétales. Elle permet aussi d'obtenir, sur un seul document, une vue synthétique des principales régions naturelles du territoire étudié. A ce titre, elle peut être d'une grande utilité comme cadre de référence géograhique dans la définition des grands objectifs d'aménagement du territoire lors du processus de planification.

3. Cartographie des Districts Ecologiques.

Les Districts Ecologiques du Territoire de la Baie James seront décrits et cartographiés par l'équipe de SEER durant l'année en cours. La carte des Districts Ecologiques se veut être une synthèse permettant de saisir la réalité globale de l'ensemble du territoire dans ses aspects climatiques, phyto-géographiques, géologiques et géomorphologiques.

4. Classification des Types Ecologiques.

La classification provisoire des Types Ecologiques du Territoire de la Baie James est disponible (Jurdant, 1975). Un rapport descriptif de la classification définitive est en préparation. Rappelons que chaque Système Ecologique (l'unité cartographique de base de l'inventaire écologique) est défini comme étant un pattern de Types Ecologiques, à chaque unité cartographiée correspond une fiche décrivant le pourcentage de l'unité couvert par les Types Ecologiques qui le constituent.

5. Classification des Phases Ecologiques.

Le module 'Végétation' de l'équipe du SEER travaille actuellement à la détermination des groupes écologiques d'espèces. Ceci permettra d'ici deux ans de produire une classification complète de tous les groupements végétaux du Territoire de la Baie James. A l'aide de cette classification, les Phases Ecologiques seront décrites, condition préalable à la détermination des chronoséquences végétales.

6. Cartographie de la végétation actuelle.

Bien que le projet de classification et cartographie écologique du Territoire de la Baie James ne prévoit pas le relevé systématique de ce thème cartographique, une méthode a été mise au point (Ducruc *et al.*, 1974) et déjà appliquée sur une superficie de 50,000 km^2.

7. Interprétations des cartes écologiques pour l'aménagement du territoire.

Dans le but de fournir à l'aménagiste les outils

nécessaires à son travail, nous avons préparé un certain nombre de documents permettant d'interpréter les cartes écologiques de base. Il est essentiel que l'écologiste traduise son *jargon* en termes compréhensibles pour le gestionnaire. Certaines interprétations sembleront sans doute osées et insuffisamment étayées par une expérimentation rigoureuse aux yeux de nombreux scientifiques. La subjectivité inhérente à ces évaluations est cependant contrebalancée par la possibilité de réévaluer toute interprétation sur la base de nouveaux critères, mais en utilisant toujours les données biophysiques de base de la carte écologique dont le niveau de subjectivité est comparativement moindre.

Quelques exemples d'élaboration de clefs d'interprétation sont exposés par Mondoux *et al.*, (1976). Parmi les documents interprétatifs disponibles, signalons:

- les interprétations pour le secteur ingénierie (SEER, 1974),
- l'évaluation de l'attrait du paysage (Jurdant, 1975),
- les interprétations pour la traficabilité, les risques de chablis et les risques d'érosion (Jurdant et Bélair, 1974),
- l'évaluation du potentiel récréatif des écosystèmes aquatiques (Jurdant, 1975),
- l'évaluation du potentiel forestier (Jurdant, 1975),
- l'évaluation du potentiel pour le castor (Traversy, 1974),
- l'évaluation du potentiel pour la sauvagine (Bélair et Zarnovican, 1975),
- l'évaluation du potentiel pour la petite faune terrestre (Gingras, 1975),
- l'évaluation du potentiel pour la truite mouchetée, la truite grise, le doré, le brochet et la ouananiche (Mondoux, 1976: en préparation).

Parmi les interprétations qui seront réalisées au cours des deux prochaines années, signalons:

- l'évaluation du potentiel agricole,
- l'évaluation du potentiel pour la récréation dans la nature,
- l'évaluation du potentiel de régénération naturelle des principales essences forestières,
- les chronoséquences végétales après coupe à blanc et après feu.

UTILE PRATIQUE

La crise de l'environnement que nous connaissons aujourd'hui résulte souvent d'un manque d'attention accordé aux facteurs écologiques dans le processus décisionnel. La carte écologique répond à un besoin d'information écologique de base (environmental base-line data) nécessaire à diverses étapes du processus de développement, de planification et d'aménagement du territoire. La connaissance des caractéristiques biophysiques des écosystèmes et de leurs inter-relations, obtenue grâce à un inventaire écologique permet de rationaliser la plupart des décisions relatives à l'utilisation du milieu naturel. Sans être exhaustive, la liste suivante permet de mesurer l'importance pratique de ce type de document:

- la détermination du niveau de complémentarité et de compatibilité des diverses ressources naturelles,
- le zonage intégré du territoire,
- la localisation des écosystèmes fragiles afin d'en prévenir la destruction ou la dégradation,
- la localisation des paysages exceptionnels du point de vue esthétique et/ou culturel,
- le choix des aires à protéger: réserves écologiques, centres d'interprétation de la nature, etc...,
- le choix des aires les plus propices à un aménagement intensif, (forestier, agricole, cynégétique ou récréatif),
- le choix des cultures agricoles,
- la détermination des coûts de production des diverses cultures agricoles,
- le choix des essences à reboiser,
- le choix des aires à reboiser,
- la détermination des coûts de reboisement et de production des plantations forestières,
- les analyses d'impact des grands projets,
- le choix des aires les plus adéquates pour les équipements collectifs: routes, chemins de fer, aéroports, lignes de transport d'énergie, installations portuaires, barrages, oléoducs, gazoducs, etc...
- la détermination des pratiques sylvicoles à but commercial ou esthétique,
- la planification des opérations liées à l'exploitation de la matière ligneuse,
- la planification du système de protection contre les incendies de forêt.

CONCLUSION

Alors que nous sommes engagés dans la dernière phase de ce programme de classification et de cartographie écologique du territoire de la Baie James, nous formulons l'espoir qu'il suscitera un dialogue fructueux entre tous ceux qui, de près ou de loin, sont touchés par l'aménagement du territoire: non seulement les écologistes, les planificateurs et les aména-

gistes, mais aussi les mandataires publics (à tous les échelons de responsabilité administrative), les industriels, les commerçants les groupes populaires et tous les citoyens qui, réalisant que l'environnement est un bien collectif, s'appliqueront à ce que la collectivité, dans son ensemble, veille à son aménagement.

Si l'inventaire du 'Capital-Nature' permet de calculer le coût de la terre, du sol, de l'eau, du paysage, peut-être alors, aurons-nous modestement contribué à promouvoir une utilisation plus rationnelle, plus respectueuse et surtout plus juste de la nature, condition indispensable au véritable avenir social de l'homme.

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ANNEXE I: UTILISATION DE LA VÉGÉTATION DANS LA CLASSIFICATION ET LA CARTOGRAPHIE ÉCOLOGIQUE DU TERRITOIRE DE LA BAIE JAMES

Les Régions Ecologiques du territoire de la Baie James.

Richard Zarnovican, V. Gerardin,
J.P. Ducruc, M. Jurdant et G. Audet,
Service des études écologiques régionales
Direction régionale des terres
Environnement Canada
Québec.

La carte des *Régions Ecologiques* constitue une carte éco-climatique. Son intérêt pratique réside dans le fait que les unités de base, les *Régions Ecologiques*, fournissent un cadre de référence à l'intérieur duquel l'aménagiste retrouvera les mêmes chronoséquences végétales sur des habitats semblables.

Les travaux de terrain sur l'ensemble des 400.000km^2 du Territoire de la Baie James, dans le cadre du projet ETBJ ont été effectués durant les étés 1973, 1974 et 1975. Les données de base récoltées se subdivisent en deux types:

963 *Reconnaissances Ecologiques:* La Reconnaissance Ecologique consiste en un transect de cinq à huit km au long duquel une équipe constituée d'un pédologue et d'un phytosociologue effectue une cartographie détaillée des sols et de la végétation. L'objectif de Reconnaissance Ecologique est la compréhension, la description et la classification, par l'équipe, des écosystèmes parcourus. Chaque Reconnaissance Ecologique est concrétisée sous la forme d'un rapport de reconnaissance dans lequel sont décrits un certain nombre de "points d'observation". Pour chacun de ceux-ci l'équipe détermine le Type Physionomique de végétation, le Type Ecologique et le Type de roche-mère pédologique (re: Jurdant, 1975).

2088 *Stations Ecologiques de Référence:* Ces stations écologiques de référence sont décrites par les diverses équipes aux endroits choisis comme étant les plus représentatifs des divers milieux rencontrés au cours de leur Reconnaissance Ecologique. Les données recueillies (re: Jurdant, 1975) constituent la base de toute l'analyse et de toute la classification écologique aux divers niveaux de perception écologique de l'espace, y compris celui de la *Région Ecologique*.

Le présent exposé donne une définition des *Régions Ecologiques*, leur regroupement en *Domaines* et *Zones* ainsi que la carte des *Régions Ecologiques* à l'échelle du 1:1.000.000.

Par la suite, nous préciserons les limites de ces *Régions Ecologiques* sur les cartes des *Systèmes Ecologiques* au 1:125.000 et nous procéderons à la détermination des chronoséquences végétables pour chaque *Type Ecologiques* dans chacune des *Régions Ecologiques*.

Nous pensons cependant que l'aménagiste peut déjà utiliser la carte des *Régions Ecologiques* présentée ici comme base de travail pour la présentation générale du territoire sous ses aspects bio-climatiques, bio-géographiques et biologiques.

MÉTHODE ET MATÉRIEL

Dans la première étape nous avons utilisé la technique des profils pondérés d'espèces de 202 Stations Ecologiques de référence sur till bien drainé par les groupes d'espèces indicatrices des trois variables écologiques suivantes: longitude, latitude et altitude.

La méthodologie et la technique des profils pondérés d'espèces ont été décrites en détail par Gerardin *et al.* (1975). Cette étape nous a permis de connaître la valeur indicatrice de quelques 140 espèces vis-à-vis ces trois variables écologiques et ainsi d'établir une zonation latitudinale.

Comme la distribution des tills bien drainés dans le territoire n'est pas uniforme, la technique des profils pondérés est restée limitée quant aux possibilités interprétatives des résultats obtenus, pour certaines parties du territoire.

Nous avons donc procédé, dans une deuxième étape, à l'analyse des Types Physionomiques de végétation (Jurdant, 1975) dominants de toutes les Reconnaissances effectuées (le Type Physionomique dominant est celui qui forme au moins 60% de tous les points d'observation effectués au cours de la même Reconnaissance Ecologique). De cette façon, chaque Reconnaissance est identifiée au moyen d'un Type Physionomique de végétation reporté sur un fond topographique au 1:500.000. Ce procédé nous a permis, d'une part, de préciser et fixer les limites de *Zones* et de *Sous-Zones* telles que fournies par les profils pondérés et, d'autre part, d'identifier les *Domaines*.

Notons cependant, que pour fixer les *Zones* extrêmes, arctique au nord et boréale au sud, nous avons utilisé en plus des espèces différentielles. La limite de la *Zone arctique* suit la limite sud de l'aire de distribution de

certaines espèces arctiques tandis que la *Zone boréale* suit la limite nord de certaines plantes boréales.

Nous avons ensuite procédé à l'établissement des limites des *Régions Ecologiques*. Une *Région Ecologique* a été définie à l'intérieur d'un *Domaine* au moyen de l'espèce ou des espèces arborescentes caractéristiques d'une région et à la fois différentielle des autres régions ainsi qu'à l'aide des composantes caractéristiques des strates inférieures.

Il est à remarquer, que pour certains grands *Domaines*, nous avons procédé à leur division en *Régions Ecologiques* au moyen de limites arbitraires.

Une fois le territoire de la Baie James, divisé en *Zones*, *Sous-Zones*, *Domaines* et *Régions*, nous avons recherché les coïncidences possibles entre les limites trouvées et les limites de certains indices climatiques, telles que fournies par Gagnon et Ferland (1967) et Wilson (1971), et nous les commentons ci-dessous.

RÉSULTATS ET DISCUSSIONS

Le résultat de la classification des *Régions Ecologiques* se traduit, en premier, par la carte des *Régions Ecologiques* à l'échelle du 1:1.000.000 (Figure 1).

La clé explicative suivante permettra, nous l'espérons, de mieux saisir la définition et l'importance des différentes *Régions Ecologiques*.

Zone arctique: Elle se présente sous forme de landes arctiques, ou toundra, dominées par les lichens et plantes herbacées avec un faible recouvrement des arbustes rabougris. On la distingue par la présence des espèces arctiques suivantes:

Arenaria uliginosa
Carex atrofusca
Carex misandra
Carex Williamsii
Deschampsia pumila
Koenigia islandica
Carex norvegica

Ces dernières, sont ici, à leur limite sud.

Domaine maritime des landes arctiques: Ce domaine s'étend sur une bande côtière plus ou moins étroite de Pointe Attiquane au sud, jusqu'à Bear Islands au nord et ne comprend qu'une seule *Région Ecologique:* Pointe Louis XIV. Cette *Région Ecologique* coïncide avec la limite de 600 mm de moyenne annuelle des précipitations totales (Wilson, 1971).

Zone hémiarctique: Cette *Zone* couvre la partie la plus septentrionale du territoire de la Baie James. La limite entre l'hémiarctique et le subarctique coïncide avec l'isoligne de la date moyenne de la fin de l'hiver le 10 mai et celui de la date moyenne du début de la saison de croissance le 31 mai. Mais c'est surtout l'isoligne de 800 degrés jours (Gagnon et Ferland, 1967) qui constitue sa limite méridionale la plus significative. Elle est caractérisée par quatre *Domaines*.

Domaine maritime des landes boisées à Epinette blanche et lichens: Ce domaine comprend une seule *Région Ecologique:* Manitounuk. Elle s'étend sur une bande côtière étroite de Bear Islands au sud, débordant les limites nord du territoire au delà du 56ème. Cette *Région* est caractérisée par la constance de l'Epinette blanche arborescente; la densité des groupements n'atteint pas cependant 25% du recouvrement.

Domaine des landes à lichens: Un *Domaine* ou le Type Physionomique prédominant est la lande à lichens: formations végétales où les espèces ligneuses n'atteignent pas la hauteur de 3 m. On remarque l'abondance des arbustes comme *Betula glandulosa*, *Alnus crispa* et *Salix* spp. Le *Domaine* comprend une *Région Ecologique:* Lac Bienville. Au niveau de la strate inférieure, c'est la prédominance des lichens.

Domaine des landes boisées à Mélèze, Epinette noire et lichens: Caractérisé surtout par la constance du Mélèze au niveau de la strate arborescente. Même si les espèces ligneuses, telles le Mélèze et l'Epinette noire dépassant la hauteur de 3 m, il est rare qu'elles atteignent un recouvrement de 25%. Au niveau de la strate inférieure, les lichens prédominent encore. Ce *Domaine* comprend une seule *Région Ecologique:* Lac Delorme.

Domaine montagnard des landes à lichens: Il est caractérisé par la bande à lichens comme Type Physionomique prédominant. Les limites du *Domaine* correspondent avec les limites de la *Région Ecologique:* Monts Shefferville. Caractérisée par des groupements arbustifs dominés par *Betula glandulosa*, *Alnus crispa* et l'Epinette noire rabougrie avec un tapis de lichens dans la strate inférieure. Géographiquement, la limite de la *Région Ecologique* correspond à la limite altitudinale de 2000 pieds.

Zone subarctique: La *Zone subarctique* couvre

presque 75% du territoire de la Baie James et s'étend d'est en ouest, entre le 50e et le 55e Nord. Hare (1950) la définit sous le nom de "*Open Boreal Woodland*", tandis que Rousseau (1952) définit la forêt subarctique comme "*un parc aux arbres espacés*", ceci correspond bien au Type Physionomique, Lande boisée à Epinette noire et lichens lequel forme un *Domaine*, dans la partie la plus septentrionale. C'est en considérant la distribution de différents *Domaines* et aussi des limites climatiques naturelles que nous avons subdivisé la *Zone subarctique* en trois *Sous-Zones*.

Sous-Zone Haut Subarctique: Cette *Sous-Zone* est séparée, au sud, du *Moyen Subarctique*, par l'isoligne 1200 du nombre annuel de degrés jours de croissance de Wilson (1971). Elle comprend deux *Domaines*.

Domaine maritime des landes boisées à Epinette blanche et lichens: Les limites du *Domaine* correspondent avec les limites de la *Région Ecologique:* Rivière Roggan. Caractérisée par la constance de l'Epinette blanche arborescente dont la densité des peuplements est inférieure à 25%. Les strates inférieures sont dominées par les lichens.

Domaine des landes boisées à Epinette noire et lichens: Il correspond à l'*Open Boreal Woodland* de Hare (1950) ou au *Parc aux arbres espacés* de Rousseau (1952) et est dominé par le Type Physionomique lande boisée à Epinette noire dont le tapis lichenique forme la strate inférieure. Le *Domaine* se divise en deux *Régions Ecologiques: Région* Rivière Kanaaupscow à l'ouest plus sèche et *Région* Lac Legrand plus humide à l'est. Elles sont séparées par l'isoligne 28e de précipitations totales annuelles.

Sous-Zone Moyen Subarctique: Cette *Sous-Zone* se différencie de la *Sous-Zone Bas Subarctique* par plusieurs limites climatiques naturelles: l'isoligne de la date moyenne de la fin de l'hiver le 30 avril, l'isoligne de la date moyenne, au printemps, à laquelle la température moyenne quotidienne dépasse 50°F (10°C), et l'isoligne de la date moyenne, en automne, à laquelle la température moyenne quotidienne tombe au dessous de 50°F (10°C) Wilson (1971). Il semble que la limite septentrionale du *Moyen Subarctique* ait une signification écologique très importante puisqu'elle coïncide avec la limite des forêts de densité D (25 à 40%) et C (40% à 60% de recouvrement). Le *Moyen Subarctique* comprend quatre *Domaines*, en commençant à l'ouest.

Domaine maritime de la Pessière à Epinette blanche et mousses: dont les limites coïncident avec la *Région Ecologique:* Fort Georges. C'est une étroite bande côtière entre le 54e au nord de l'embouchure de la rivière Conn au sud. Elle est dominée par les Pessières blanches (densité: class D; hauteur: classe D) avec un tapis de mousses qui domine les strates inférieures.

Domaine de la Pessière à Epinette noire, mousses et Ledum: qui comprend une seule *Région Ecologique:* Lac Sakami. Caractérisée par les forêts d'Epinette noire (densité: classes D et C; hauteur: classes 4 et 3) mais c'est au niveau des strates inférieures que nous trouvons les éléments différentiels du *Domaine* suivant, c'est-à-dire mousses et *Ledum*.

Domaine de la Pessière à Epinette noire et lichens: Le *Domaine* se distingue du *Domaine* précédent, d'une part, par l'absence de mousses remplacées par les lichens et, d'autre part, par l'isoligne 700 mm de moyenne annuelle de précipitations totales (Wilson, 1971 et Gagnon et Ferland, 1967). Le *Domaine* comprend une seule *Région Ecologique:* Lac Nitchicun. Le Type Physionomique prédominant qui la caractérise est une forêt d'Epinette noire (densité: classe D; hauteur: classes 4 et 3) avec un tapis lichenique.

Domaine montagnard des landes boisées à Epinette noire et lichens: Le dernier *Domaine* du *Moyen Subarctique*, distingué du *Domaine* précédent par l'isoligne 800 mm de moyenne annuelle des précipitations totales (Wilson, 1971) et géographiquement déterminé, au dessus de l'altitude de 2000 pieds. Le *Domaine* coïncide avec la *Région Ecologique:* Lac Opiscoteo. Elle est caractérisée par la diminution de la densité des peuplements et le Type Physionomique prédominant est la lande boisée à Epinette noire (hauteur: classe 4) tandis que la composante principale des strates inférieures est un tapis de lichens.

Sous-Zone Bas Subarctique: La dernière *Sous-Zone* de la *Zone Subarctique* dont la limite septentrionale suit plus ou moins le 52° 30' de latitude nord a été fixée et précisée par la limite nord de la distribution du Sapin baumier et du Bouleau blanc dans les relevés floristiques où ces deux espèces atteignaient 25% du recouvrement de la strate arborescente. De cette façon, ces espèces deviennent à la fois caractéristiques pour le *Bas Subarctique* et, en même temps, différentielles de la *Sous-Zone Moyen Subarctique*. La limite méridionale entre le *Bas Subarctique* et la *Zone Boréale* suit l'isoligne 1400 degrés jours de croissance (Gagnon et Ferland, 1967). Cette

Sous-Zone comprend trois *Domaines*.

Domaine maritime de la pessière à Epinette blanche, Sapin baumier et mousses: C'est le *Domaine* le plus méridional de l'Epinette blanche du territoire de la Baie James à laquelle s'associe le Sapin baumier, espèce différentielle du *Bas subarctique*. La constance de l'Epinette blanche sur la côte a été remarquée par Hustich (1949 et 1950) et il l'appelait la *maritime tree line*. Payette (*verbatim*) associe la présence de l'Epinette blanche à l'humidité atmosphérique élevée due à la grande fréquence des brouillards. Pour notre part, nous avons observé, en plus, une nette préférence de l'Epinette blanche pour les dépôts littoraux bien drainés. Ce *Domaine* coïncide avec une seule *Région Ecologique:* Baie de Rupert caractérisée par le Type Physionomique suivant: Forêt d'Epinette blanche, Sapin baumier (densité: classes B et C; hauteur: classe 2) à mousses. La *Région* forme une étroite bande côtière depuis la frontière provinciale de l'Ontario jusqu'à l'embouchure de la rivière Eastmain.

Domaine de la Pessière à Epinette noire, Sapin baumier, Bouleau blanc et mousses: Le *Domaine* se distingue du *Domaine* précédent par l'absence d'Epinette blanche, par la présence constante d'Epinette noire et Sapin baumier comme espèces caractéristiques et l'apparition du Bouleau blanc. Au niveau des strates inférieures, c'est la dominance des mousses. Le *Domaine* comprend deux *Régions Ecologiques:* à l'ouest, la *Région* Lac Evans caractérisée par le Type Physionomique dominant: Forêts d'Epinette noire, Sapin baumier, Bouleau blanc (densité: classes B et C; hauteur: classes 3 et 2) à mousses. Cette région s'étend jusqu'au 76e à l'est. A l'est de l'isoligne de 28 pouces de précipitations annuelles totales, c'est la *Région Ecologique:* Lac Mistassini, donc une *Région Ecologique* plus humide, semblable à la *Région* précédente mais, par contre, l'abondance du Sapin baumier dans les Types Physionomiques dominants devient plus grande. A l'est cette *Région Ecologique* déborde probablement les limites du territoire étudié.

Domaine montagnard de la pessière à Epinette noire, Sapin baumier et mousses: Ce *Domaine* se distingue du *Domaine* précédent par la diminution du Bouleau blanc et sa limite coïncide avec l'isoligne 900 mm de moyenne annuelle des précipitations totales (Wilson, 1971). De plus, ce *Domaine* comprend deux *Régions Ecologiques:* la *Région Ecologique* Lac Hippocampe caractérisée par le Type Physionomique dominant, Forêts d'Epinette noire et Sapin baumier (densité: classes C et D; hauteur: classes 3 et 4) avec les mousses qui dominent les strates inférieures, et la *Région Ecologique* Monts Otish qui comprend les piedmonts des Monts Otish avec les forêts d'Epinette noire et Sapin baumier (dentisté: classes B et C; hauteur: classes 3 et 2) avec les mousses dominant les strates inférieures, mais aussi les sommets alpins avec leur végétation particulière de landes à lichens.

Zone boréale: La *Zone* bioclimatique la plus méridionale du territoire de la Baie James. La limite septentrionale suit la limite nord de l'aire de distribution des espèces suivantes:

Acer spicatum
Sambucus pubens
Aralia nudicaulis
Streptopus roseus
Pteridium aquilinum

Cette limite coïncide avec l'isoligne 1400 degrés jours de croissance établie par Gagnon et Ferland (1967). La *Zone* comprend un seul *Domaine:*

Domaine de la Pessière à Epinette noir, Sapin baumier, Bouleau blanc, mousses et herbacées: Caractéristé par le Type Physionomique prédominant: forêts d'Epinette noire, Sapin baumier, Bouleau blanc (densité: classes B et C; hauteur: classes 3 et 2); au niveau des strates inférieures notons, en plus d'une abondance constante des mousses, une constance des herbacées. Le *Domaine* se divise en deux *Régions Ecologiques* à savoir: la *Région* Lac Matagami à l'ouest et la *Région* Lac Chibougamau à l'est. La limite qui les sépare passe entre le 76e et 77e longitude ouest, et il faut signaler que cette limite est, pour le moment, arbitraire.

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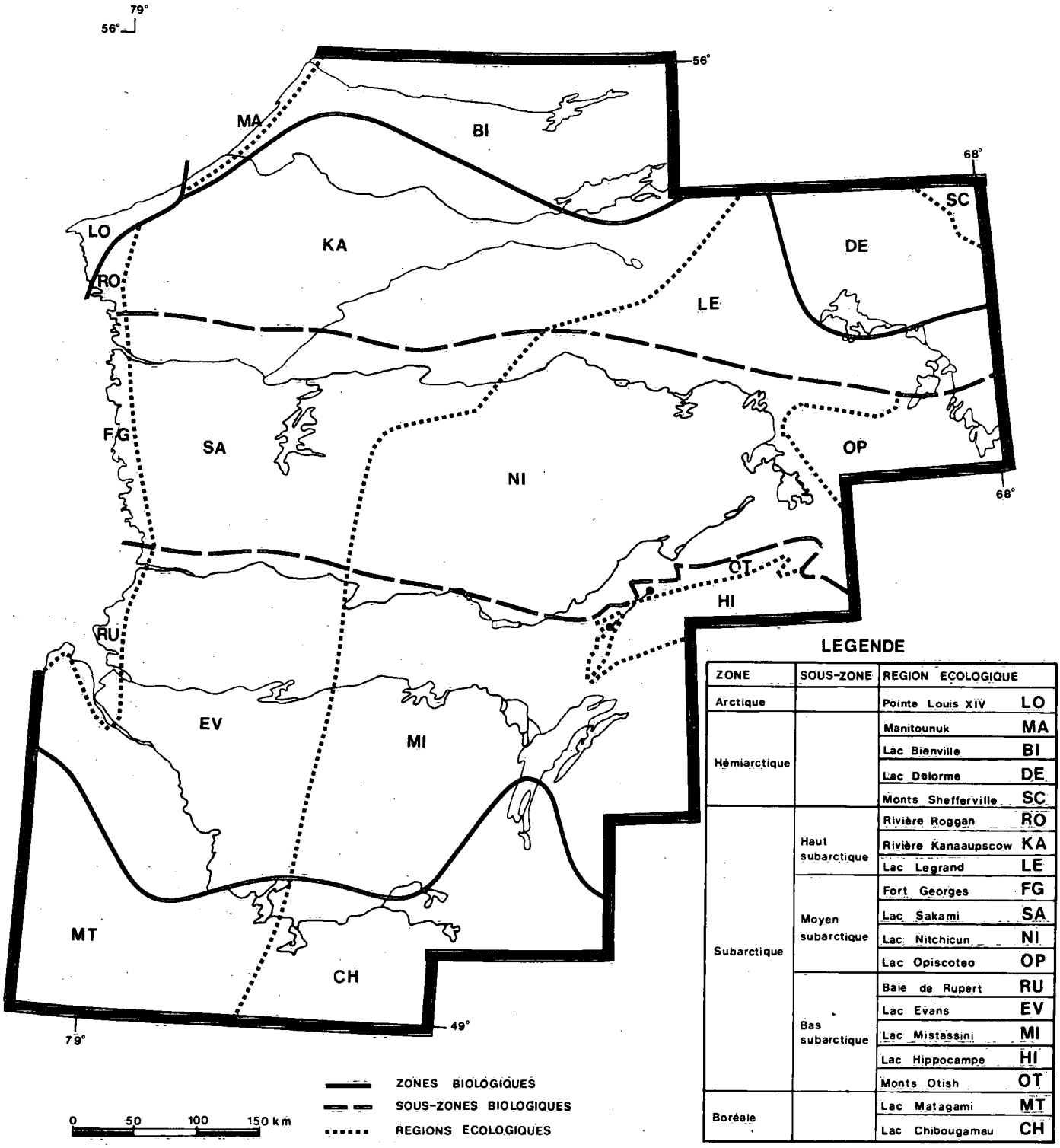
Figure 1

LES REGIONS ECOLOGIQUES DU TERRITOIRE DE LA BAIE DE JAMES



ZONE	SOUS-ZONE	REGION ECOLOGIQUE	
Arctique		Pointe Louis XIV	LO
Hémiarctique		Manitounuk	MA
		Lac Bienville	BI
		Lac Delorme	DE
		Monts Shefferville	SC
Subarctique	Haut subarctique	Rivière Roggan	RO
		Rivière Kanaaupscow	KA
		Lac Legrand	LE
	Moyen subarctique	Fort Georges	FG
		Lac Sakami	SA
		Lac Nitchicun	NI
		Lac Opiscoteo	OP
	Bas subarctique	Baie de Rupert	RU
		Lac Evans	EV
		Lac Mistassini	MI
		Lac Hippocampe	HI
		Monts Otish	OT
Boréale		Lac Matagami	MT
		Lac Chibougamau	CH

ANNEXE 2: EXEMPLES DE DESCRIPTIONS DES SYSTÈMES ÉCOLOGIQUES

par

Michel Jurdant, J.L. Bélair, V. Gérardin
et J.P. Ducruc
Service des études écologiques régionales
Direction régionale des terres à Québec
Environnement Canada

Le texte qui suit constitue l'annexe 2 d'une publication que les auteurs viennent de terminer et qui sera publiée prochainement sous le titre "L'Inventaire du Capital Nature".

Nous croyons que l'inclusion telle quelle de cette information sera de nature à éclaircir certains éléments relatifs à la compréhension du système de classification utilisé par le SEER dans le territoire de la Baie James.

Nous incluons également quelques cartes tirées de cette publication:

la carte #4: Les Systèmes Ecologiques

la carte #23: L'aptitude des sols pour la forêt

la carte #24: La production forestière potentielle (m^3/ha/année)

la carte #31: Le potention de régénération naturelle du Pin gris

la carte #44: Le potentiel pour le Castor

la carte #47: L'indice du Capital-Nature

Le SYSTEME ECOLOGIQUE est une portion de territoire caractérisée par un pattern propre du relief, des matériaux géologiques de surface, des sols, des chronoséquences végétales et des plans d'eau.

Nous illustrons ici la description, la classification et la signification pour l'aménagiste (tableau A2-1) des *Systèmes Ecologiques* à l'aide de quatre unités provenant de la carte 4 (annexe 1). Dans les rapports d'inventaire écologique chaque carte est accompagnée d'un fichier où les *Systèmes Ecologiques* sont decrits en ordre alpha-numérique. Les quatre unités choisies seraient ainsi rangées:

JHI-5E-1-a44
OH4-1V1A-1-b11
OR2-1A1V-1-f22
SM8-01V-1-a11

Chaque *Système Ecologique* est identifié par une série de caractères symbolisant les éléments suivants:

(1) *LE CLIMAT REGIONAL.* La première lettre majuscule caractérise et correspond au symbole de la *Région Ecologique* dans laquelle se situe le Système Ecologique considéré. Les quatre Systèmes Ecologiques pris en example sont respectivement situés:
dans les Basses Terres du Haut-Saguenay: JH1-5E-1
dans les Contreforts des Laurentides: OH4-1V1A-1-b11 et OR2-1A1V-1-f22
dans les Hautes Laurentides: 5M8-01V-1-a11

(2) La seconde lettre majuscule identifie *LE RELIEF* du *Système Ecologique* (fig. 14):
F: relief plat,
U: relief ondulé,
R: relief moutonné,
H: relief montueux ou accidenté,
M: relief montagneux ou très accidenté.

(3) Le chiffre suivant représente les combinaisons d'*EPAISSEUR DE MATERIAUX MEUBLES* dans le *Système Ecologique:*
1. épais,
2. épais et mince,
3. épais et affleurements,
4. mince et épais,
5. mince,
6. mince et affleurements,
7. affleurements et épais,
8. affleurements et mince,
9. affleurements.

(4) Les symboles alpha-numériques qui suivent caractérisent LA NATURE, L'ORIGINE ET LA MORPHOLOGIE DES MATERIAUX GEOLOGIQUES DE SURFACE les plus abondants du *Système Ecologique*. Lors des travaux exécutés au Saguenay/Lac-Saint-Jean nous avons retenu les catégories suivantes:

<u>Nature et origine des matériaux géologiques de surface</u>:
1: till,
2: sédiments fluvio-glaciaires,
3: sédiments deltaiques,
4: sédiments fluviatiles ou glacio-lacustres,
5: sédiments argilo-marins,
5*: sédiments littoraux ou deltaiques sur sédiments marins,
6: sédiments littoraux,
7: sédiments organiques ombrotrophes,
7*: sédiments organiques minérotrophes,
8: dépôts de versants,
9: sédiments éoliens,
0: roche en place.

<u>Morphologie des matériaux géologiques de surface</u>:
A: contrôlée par la roche en place,
C: cannelée,

D: drumlinoide,
E: érodée,
F: deltaique,
H: bosselée,
N: non structurée,
P: en plaine,
R: en crêtes,
S: structurée,
T: en terrasses,
V: plaquage,
X: complexe.

(5) LE NUMERO D'ORDRE du *Système Ecologique* réfère au rapport ou au fichier accompagnant la carte écologique. Il permet de distinguer les unités sur la base du *Pattern* des sols et des chronoséquences végétales. Un example des fiches descriptives des quatre *Systèmes Ecologiques* est illustré aux pages suivantes. Chaque fiche comprend l'énumération des *Types Ecologiques* présents dans le *Système Ecologique*, le pourcentage de recouvrement de chacun d'eux, ainsi que la description des matériaux géologiques de surface, des types de sols et des chronoséquences végétales.

(6) LES ECOSYSTEMES AQUATIQUES sont décrits pour chaque *Système Ecologique* de la manière suivante:
La catégorie d'écosystème aquatique est identifiée à l'aide d'une lettre minuscule dans la dernière partie du symbole. Dans l'exemple, tiré des travaux effectués dans la région du Saguenay/Lac-Saint-Jean, les symboles retenus sont les suivants:

a: moins de 5% de la surface de l'unité est recouverte par des étendues aquatiques,
b: 5 à 15% de la surface de l'unité est recouverte par des lacs plus petits que 250 ha,
c: plus de 15% de la surface de l'unité est recouverte par des lacs plus petits que 250 ha,
f: plus de 15% de la surface de l'unité est recouverte par des lacs dont la superficie varie entre 250 et 500 ha,
g: plus de 15% de la surface de l'unité est recouverte par des lacs dont la superficie varie entre 500 et 1000 ha,
n: plus de 15% de la surface de l'unité est recouverte par des lacs dont la superficie varie entre 1000 et 2500 ha,
r: plus de 15% de la surface de l'unité est recouverte par des lacs plus grands que 2500 ha,
h: plus de 5% de la surface de l'unité est recouverte par des rivières de plus de 20 m de largeur,
y: unités en bordure du Saguenay.

Les caractéristiques morphométriques des écosystèmes aquatiques sont décrits dans le fichier à l'aide du système de classement suivant:

Premier chiffre:

Classe	Lac découpage du périmètre aquatique	Rivière forme du cours d'eau
1	régulier	sinueuse
2	irrégulier	en méandres
3	très irrégulier	anastomosée

Deuxième chiffre:

Classe	Lac pente de la berme	Rivière présence de rapides
1	douce	aucun
2	modérée	peu
3	abrupte	beaucoup

Troisième chiffre:

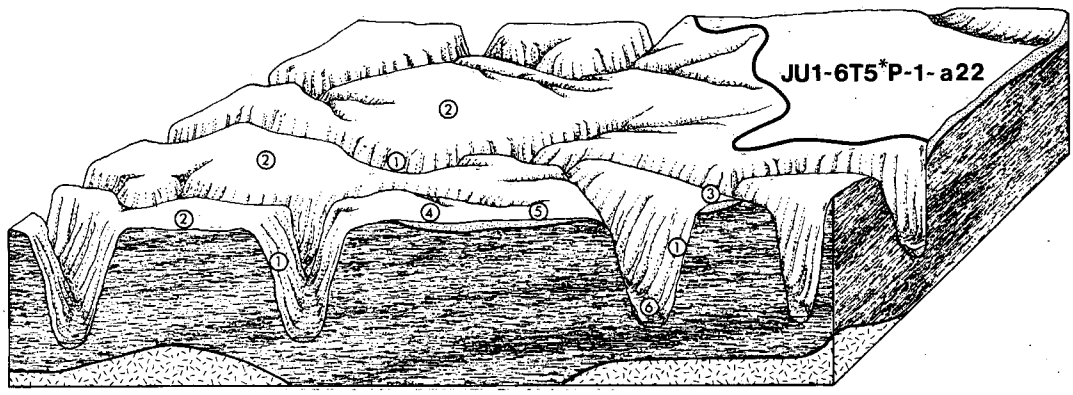
Classe	Pente des rives
1	douce
2	douce et modérée
3	douce et abrupte
4	modérée et douce
5	modérée
6	modérée et abrupte
7	abrupte et douce
8	abrupte et modérée
9	abrupte

Quatrième chiffre:

Classe	Système de drainage de profondeur
1	ouvert et profond
2	ouvert et peu profond
3	ouvert et tourbeux
4	restreint et profond
5	restreint et peu profond
6	restreint et tourbeux
7	fermé et profond
8	fermé et peu profond
9	fermé et tourbeux

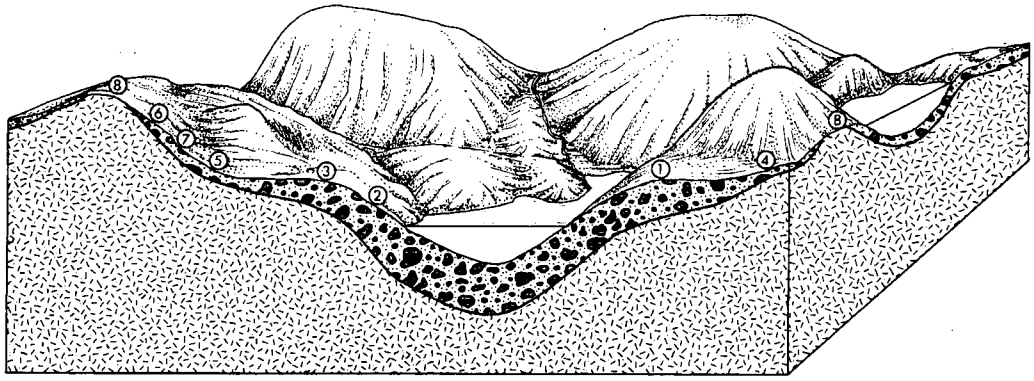
La nature des matériaux déologiques de surface des rives sont décrits dans le fichier à l'aide de la nomenclature utilisée pour la description des matériaux géologiques de surface du *Système Ecologique*.

Système Ecologique: JH1-5E-1-a44 - Territoire très accidenté dû à une érosion intense, situé dans la plaine argileuse des Basses Terres du Haut-Saguenay; dominance d'argile marine; peu ou pas de lacs et rivières; beaucoup de ruisseaux et de zones ripariennes



NUMERO DE REFERENCE	SUPERFICIE RELATIVE	TYPE ECOLOGIQUE	GEOMORPHOLOGIE	SOLS	VEGETATION
1	55%	1r23J	Argile marine: 5a; parties convexes des milieux et hauts de pentes; pente modale: 5-30%	Argile limoneuse à limon argileux; drainage bon à modérément bon; Brunisol dystrique orthique; Série Larouche: 1r	Terres cultivées ou pâturages; Tremblaie à *Rubus pubescens*
2	10%	ch4J	Argile marine: 5a; pentes douces de 2 à 5%	Argile limoneuse; drainage imparfait; Gleysol orthique; Série Chicoutimi: ch	Terres cultivées ou pâturages; Tremblaie à *Rubus pubescens* et *Petasites palmatus*
3	10%	tl23J	Matériaux de bas de plage, ou glacio-deltaiques, sur argile marine: 6b/5, 3C/5; parties convexes des hauts de pentes; pente modale: 5-9%	Limon sur argile; drainage bon à modérément bon; Podzol humo-ferrique minimal; Série Taillon: tl	Terres cultivées ou pâturages; Tremblaie à *Rubus pubescens*
4	10%	am4J	Matériaux de bas de plage, ou glacio-deltaiques, sur argile marine: 6b/5, 3C/5; pentes douces de 2 à 5%	Limon sur argile; drainage imparfait; Gleysol humique faiblement éluvié; Série Alma: am	Terres cultivées ou pâturées; Tremblaie à *Rubus pubescens* et *Alnus rugosa*
5	10%	gi23J	Matériaux de bas de plage ou glacio-deltaiques, sur argile marine: 6b/5, 3C/5, parties convexes des hauts de pentes; pente modale: 5-9%	Loam sableux sur argile; drainage bon à modérément bon; Podzol humo-ferrique orthique; Série Girard: gr	Terres cultivées ou pâturages; Tremblaie à *Rubus pubescens*
6	5%	al16J*	Alluvions récentes: 4c; berges de ruisseaux; pente modale: 0-0,5%	Texture variable; drainage très mauvais avec seepage; Régosol gleyifié; Alluvions: all	Aulnaie alluviale

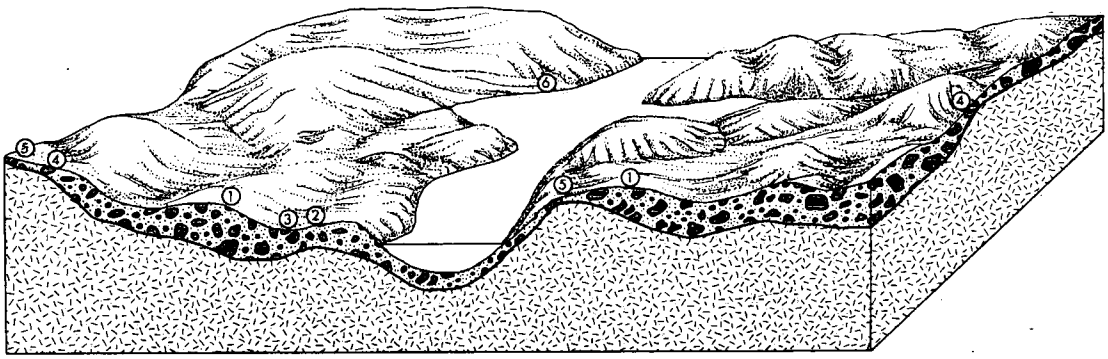
Système Ecologique: OH4-1V1A-1-b11 - Territoire montueux des Contreforts des Laurentides; dominance de till épais et de till mince; 5 à 15% de la surface est constituée par des lacs plus petits que 250 ha; très peu de ruisseaux et de zones ripariennes.



NUMERO DE REFERENCE	SUPERFICIE RELATIVE	TYPE ECOLOGIQUE	GEOMORPHOLOGIE	SOLS	VEGETATION
1	10%	ty20	Till épais: la; parties convexes des milieux de pentes; pente modale: 5-9%	Loam sableux fin caillouteux; drainage bon; Podzol humo-ferrique orthique; Série Tremblay: ty	Pessière à épinette noire et mousses ou Tremblaie à érable rouge et érable à épis, évoluant vers une Sapinière à bouleau jaune et *Pteridium*
2	10%	ar30*	Till épais: la, parties concaves des pentes inférieures; pente modale: 15-30%	Loam sableux fin caillouteux; drainage modérément bon avec seepage; Podzol humo-ferrique fleyifié; Série Armissan: ar	Tremblaie à érable à épis et *Athyrium* ou Bétulaie blanche à érable à épis et *Athyrium* ou Bétulaie blanche à sapin, érable à épis et bouleau jaune, évoluant vers une Sapinière à bouleau jaune, *Oxalis* et *Athyrium*
3	30%	dq20	Till mince: la(R); parties convexes des hauts de pentes; pente modale: 9-15%	Loam sableux fin caillouteux; drainage bon; Podzol humo-ferrique orthique; Série Dequen: dq	Pinède à pin gris, *Kalmia*, *Alnus crispa* et *Cornus canadensis* ou Tremblaie à érable rouge et érable à épis, évoluant vers une Pessière à épinette noire, mousses et lichens, ensuite vers une Pessière à épinette noire, sapin et amelanchier et finalement, une Sapinière à bouleau jaune et *Pteridium*
4	10%	po2 *	Till mince: la(R); parties concaves des hauts de pentes; pente modale: 15-30%	Loam sableux fin caillouteux; drainage bon avec seepage; Podzol humo-ferrique orthique; Série Portage: po	Tremblaie à érable à sucre et érable rouge, évoluant vers une Erablière à érable à sucre, bouleau jaune et érable rouge
5	10%	ge30*	Till mince: la(R); parties concaves des hauts de pentes; pente modale: 9-15%	Loam sableux fin caillouteux; drainage modérément bon avec seepage; Série Gamelin: ge	Tremblaie à érable à épis et *Athyrium* ou Bétulaie blanche à érable à épis et bouleau jaune, évoluant vers une Sapinière à bouleau jaune, *Oxalis* et *Athyrium*
6	10%	dp20	Till très mince: la-R; parties convexes des sommets et des hauts de pentes; pente modale: 9-15%	Loam sableux fin caillouteux; drainage bon; Podzol humo-ferrique lithique; Série Du Plateau: dp	Pinède à pin gris, *Alnus crispa* et *Cornus canadensis* ou Tremblaie à érable rouge et *Pteridium*, évoluant vers la Pessière à épinette noire, amelanchier et érable rouge, évoluant vers la Sapinière à bouleau jaune et *Pteridium*
7	10%	dp20*	Till très mince: la-R; parties concaves des hauts de pentes; pente modale: 9-15%	Loam sableux fin caillouteux; drainage bon avec seepage; Podzol humo-ferrique lithique; Série Du Plateau: dp	Pinède à pin gris, *Alnus crispa* et *Cornus canadensis* ou Tremblaie à érable rouge et *Pteridum*, évoluant vers la Pessière à épinette noire, amelanchier et érable rouge, évoluant vers la Sapinière à bouleau jaune et *Oxalis*
8	10%	be20	Affleurements rocheux: R; sommets et versants abrupts; pente modale: 15-30%	Affleurements rocheux; drainage bon; Régosol lithique; Série Bédard: be	Lande sèche à *Kalmia*, évoluant vers la Pinède à pin gris, *Kalmia* et lichens; évoluant vers la Pessière à épinette noire et lichens; évoluant vers la Pessière à épinette noire, amélanchier et érable rouge

TYPE ECOLOGIQUE AQUATIQUE: b11-3381-10: lacs plus petits que 250 ha occupant de 5 à 15% de la surface du Système Ecologique,
très peu de ruisseaux,
très peu de zones ripariennes,
découpage du périmètre aquatique: très irrégulier,
pente de la berme: abrupte,
pente des rives: abrupte et modérée,
système de drainage ouvert; lacs profonds,
matériaux géologiques de surface des rives: till et affleurements rocheux.

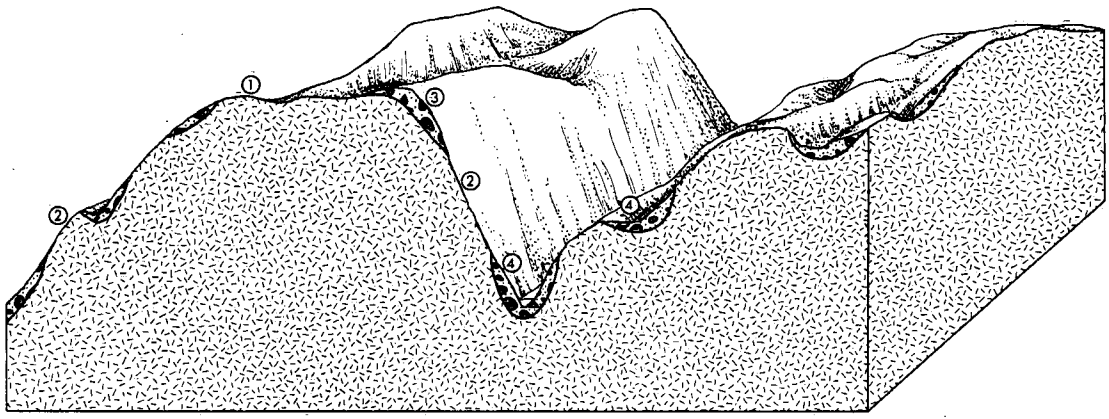
Système Ecologique: OR2-1AIV-1-f22 - Territoire moutonné des Contreforts des Laurentides; dominance de till épais et de till mince; plus de 15% de la surface est constituée par des lacs plus grands que 250 ha et plus petits que 500 ha; peu de ruisseaux et de zones ripariennes



NUMERO DE REFERENCE	SUPERFICIE RELATIVE	TYPE ECOLOGIQUE	GEOMORPHOLOGIE	SOLS	VEGETATION
1	40%	ty20	Till épais: la; parties convexes des milieux de pentes; pente modale: 5-9%	Loam sableux fin caillouteux; drainage bon; Podzol humo-ferrique orthique Série Tremblay: ty	Pessière à épinette noire et mousses ou Tremblaie à érable rouge et érable à épis, évoluant vers une sapinière à bouleau jaune et *Pteridium*
2	10%	ar30	Till épais: la; parties convexes des milieux et bas de pentes, pente modale: 2-5%	Loam sableux fin caillouteux; drainage modérément bon; Podzol humo-ferrique orthique; Série Armissan: ar	Tremblaie à érable à épis et *Athyrium*, évoluant vers la Sapinière à bouleau jaune, *Oxalis* et *Athyrium*
3	10%	me40	Till épais: la; parties en pente douce; pente modale: 2-5%	Loam sableux fin caillouteux; drainage imparfait; Podzol humo-ferrique gleyifié; Série Mésy: me	Pessière à épinette noire, mousses et Sphaignes, ou Pessière à épinette noire, sapin et sphaignes, ou Sapinière à bouleau blanc, *Hylocomium* et sphaignes
4	20%	dq20	Till mince: la(R); hauts de pentes convexes; pente modale: 9-15%	Loam sableux fin caillouteux; drainage bon; Podzol humo-ferrique orthique; Série Dequen: dq	Pinède à pin gris, *Kalmia*, *Alnus crispa* et *Cornus canadensis* ou Tremblaie à érable rouge et érable à épis, évoluant vers une Pessière à épinette noire, mousses et lichens, ensuite vers une Pessière à épinette noire, sapin et amelanchier et finalement vers une sapinière à bouleau jaune et *Pteridium*
5	15%	dp20	Till très mince; la-R; hauts de pentes concaves, pente modale: 9-15%	Loam sableux fin caillouteux; drainage bon avec seepage; Podzol humo-ferrique lithique, Série Du Plateau: dp	Pinède à pin gris, *Alnus crispa* et *Cornus canadensis* ou Tremblaie à érable rouge et *Pteridium*, évoluant vers la Pessière à épinette noire, amelanchier et érable rouge, évoluant vers la Sapinière à bouleau jaune et *Oxalis*
6	5%	al160*	Alluvions récentes: 4c; berges de cours d'eau, ou de lacs; pente modale: 0-0,5%	Texture variable; drainage très mauvais avec seepage; Régosol gleyifié; Alluvions: all	Aulnaie alluviale

TYPE ECOLOGIQUE AQUATIQUE: f-22-1365-41: Lacs plus grands que 250 ha et plus petits que 500 ha, occupant plus de 15% de la surface du Système Ecologique,
peu de ruisseaux,
peu de zones ripariennes,
découpage du périmètre aquatique: régulier,
pente de la berme: abrupte,
pente des rives: modérée et abrupte,
système de drainage restreint et lacs peu profonds,
matériaux géologiques de surface des rives: sédiments glacio-lacustres et till.

Système Ecologique: 3M8-01V-1-a11 - Territoires montagneux des Hautes Laurentides; dominance d'affleurements rocheux et de till mince; peu ou pas de lacs, rivières, ruisseaux et zones ripariennes.



NUMERO DE REFERENCE	SUPERFICIE RELATIVE	TYPE ECOLOGIQUE	GEOMORPHOLOGIE	SOLS	VEGETATION
1	20%	ca1S	Affleurements rocheux: R; sommets et versants abrupts; pente modale: 15-50%	Affleurements rocheux; drainage excessif; Régosol lithique; Série Caron: ca	Pessière à épinette noire, *Kalmia* et lichens
2	40%	be2S	Affleurements rocheux: R; versants abrupts; pente modale: 15-50%	Affleurements rocheux; drainage bon; Régosol lithique; Série Bédard: be	Pessière à épinette noire, *Kalmia* et lichens
3	30%	gt2S	Till très mince; la-R; parties convexes des hauts de pentes; pente modale: 15-30%	Loam sableux fin caillouteux; drainage bon; Podzol ferro-humique lithique; Série Gatien: gt	Pessière à épinette noire, *Kalmia*, lichens et *Cornus canadensis* évoluant vers une Pessière à épinette noire, mousses et *Kalmia*
4	10%	lg3S*	Till mince: la(R); parties concaves des bas de pentes; pente modale: 15-30%	Loam sableux fin caillouteux; drainage modérément bon avec seepage; Podzol humo-ferrique orthique; Série Le Cite: lg	Bétulaie blanche à sapin et érable à épis évoluant vers une Sapinière à bouleau blanc, érable à épis et *Athyrium*

Tableau A2-1: Interprétations pour l'aménagement du territoire de quatre *systèmes écologiques* situés dans la région du Saguenay-Lac-Saint-Jean.

Carte N° (Annexe 1)	INTERPRETATION	JH1-5E-1-a44	OH4-1V1A-1-b11	OR2-1A1V-1-f22	SM8-01V-1-a11
19	Aptitude des sols pour l'agriculture	$5^{6}_{\text{t}}\ 2^{2}_{\text{w}}\ 3^{2}_{\text{t}}$	$5^{5}_{\text{pr}}\ 7^{3}_{\text{rt}}\ 5^{2}_{\text{pt}}$	$5^{7}_{\text{pt}}\ 7^{2}_{\text{rt}}\ 5^{1}_{\text{w}}$	$7^{9}_{\text{rt}}\ 5^{1}_{\text{pr}}$
20	Aptitude des sols pour la gourgane	$2^{6}\ 1^{4}$	$3^{8}\ 2^{2}$	$2^{5}\ 3^{5}$	3
21	Risques d'érosion du sol	$3^{6}\ 1^{3}\ 2^{1}$	$2^{6}\ 3^{3}\ 1^{1}$	$1^{7}\ 2^{2}\ 3^{1}$	$3^{9}\ 2^{2}$
22	Besoins de drainage artificiel	$1^{7}\ 3^{3}$	1	1	1
23	Aptitude des sols pour la forêt	3	$4^{5}_{\text{mr}}\ 3^{4}\ 6^{1}_{\text{mr}}$	$3^{6}\ 4^{4}_{\text{mr}}$	$6^{6}_{\text{mr}}\ 5^{3}_{\text{mr}}\ 3^{1}$
24	Production forestière potentielle (m^3/ha/année)	6,6	4,8	4,7	1,7
25	Aptitude des sols pour le bouleau jaune	3	$2^{5}\ 1^{4}\ 3^{1}$	$2^{7}\ 3^{3}$	3
26	Difficulté de plantation	2_{g}	$2^{4}_{\text{c}}\ 3^{3}_{\text{rc}}\ 4^{3}_{\text{rc}}$	$2^{8}_{\text{c}}\ 4^{2}_{\text{rc}}$	$5^{6}_{\text{r}}\ 4^{3}_{\text{rc}}\ 3^{1}_{\text{rc}}$
27	Coût de production des plantations ($\$/m^3$)	4	7	9	28
28	Traficabilité	$3^{7}_{\text{gm}}\ 4^{2}_{\text{gw}}\ 5^{1}_{\text{w}}$	$2^{5}_{\text{tr}}\ 5^{3}_{\text{r}}\ 3^{2}_{\text{tm}}$	$1^{4}\ 2^{3}_{\text{tr}}\ 5^{3}_{\text{rw}}$	$5^{9}_{\text{r}}\ 3^{1}_{\text{tm}}$
29	Risques de chablis	$1^{7}\ 3^{3}$	$2^{6}\ 3^{3}\ 1^{1}$	$1^{5}\ 3^{3}\ 2^{2}$	$3^{9}\ 2^{1}$
30	Potentiel de régénération naturelle de l'épinette et du sapin	3	$2^{8}\ 3^{2}$	$2^{8}\ 1^{2}$	$2^{7}\ 1^{3}$
31	Potentiel de régénération naturelle du pin gris	3	$3^{9}\ 1^{1}$	3	3
32	Potentiel de régénération naturelle du peuplier faux-tremble	1	$1^{7}\ 2^{2}\ 3^{1}$	$1^{7}\ 2^{2}\ 3^{1}$	3
33	Attrait du paysage (pondération "a")	4253	4261	5198	5213
34	Attrait du paysage (pondération "b")	5193	4283	4234	5193
35	Potentiel récréatif des écosystèmes aquatiques	70	573	3152	70
36	Potentiel pour la récréation dans la nature	5120	5150	5150	680
37	Possibilité d'utilisation des sols pour l'ingénierie	$4^{7}_{\text{g}}\ 5^{3}_{\text{w}}$	$4^{5}_{\text{r}}s\ 5^{3}_{\text{r}}s\ 3^{2}_{\text{g}}s$	$2^{5}_{\text{g}}\ 4^{3}_{\text{r}}w\ 5^{2}_{\text{r}}w$	$5^{9}_{\text{r}}\ 4^{1}_{\text{r}}s$
38	Types de terrain pour l'ingénierie	C+M	$(T/R)^5(R)^3(T)^2$	$(T)^6(T/R)^2(R)^2$	$(R)^9(T/R)^1$
39	Capacité de rétention en eau des sols	$1^{7}\ 5^{3}$	$5^{5}\ 4^{4}\ 3^{1}$	$3^{4}\ 4^{3}\ 5^{3}$	5
40	Potentiel pour l'orignal	3^{F}	2^{C}	2^{C}	4^{MR}
41	Potentiel pour le caribou	7^{C}	7^{C}	7^{C}	4^{MR}
42	Potentiel pour le chevreuil	7^{C}	2^{C}	2^{C}	7^{C}
43	Potentiel pour la sauvagine	3	3	3	3
44	Potentiel pour le castor	1	3	3	3
45	Aptitude des sols pour l'érable à épis	$2^{8}\ 1^{2}$	$2^{4}\ 1^{3}\ 3^{3}$	$2^{8}\ 3^{2}$	$3^{9}\ 1^{1}$
46	Niveau d'intégration requis	III AF(R)	III RF(O)	III FR	I F
47	Indice du Capital-Nature	180	130	150	60

Carte 4

LES SYSTEMES ECOLOGIQUES

Echelle 1:125.000

0 2,5 5 km

Le SYSTEME ECOLOGIQUE est une portion de territoire caractérisée par un pattern propre du relief, des matériaux géologiques de surface, des sols, des chronoséquences végétales et des plans d'eau.

RELIEF

Δ altitude (mètres/km): 800, 400, 200, 100, 30, 5, 0

pente modale %: 3, 8, 15, 30, 60, 100

M montagneux ou très accidenté
H
R
U montueux ou accidenté
F plat ondulé
moutonné

CATEGORIE D'ECOSYSTEME AQUATIQUE

- a moins de 5% de la surface constituée par des étendues aquatiques
- b 5% à 15% de la surface constituée par des lacs < 250 ha
- c plus de 15% de la surface constituée par des lacs < 250 ha
- f la surface comprend des lacs > 250 ha et < 500 ha
- g la surface comprend des lacs > 500 ha et < 1000 ha
- n la surface comprend des lacs > 1000 ha et < 2500 ha
- r la surface comprend des lacs > 2500 ha
- h unité en bordure des petites rivières
- y unité en bordure du Saguenay

ABONDANCE DE RUISSEAUX

1 absents ou très peu abondants
2 peu abondants
3 moyennement abondants
4 très abondants
5 extrêmement abondants

ABONDANCE DE ZONES RIPARIENNES

1 absentes ou très peu abondantes
2 peu abondantes
3 moyennement abondantes
4 très abondantes
5 extrêmement abondantes

EPAISSEUR DES MATERIAUX MEUBLES

1 épais
2 épais et mince
3 épais et affleurements
4 mince et épais
5 mince
6 mince et affleurements
7 affleurements et épais
8 affleurements et mince
9 affleurements

OH4 · 1V1A · 1 · a11

REGION ECOLOGIQUE: voir carte des Régions Ecologiques

NUMERO D'ORDRE DE L'UNITE

Le numéro d'ordre réfère au rapport accompagnant la carte écologique et qui comprend la description du pattern des TYPES ECOLOGIQUES constituant l'unité.

Le TYPE ECOLOGIQUE est une portion de territoire caractérisée par une combinaison relativement uniforme du sol et de la chronoséquence végétale.

En outre chaque unité est décrite quant aux caractéristiques morphométriques des écosystèmes aquatiques et aux matériaux géologiques de surface en bordure des étendues aquatiques.

MATERIAUX GEOLOGIQUES DE SURFACE

NATURE ET ORIGINE

1 till
2 sédiments fluvio-glaciaires
3 sédiments deltaïques
4 sédiments fluviatiles ou glacio-lacustres
5 sédiments argilo-marins
5' sédiments littoraux ou deltaïques sur sédiments marins
6 sédiments littoraux
7 sédiments organiques ombrotrophes
7' sédiments organiques minérotrophes
8 dépôts de versants
9 dépôts éoliens
0 roche en place

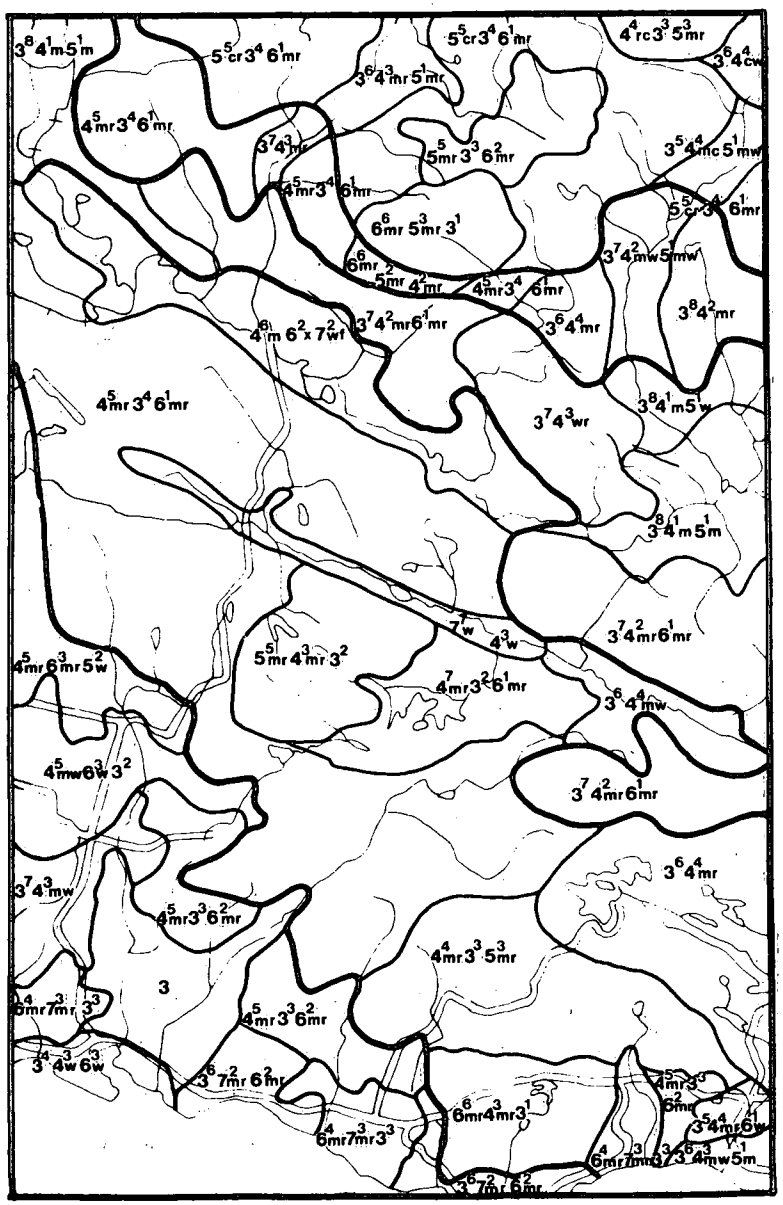
MORPHOLOGIE

A contrôlée par la roche en place
C cannelée
D drumlinoïde
E érodée
F deltaïque
H bosselée (hummocky)
N non-structurée
P en plaine
R en crêtes (ridged)
S structurée
T en terrasses
V plaquage
X complexe

LIMITES

- Région Ecologique
- Système Ecologique
- Ecosystème aquatique

SECTION REPRESENTEE SUR LA CARTE DES TYPES ECOLOGIQUES



Carte 23

APTITUDE DES SOLS POUR LA FORET

Echelle 1:125.000

0 2,5 5 km

Le système de classification est celui de l'Inventaire des Terres du Canada (Mc Cormack 1967) qui groupe les unités en classes d'après leur aptitude à produire du bois marchand.

Le chiffre majuscule indique la classe d'aptitude et l'exposant (x 10) donne le pourcentage de cette classe dans l'unité considérée.

Les lettres minuscules indiquent les sous-classes c'est-à-dire la nature des limitations.

CLASSE	DESCRIPTION DE LA CLASSE
2	très bonne Faibles limitations à la croissance. Production potentielle de 6,3 à 7,7 m^3/ha/année (90 à 110 pc/acre/année)
3	bonne Limitations modérées à la croissance. Production potentielle de 5,0 à 6,2 m^3/ha/année (71 à 90 pc/acre/année)
4	moyenne Limitations modérément graves à la croissance. Production potentielle de 3,6 à 4,9 m^3/ha/année (51 à 70 pc/acre/année)
5	faible Limitations graves à la croissance. Production potentielle de 2,2 à 3,5 m^3/ha/année (31 à 50 pc/acre/année)
6	très faible Limitations très graves à la croissance. Production potentielle de 0,8 à 2,1 m^3/ha/année (11 à 30 pc/acre/année)
7	nulle Limitations si sévères qu'elles empêchent la croissance d'espèces commerciales. Production potentielle inférieure à 0,8 m^3/ha/année (10 pc/acre/année)

SOUS-CLASSE	NATURE DE LA LIMITATION
c	climat défavorable
f	sols peu fertiles
m	sols trop secs
r	sols trop minces
w	sols trop humides
x	combinaison de plusieurs limitations

Région Ecologique

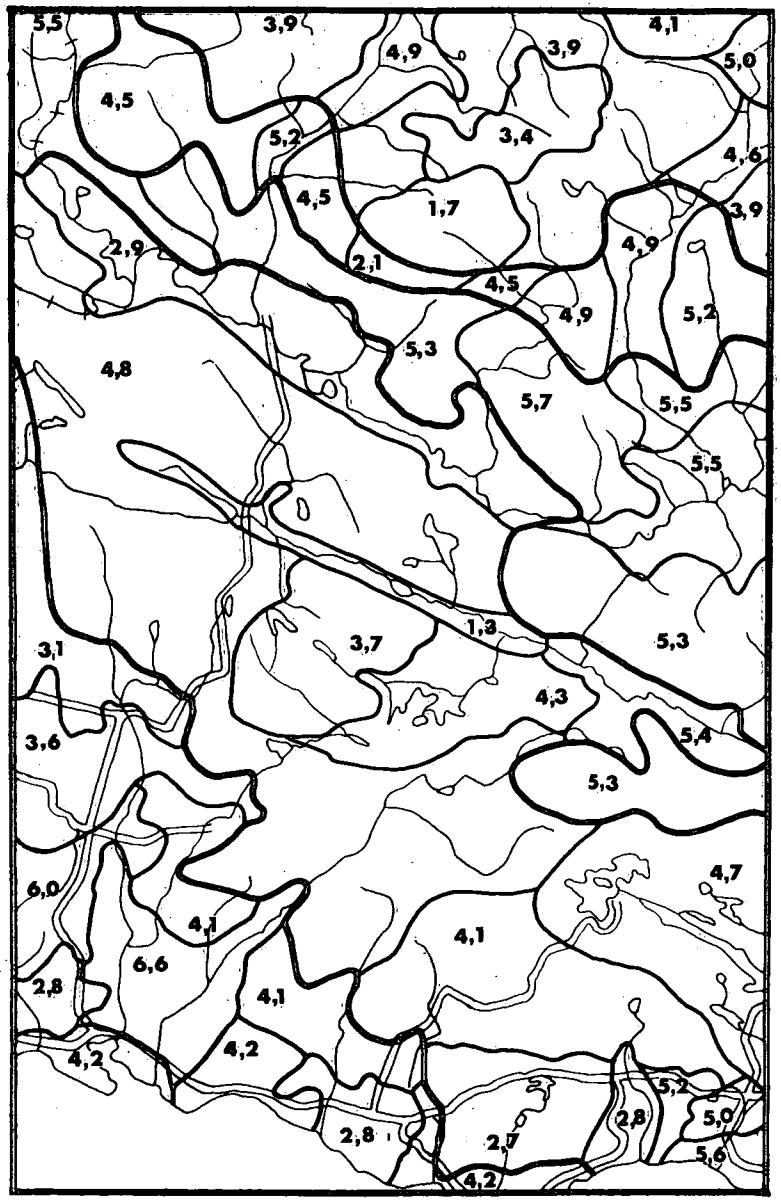
Système Ecologique

Carte 24

PRODUCTION FORESTIERE POTENTIELLE (m^3/ha/année)

Echelle 1:125.000

0 2,5 5 km



6,0 à 6,9 m^3/ ha /année

5,0 à 5,9 m^3/ ha /année

4,0 à 4,9 m^3/ ha /année

3,0 à 3,9 m^3/ ha /année

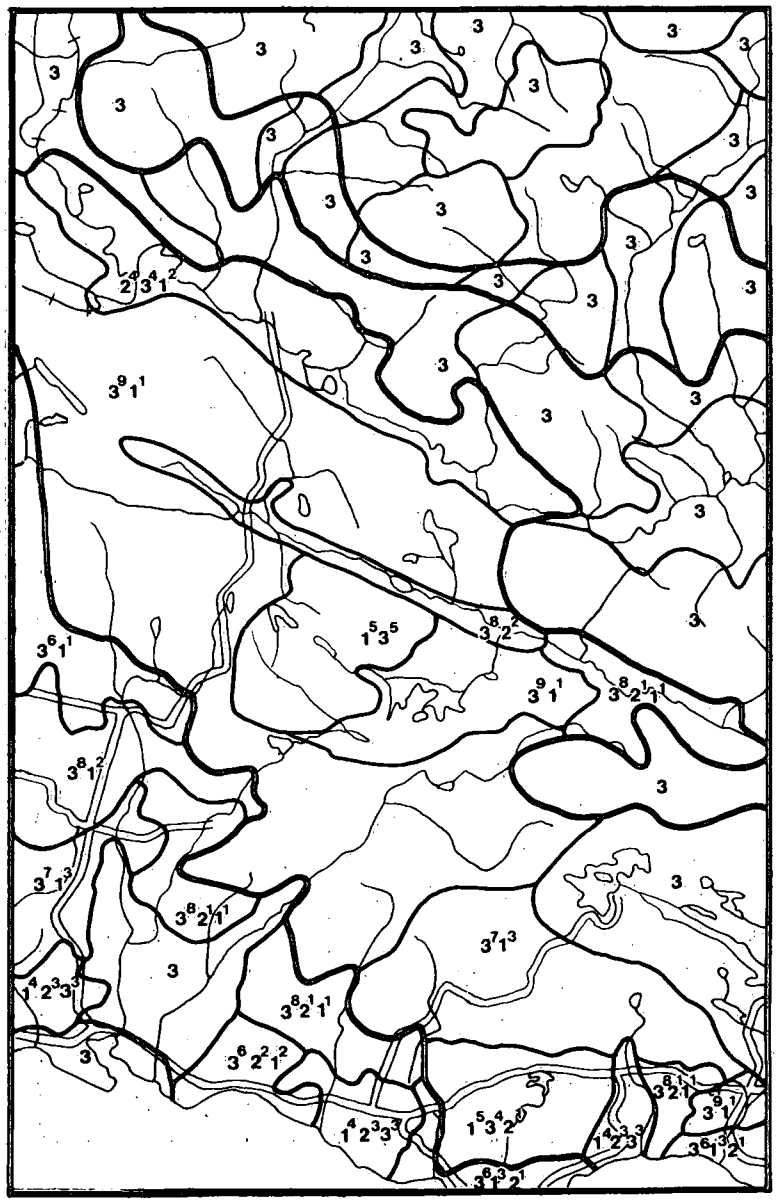
2,0 à 2,9 m^3/ha /année

1,0 à 1,9 m^3/ ha /année

0,0 à 0,9 m^3/ ha /année

Région Ecologique

Système Ecologique



Carte 31

POTENTIEL DE REGENERATION NATURELLE DU PIN GRIS

Echelle 1: 125.000

0 2,5 5km

Le chiffre majuscule indique la classe d'aptitude et l'exposant (x 10) donne le pourcentage de cette classe dans l'unité considérée.
Les lettres minuscules indiquent les sous-classes c'est-à-dire la nature des limitations.

Classe	Potentiel de régénération
1	excellent à très bon
2	bon à moyen
3	faible à très faible

Région Ecologique

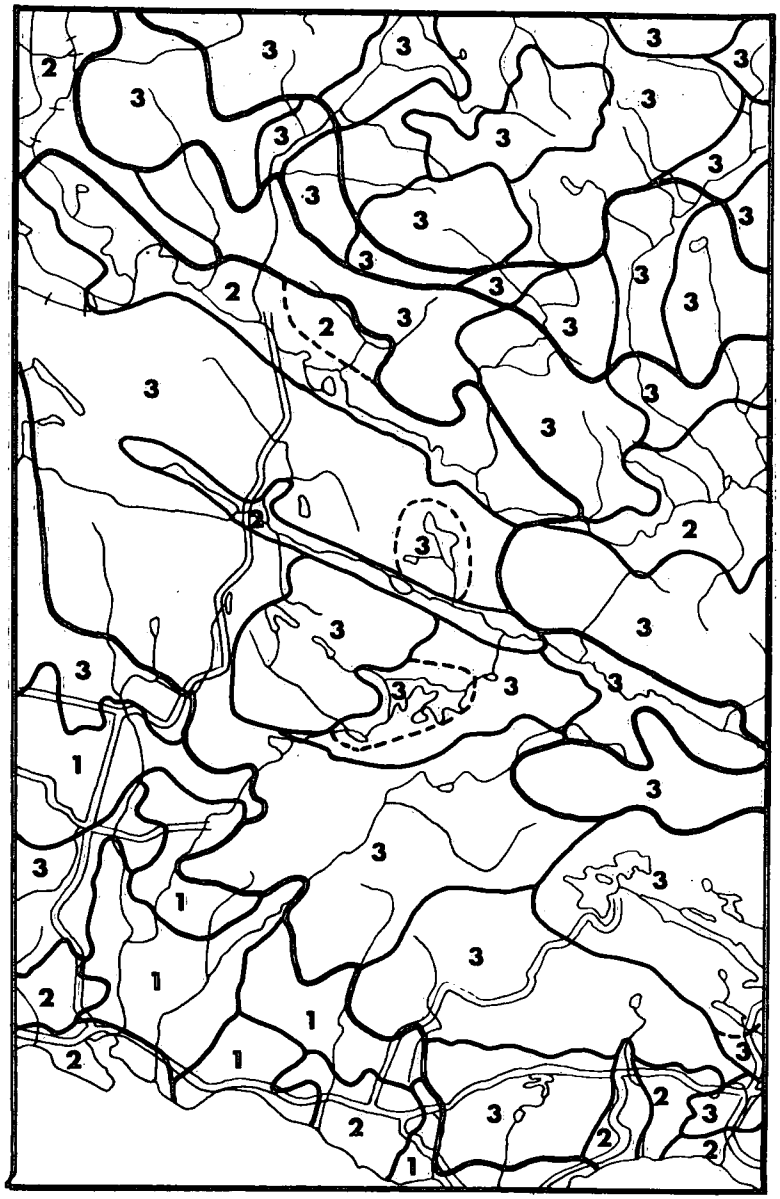
Système Ecologique

Carte 44

POTENTIEL POUR LE CASTOR

Echelle 1:125.000

0 2,5 5 km



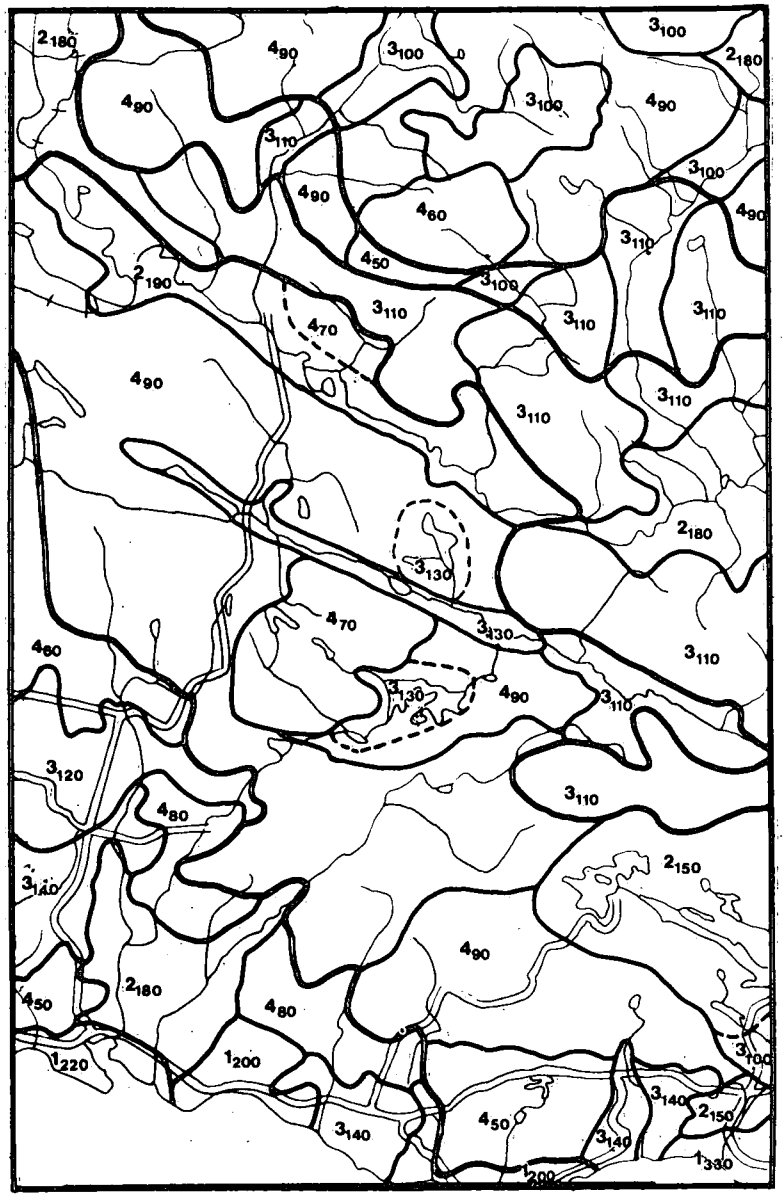
Classe

1	très bon à bon
2	moyen à faible
3	très faible à nul

Région Ecologique

Système Ecologique

Ecosystème aquatique



Carte 47

INDICE DU CAPITAL-NATURE

Echelle 1:125.000

0 2,5 5 km

L'indice du Capital-Nature est obtenu par l'addition des Valeurs d'Importance Socio-Economique des ressources naturelles renouvelables. Il constitue un indice de la <u>richesse</u> et de la <u>diversité</u> des unités considérées.

Classe	Richesse et diversité écologiques	Indice du CAPITAL-NATURE
1	très élevées	(200 et plus)
2	élevées	(150 à 199)
3	moyennes	(100 à 149)
4	basses	(50 à 99)
5	très basses	(0 à 49)

Région Ecologique

Système Ecologique

Ecosystème aquatique

BIOPHYSICAL LAND CLASSIFICATION OF NORTHERN MANITOBA

G.F. Mills
Canada-Manitoba Soil Survey
Winnipeg, Manitoba

ABSTRACT

A systematic biophysical land classification of northern Manitoba was initiated in July, 1974. Development of the system took place over the first year and at present an operational program has completed a field inventory of some 85,500 km^2 (33,000 mi^2). The objective of this land classification is to classify map terrain in terms of landforms, surface deposits, vegetation, soils, drainage, permafrost, associated aquatic systems and climate. The inventory is designed to provide an ecologically sound basis for making land use decisions concerning forestry, agriculture, recreation, wildlife, community development and hydrology. The methodology for data collection, compilation and presentation is described. An example of the methodology illustrating the hierarchical nature of the system is taken from the Hayes River area in northeastern Manitoba. The strength of this methodology appears to lie in an integrated approach to data presentation enabling a more complete description of the land element of the terrain. Some anticipated uses and limitations of the data, together with estimated costs of the inventory, are presented.

RÉSUMÉ

Une classification biophysique systématique du territoire a débuté en juillet 1974 dans le nord du Manitoba. La première année a été consacrée à la mise au point du système et, jusqu'ici, un programme opérationnel a permis la réalisation d'un inventaire sur place de quelque 85,000 km^2 (33,000 mi^2). Cette classification a pour objectif la répartition des terres et l'établissement des cartes compte tenu de diverses caractéristiques telles que le relief, les dépôts de surface, la végétation, la nature des sols, le drainage, le pergélisol, les systèmes aquatiques associés et le climat. Cet inventaire est destiné à servir de fondement environnemental de la prise de décisions concernant l'utilisation des terres dans les domaines des forêts, de l'agriculture, de la récréation, de la faune, de la croissance des communautés et de l'hydrologie. Le document présente une description de la méthodologie de collecte, de compilation et de présentation des données. Un exemple de la méthodologie illustrant la nature hiérarchique de système est donné pour la région de la rivière Hayes, dans le nord-est du Manitoba. La valeur de cette méthodologie semble provenir d'une approche intégrée à la présentation des données, qui rend possible une description plus complète des éléments terrestres des zones étudiées. Le document présente en outre diverses utilisations et limites éventuelles des données, de même qu'une estimation des coûts de l'inventaire.

INTRODUCTION

During the last few decades, resource development activities in northern Manitoba have increased to a great extent. Developments in the north are often in the form of large projects; the establishment of Thompson, a community which became in a few years the third largest population centre in the province, and the hydro-electric developments on the Nelson and Churchill Rivers are examples of the kind and magnitude of some recent northern projects. It is apparent that the effects these developments have on the environment and the people in the north will be great. It can be expected that similar projects will be proposed and very likely implemented in the north in the not too distant future.

To be able to plan for future developments, resource use planners require information about the resources and the environment. These requirements will not be the same for

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

all resource use planners, but will have a common need for some kind of basic information. This information relates to elements in the environment - landforms, climate, soils, permafrost, vegetation, water bodies - that form homogeneous or ecologically significant land units which can be recognized and mapped. Recognizing a need for certain kinds of basic resource data in the planning process, the Manitoba Department of Mines, Resources and Environmental Management initiated the Northern Resource Information Program (NRIP) in 1974.

OBJECTIVE

The purpose of the Northern Resource Information Program is to provide data for resource use planners that will help them plan for the development of natural resources in a way that will benefit all Manitobans. This means generally the provision of data useful for macro scale planning, although the data may be in some instances sufficient for limited micro scale planning. However, because of the reconnaissance nature of the program, usefulness of the data will be greatest when applied at a broad regional level. This means that the data will be useful for planning for the development of renewable and nonrenewable resources on a regional basis; for planning for industrial and community development, the protection of the environment, the development of infrastructure, etc.

During the first year of this program, a system of land classification was developed for northern Manitoba and a systematic survey initiated. The main objective of this survey is to classify approximately 388,500 km^2 (150,000 mi^2) of Manitoba into ecologically significant land units. A system that classifies land units on such a basis is commonly referred to as a biophysical land classification.

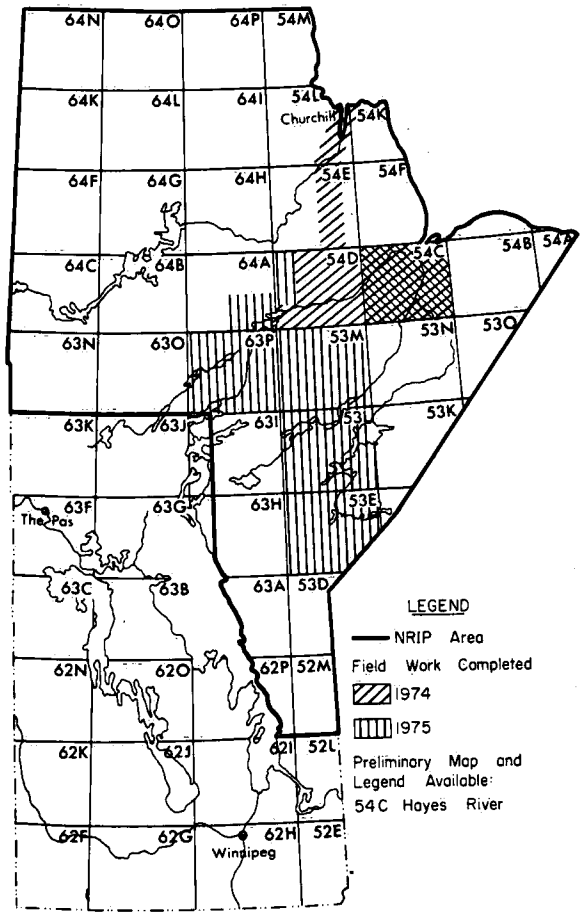
The objective of the present land classification as with numerous other integrated ecological surveys, is to classify and map terrain in terms of landforms and surface deposits, vegetation, soils, drainage, permafrost, associated aquatic systems and climate. Such an inventory will provide an ecologically sound basis for making land use decisions concerning forestry, agriculture, recreation, wildlife, community development and hydrology. The portion of Manitoba for which a biophysical land classification has been requested and the status of work done to date is shown in Figure 1.

METHODOLOGY

Team Approach - To achieve the objectives established for the biophysical land classification of Manitoba a team approach was chosen. A multidisciplinary team consisting of two people from the staff of the Canada-Manitoba Soil Survey and two people from the Manitoba Department of Mines, Resources and Environmental Management was brought together. In the first year of the program, the team consisted of the following areas of expertise:

Northern Resource Information Program Study Team - 1975. Left to right, front row: J. Clark, H. Morris, S. Forrester, D. Forrester, H. Veldhuis, R. Schmidt, G.F. Mills. Back row: R. Bakowsky, C. Fryer, K. Dutchak.

Figure 1: Location of biophysical land classification projects in Northern Manitoba and status of work done to-date.



- senior pedologist - project leader
- forester - pedologist
- wildlife ecologist
- forest ecologist

During the second year of the program, the team was expanded to include a botanist and a resource technician to expedite field operations and to provide input to water body investigations.

A provincial advisory committee was established at the outset of the program to provide leadership and direction for the study team and to promote liaison with users. This advisory group was made up of expertise in the following areas:

- resource planning
- biophysical survey and classification
- remote sensing
- water body classification
- vegetation - wildlife - environment concerns
- data management
- project leader

This group functioned mainly in an advisory capacity during the first year of the program. Contact with users was maintained through the committee and it provided the initial evaluation of available systems for carrying out a biophysical land classification. Once a satisfactory methodology was selected, the advisory role of the group diminished, although it continues to provide liaison and contact with users. In this way, the group helps to determine priority areas in the province where the study team should concentrate its efforts.

Pilot Project - The first year of the program served as a pilot project to develop the system of classification and the method of presenting the data to potential users. It soon became apparent, that to classify and map the large area with which the program was concerned within a reasonable time frame, the amount of ground truthing must be limited and much of the mapping had to be done by means of air

photo interpretation. This in turn, necessitates that the system classify the map patterns of soil, landform, vegetation and water rather than small units containing discrete soil types, vegetation communities, or drainage conditions. Scale of presentation, time frame and intensity of ground truthing all indicated that the land base should be delineated into land units throughout which there is a recurring pattern of landforms, soils and vegetation.

Based on experience from the pilot study and subsequent comments from users, the number of ground truth stops per map sheet was increased. It was felt that 80 to 90 stops per map sheet would provide the coverage required to adequately map the various deposits and soils and vegetation conditions, especially if many of the stops consisted of a short transect describing two or more site conditions. Collection of vegetation data also required some improvement and should provide a floristic list and mensurational data as well as some information on cover and sociability.

Because most of the field operations were now carried out from remote base camps, the logistical component of the survey became very important. To ensure a smooth field operation, the resource technician acted as expeditor in addition to his involvement in other aspects of the program.

The System of Classification (see Appendix I) - Previous work in Canada has led to the establishment of a relatively uniform methodology for carrying out biophysical classifications. After examining some of the approaches taken to terrain classification, the study team decided to utilize a hierarchical system patterned closely after that proposed and defined by Lacate (1969).

DATA COLLECTION, COMPILATION AND PRESENTATION

A realistic evaluation of the data collection phase in the Manitoba program has been made based on the first full field season. However, at present, only a rather cursory evaluation of the data compilation and data presentation phases has been carried out.

Data Collection - In 1975, field studies were carried out from June 12 to September 19. During this period, a biophysical land classification was completed on 62,640 km^2 (24,500 mi^2) equivalent to 4 1/2 N.T.S. 1:250,000 scale map sheets, mainly in the Northeastern Planning Zone of northern Manitoba.

Terrain investigations in this area required 68 days during which a total of 382 stops were made and detailed information on 567 sites collected. The terrain studies had full helicopter support enabling data collection on soil, landform and vegetation by one or two 2-3 man crews. An average of 35 minutes of helicopter time was expended per stop. Ground truth stops varied from about one hour to 2.5 hours, the longer stops permitting the characterization of two or three significantly different sites by means of short transects of 1 to 2 km.

Water studies throughout the area were carried out on a selection of large, medium-sized and small lakes and several water courses. Data were collected on the following parameters:

- specific conductance
- temperature
- depth
- shoreline characteristics
    - materials
    - length
    - configuration
    - vegetation
- backshore properties
    - materials
    - slope
    - drainage
    - vegetation

An eighteen-second lake survey (Nelson and Faulkner, 1971) using an instrument-equipped helicopter provided data for the first three parameters. The last two items were assessed visually from the helicopter while flying and through examination of the air photos in conjunction with terrain studies. A total of nine days in the field and 39 hours of helicopter time was utilized to obtain data on 295 water bodies.

The wildlife biologist on the study team characterized major landform-soil-vegetation associations present in each map sheet in terms of small mammal counts (traplines) and song bird counts (short transects in early morning) and by means of winter aerial surveys for moose and caribou. These data are combined with biophysical relations derived by

other team members to form a basis for identification of wildlife habitat within biophysical map units. The wildlife biologist was also responsible for wetland and waterfowl studies. A small fixed-wing aircraft flown at 70 to 90 m.p.h. and 50 to 300 feet above ground was utilized to examine 987 water bodies (lakes, ponds and streams). Data collected comprised numbers and species of waterfowl, water depth, turbidity and colour, relative abundance of aquatic vegetation and shoreline and backshore features.

Data Compilation - Landform, soil and vegetation data were recorded in the field on forms designed for direct input to an automated storage and retrieval system. The forms for soil and landform characteristics were those developed by the Canada Soil Information System (CanSIS). Field forms for vegetation and water body studies were designed under a similar format as the CanSIS forms in order that they be compatible with that system. Much of the wildlife data was recorded on tape and then transcribed into a longhand format.

The study team has not had time as yet to work with the field data in any more than a preliminary fashion necessary for the production of a biophysical map and accompanying legend. Future plans call for additional effort in the analysis of field data, particularly in those areas where it is possible to be quantitative about land use, hazards to use and productivity for various uses. We realize, in many cases, that analysis of field data and backup research is necessary to become more quantitative and such effort will detract from the map production phase of the overall inventory. However, where demands are for interpretive data for particular uses, the basic biophysical information becomes more viable and has increased value to the user as a result of such studies.

Data Presentation - Although the basic document of the biophysical land classification in Manitoba is a map and legend depicting land systems at a scale of 1:125,000, the interrelationship between pattern of land types and land system is always considered in the context of Land Regions and Districts as well. Region and District boundaries are superimposed on the land system map and a description of their biophysical condition can be attached to the map in tabular form or included in narrative form in an accompanying text.

The boundaries of most map units are based initially on landform and related surface deposits and delineated on panchromatic black and white 1:60,000 scale aerial photographs. The landform units are usually further refined in terms of topographic variation and patterns of soils, drainage condition and vegetation. Such characterization of the landform units is accomplished through the field program involving detailed descriptions of the soil, vegetation and topographic conditions on selected portions of a landform. These site descriptions generally apply to a landscape segment equivalent to a Land Type or a complex of Land Types.

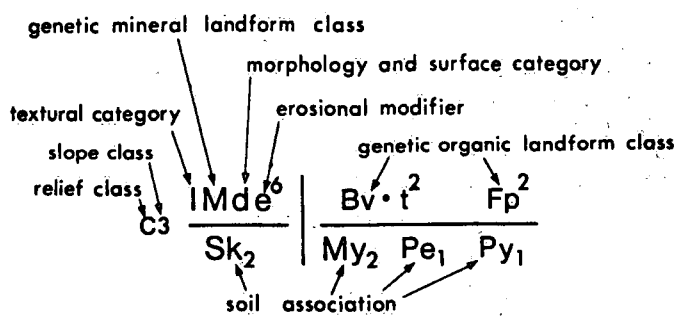
Land systems depicted at the 1:125,000 scale are characterized by a recurring pattern of landforms, soils and vegetation. The unit is described by a map symbol providing the user with a fair account of the land characteristics but for more detailed information the user must consult an extended legend.

The map symbol for a land system is set up in the following manner:

topographic expression	Mineral landforms / Soil Association(s)	Organic landforms / Soil Association(s)

The various components of the landscape in a particular land system are described in terms of genetic landform, textural category of the surficial deposits, the kind of morphology and surface form, erosional modifier, slope and relief class and soil association.

Map Symbol:



The soil association symbol directs the user to the expanded legend which will provide information about the land region, parent material, the various soil subgroups belonging to the association, drainage, landscape position of the dominant member of the association, ice content and depth of thaw where permafrost occurs, and the vegetation associated with the dominant soil subgroup.

This approach to data presentation is best described by reference to a map area recently completed in northern Manitoba. The

descriptive material for two land systems from the French River Land District in the Low Subarctic Region as described in the Biophysical Land Classification of the Hayes River area (NTS 54C) is included in Appendix II. In carrying out the classification for this area, the study team had access to surficial geology maps produced by the Geological Survey of Canada (Klassen, R.W. and J.A. Netterville, 1971-74) in addition to data collected from our own ground truth program.

ANTICIPATED USES

Ideally, a biophysical classification such as described in the foregoing section and in the Appendices will serve as an ecological basis for land use planning involving future management of lands for forestry, agriculture, recreation, wildlife, community development and hydrology. Biophysical resource data are also capable of interacting in the planning process concerning alternate land use decisions. Guidelines for terrain sensitivity can be formulated from such data. They can aid in such specific problem solving as delineation of corridors for transportation and pipeline routes.

This hierarchical approach to terrain classification should increase its adaptability to those uses which function at different scales. Land Regions and Districts provide an overview of the extremely complex relations between the biological and physical aspects of the environment. An overview at this scale is possibly of more interest to those concerned with broad macro planning at the regional and provincial level. Data portrayed at the Land System level may be sufficient for local and regional planning but users often ask for more detail. In Manitoba, we are experiencing increased pressure for detailed biophysical data around settlements. Such data would presumably be collected and portrayed at a scale equivalent to the Land Type. At present, we have no experience in carrying out completely integrated terrain surveys at the Land Type level. There are indications that work at this scale tends to become specialized into one or two disciplines, depending on the type of information required. Theoretically, it is possible to portray all terrain and related elements at all levels of detail. It may not be practical, however, to carry out a completely integrated inventory showing all terrain elements at such larger scales.

The degree to which the biophysical classification is successful in meeting user requirements is not the same in all instances. It varies with the background and expertise of the user, the kind of questions to be asked of the data and in certain cases, our inability to predict precise behavior and response of the environment to manipulation and use. Past experience in dealing with the application of natural resource data to various uses indicates that many user requirements are for interpreted information. The absence of interpretations then becomes a limitation to use of the data. This limitation can be overcome if those involved in carrying out integrated resource surveys plan either to provide an interpretation of their data or be prepared to cooperate with individual users in deriving such interpretations.

Another major limitation to use of biophysical data is the inability of both collectors and users of the data to be as precise as we might wish in predicting behavior and response of the environment under various conditions. This limitation is apparent particularly in northern areas lacking the regional experience and applied research necessary for successful interpretation of that environment. Accumulation of regional experience and inclusion of a certain research element in the data collection phase of the biophysical inventory will help to minimize this limitation.

COSTS

Cost estimates to carry out the 1:125,000 scale biophysical land classification currently being applied in northern Manitoba are based mainly on our experience during the 1975-76 fiscal year. Precise costs are available for a field program lasting 103 days with full helicopter support and operating from remote base camps. These costs, excluding salaries totalled $121,800 or $5.00/mi^2. Field costs including salaries during the field season and a prorated adjustment for developmental costs and capital equipment costs amount to $6.20/mi^2.

Exact costs of the professional and technical staff input to the program are more difficult to calculate. Estimates based on professional and technical time expended place total salaries at $99,000 (based on 3 professional S.M.Y., field and office; 2 technical S.M.Y., laboratory; and the equivalent of 2 technical S.M.Y. field and office). The total cost of the 1975-76 program is therefore $220,800 ($121,800 field costs and $99,000 salaries) or $9.00/mi^2. However, one should consider these costs in the context of what the program has produced to date. The Manitoba program has not yet achieved a balanced effort between the data collection phase (field program) and

the data processing and map production phase. This imbalance has resulted in a substantial backlog of map sheets as field work is complete on about 6 1/2 map areas with only one being published to date. A second map area is currently nearing completion.

Wildlife studies utilizing one full professional S.M.Y. also developed a backlog of unpublished information. This backlog resulted in part from the imbalance between data collection and data processing and publication phases. The developmental aspects of the wildlife part of the program further contributed to the backlog. The results of the wildlife studies, which include an interpretation of the biophysical data for wildlife, will appear shortly in a narrative style report pertaining to the first published map area.

Data collected from the water studies have been stored but not brought to any final conclusion either alone or in integrated form with the terrain data. Considerable effort researching this subject was expended by one team member and a preliminary presentation based on an hierarchical ordering of watersheds was developed. Evaluation of this approach has not been attempted as yet.

The level of field activities in 1975, in spite of the allocation of substantial effort to water and wildlife studies, achieved a certain economy and efficiency of scale. However, these efficiencies of operation are lost through inability to adequately process and present the data within a reasonable time frame. Adjustments currently being made in reducing the size of the annual inventory area and increasing the professional input on the data processing and map production phase should help to eliminate the backlog of maps and bring the two phases of the program into balance. These adjustments will also increase the costs of classification per unit area from those experienced during the first two years of operation.

SUMMARY

The nature of land inventories is rapidly changing. Operational biophysical surveys employing multidisciplinary teams of pedologists, ecologists, wildlife biologists and geomorphologists have emerged during the past decade and now make a substantial contribution to resource inventories in Canada. Prior to the advent of biophysical surveys, the Geological Survey of Canada (G.S.C.) and the cooperative Canada Soil Survey were the two main agencies concerned with "surface of the earth inventories". The G.S.C., since its inception 134 years ago, has carried out a systematic reconnaissance inventory of both bedrock materials and surface deposits over most of Canada's vast land area. Similarily, for some 50 years, the cooperative program of Soil Surveys has played an important role in the inventory of Canada's land resource. The area covered by Soil Survey is about 3,175,635 km^2 or 1,225,168 mi^2. This represents about 35% of Canada's total land mass of 9,976,700 km^2 or 3,800,000 mi^2. The soil information collected to-date does concern most of the settled portions of Canada and provides a very comprehensive assessment of the basic attributes of land. It has become some of the most useful data for much, if not most of the rational land resource planning in Canada.

In this day of comprehensive land use planning, much criticism has been leveled at single discipline or single purpose resource surveys. A single discipline study, by its very nature, is bound to have limitations for satisfying many user needs. In the past, soil surveys have been criticized for the same reason. However, methodology employed by the cooperative soil survey tends to overcome some but not all of the deficiencies of a single discipline survey. This methodology keys on the pedological concept of the soil profile as the basis for inventory. This concept presupposes that similar materials, if occurring under identical environmental conditions of regional and local climate, biological activity, relief, drainage and time, will develop identical soil profiles. It further assumes that similar soil conditions will respond in similar fashion to manipulation or management and will produce similar yields in terms of biomass. The soil profile is the most stable, environmentally sensitive element in the landscape. Thus, the concept recognizes the integrated effect of all factors of soil formation in the soil profile rather than attempting to separately evaluate each different factor. It is this end product, the identified soil profile, characterized by its chemical, physical and biological properties, that has proven to be the useful predictive model representing actual delineated landscape segments.

Recognizing an increasingly wide spectrum of users, and as well, the criticism aimed at single discipline resource studies, the Soil Survey in recent years has broadened its traditional approach to inventory so that ground-truthing, while still emphasising the soil profile, has shifted to include other "land attributes". Data collection is often by a team of specialists who attempt to define map units with greater sophistication and precision largely in terms of additional

data concerning the "land attributes" of the landscape, i.e. landform and vegetative cover. Recognizing this trend, the national Soil Survey recently adopted for its use a modification of the landform classification developed by the Geological Survey of Canada. In addition, individual soil survey groups have established a close working rapport with ecologists and botanists in order to provide a better correlation of soil and vegetation relations. No doubt, part of this shift in direction has come about through pressure on soil survey personnel to become involved in biophysical type inventories across Canada.

Many soil surveys, particularly where a wide spectrum of users is anticipated, attempt as completely as possible, to characterize landscape segments in terms of individual components, soil, landform and vegetation, all integrated within a climatic framework. By means of this approach a soil survey provides a product which is fundamentally the same as that of a biophysical land classification. Such an integrated approach to terrain classification is basic to the biophysical land classification currently being carried out in Manitoba. We retain a strong emphasis on the soil, which as the most stable and environmentally sensitive component of the landscape, is capable of interpretation for a wide range of biological and physical uses. Landform and materials are likewise relatively stable, but biological use interpretation based solely on physical parameters is of limited value when no consideration is given to the effects of regional climate and vegetation on that material. Similarly, vegetation, although sensitive to climatic and certain physical conditions, is relatively unstable and, therefore, cannot be interpreted consistently for a wide range of uses.

Biophysical land classification, on the other hand, is not a single science, but a group of sciences brought together as a mapping methodology. In Manitoba, we feel that there are advantages to working with an integrated land classification, particularly if the various elements can be ordered hierarchically as under the biophysical approach. The hierarchy enables one to be specific or generalized in depicting the various physical and biological terrain elements. It is possible to show relationships between the various components in the environment at each level of abstraction. In addition, at the Land Region level of abstration, one is able to synthesize a general climatic framework for distinguishing soil series, the basic building blocks of a soil survey.

In summary, the approach being taken to terrain classification in Manitoba differs only slightly from the standard biophysical survey developed in Canada over the past decade. The main difference lies in a stronger emphasis on soil as compared to that given to other components of the environment. The increased importance attributed to soil is justified because soil is studied and classified as an integration of several environmental factors. Soil, as a relatively stable environmental component, still remains sensitive to the effects of other less stable environmental components. Both approaches, the standard biophysical methodology and the Manitoba approach giving additional weight to soil, provide an integrated resource inventory giving a more complete picture of the biophysical environment than it is possible to obtain from a single discipline resource survey.

APPENDIX I

THE SYSTEM OF CLASSIFICATION AND THE CONCEPT OF LAND REGIONS

Previous work in Canada has led to the establishment of a relatively uniform methodology for carrying out biophysical classifications. A hierarchy of four basic classification units was proposed and defined by Lacate (1969) for the systematic description of terrain:

Land Region - an area of land characterized by a distinctive regional climate as expressed by vegetation.

Land District - an area of land characterized by a distinctive pattern of relief, geology, geomorphology and associated vegetation.

Land System - an area of land throughout which there is a recurring pattern of landforms, soils and vegetation.

Land Type - an area of land on a particular landform segment having a fairly homogeneous combination of soils and chronosequence (i.e. successsional development) of vegetation.

The approach taken in Manitoba is patterned after that of Lacate but includes some modification in the definition of the Land Region. All four levels of classification have been used in the Manitoba approach. The basic product of our biophysical classification is a map depicting Land Systems at a scale of 1:125,000. The ground truth and sampling carried out to produce the Land System map is collected at the Land Type level. Land System units, in turn, have been grouped into Land Districts on the basis of general physiographic features. However, Land Districts can also be considered as subdivisions of a Land Region. It is emphasized that the boundaries for Land Districts and Land Regions become really meaningful only after a study of interrelationships in patterns of land types and land systems.

The Land Region - Concepts and Rationale

The concept of Land Region as utilized in the present studies has been broadened somewhat in definition from that given above. Broad regions of uniform climate are identified not only on the basis of vegetation, but also on trends in soil development and permafrost features.

For example, the High Subarctic Land Region in Manitoba is defined to include those conditions of regional climate which result in a particular pattern of forest cover interspersed with treeless areas of Tundra, i.e. Forest-Tundra transition. This Land Region further exhibits permafrost conditions which are characteristic of the Continuous Permafrost Zone, i.e. depth, distribution and surface expression. The presence of permafrost in the soils of this region is associated with processes and properties which are a consequence of cold temperatures. Climate, and particularly temperature therefore, are major factors governing the development of the soils of this region. Thus, soil development, as it reflects climate, becomes a useful criterion for defining the Region.

The degree of climatic uniformity observable in a Land Region favours the development of similar ecosystems on material having similar properties. For example, similar physiographic sites (i.e. those having the same landform, slope, parent soil material and drainage characteristics) may occur in several climatic regions. Within a region, these sites will support the same vegetation communities, but in other regions vegetation on the sites will be different. Thus, beach ridges in an Arctic Land Region support low growing shrubs and forbs, whereas beaches in the Boreal Region usually have dense growth of black spruce or jack pine. Soils display similar trends, as the kind and development of soil profiles vary from region to region on similar physiographic sites. The depth of the thawed layer, and the form and kind of surface expression of permafrost also vary on similar sites between regions but remain relatively constant on comparable sites within a region (Zoltai, 1973). Land Regions, therefore, describe broad areas where one can expect to find the same kinds of vegetation and soil associations on similar sites.

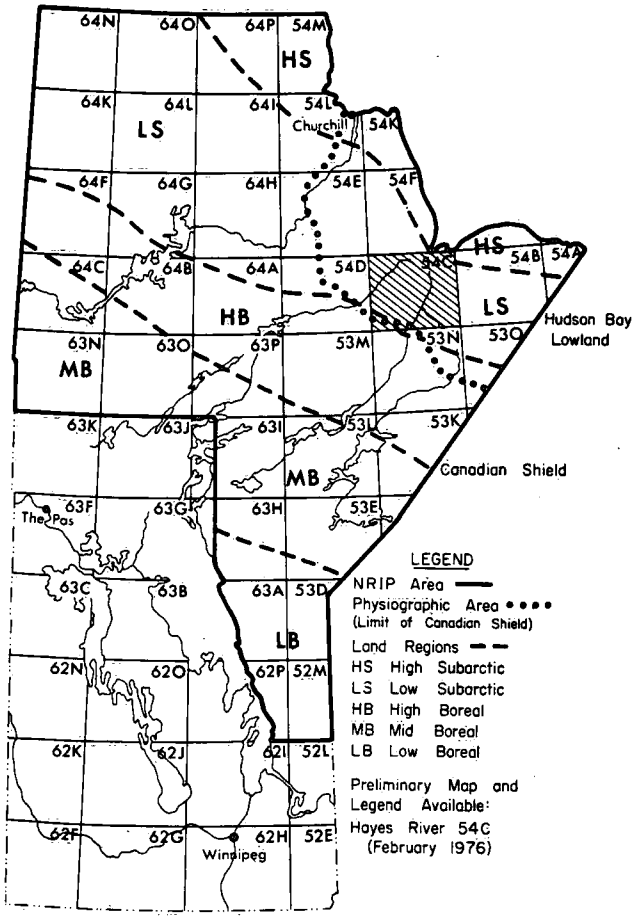
When considering Land Region differences, one should realize that regional boundaries indicate where significant ecologic changes are taking place, often over a transitional zone. A boundary occurs where change in the climate-soil-vegetation conditions appear to be most pronounced or significant when compared to adjacent areas. A line drawn in this way is only an approximation of where the majority of changes occur and there are many local variations which become obvious when mapping a smaller area in more detail (e.g. an NTS map sheet). For this reason, a particular soil name or vegetation type may be applied in two adjacent Land Regions when site conditions are similar in these regions.

This situation usually occurs only within a limited area on either side of a Land Region boundary; as distance from the boundary line increases, climatic change is sufficient to produce major, significant differences in similar site condition.

An ecological description of extensive land areas must incorporate regional variations in climate; however, climatic information needed to classify such regions does not exist for the most part. In addition, we do not always know which climatic parameters have the greatest influence and are most significant to the ecology of an area or to potential land use developments. Because meteorological data can only show trends or gradients, the critical values or ecological thresholds can only be determined through knowledge of climate-vegetation-soil relationships. Existing climatic data serve only to corroborate to a certain extent the validity of the regional division but cannot define or identify them.

Because climatic change from region to region has such importance to the ecology of an area, the Land Region is useful for establishing soil series and associations. The soils of each Land Region are associated with a range of climatic parameters which influence not only the thermal regime of the soil but also the various biological and physical activities involved in the processes of soil development. Soils developed on similar parent materials and drainage conditions but in different Land Regions are given different names according to the Land Region in which they occur to indicate that many of the associated ecologic conditions are dissimilar.

Figure 2: Land Regions in Northern Manitoba



associations typical of adjacent Land Regions. Such atypical "outlier" associations were considered too small or insignificant to be delineated separately, but their presence should be recognized.

APPENDIX II

EXAMPLE OF INTEGRATED APPROACH TO DATA PRESENTATION

Land Regions - The Hayes River map area contains parts of three Land Regions named from southwest to northeast High Boreal, Low Subarctic and High Subarctic (Figure 2).

The Land Regions shown in Figure 2 are delineated on the basis of dominant soil, vegetation and permafrost conditions occurring over large areas. Because the major changes in dominant soil, vegetation and permafrost conditions of a Region are related to climate, there is an orderly zonation from south to north. Zonation is complicated by the presence of local features such as large water bodies, valleys, extensive organic plains and north-south trending ridges. Some of these features favor development of soil-vegetation

The land regions in the Hayes River map area have been described and compared in a tentative summary of their biophysical properties by Mills *et al.* (1976). In this summary, the broad vegetation zonation is after Rowe (1972); permafrost regime has been defined by Brown (1970), and the soil characteristics are derived from exploratory surveys carried out by the Canada-Manitoba Soil Survey. An attempt has been made to describe the stable vegetation according to soil and soil moisture conditions. Local physiographic (site) conditions may change the local climate and hence vegetation development. Such conditions occur on steep south-facing slopes in protected valleys which may make the site warmer, or on north-facing slopes, exposed ridges, snow accumulation areas and in frost pockets, any of which may make the

site colder. Sites which are not so influenced may be called normal or mesic, as the vegetation on them expresses the normal effect of the regional climate (Hills, 1960).

The land district and land systems described in this Appendix are in the Low Subarctic land region. This land region is characterized by open coniferous forest or subarctic forest vegetation. The permafrost is discontinuous and widespread. Dominant soils are Brunisolic Static Cryosols, Brunisols, Luvisols, Gleysolic Static Cryosols and Organo Cryosols. The organic soils occur on peat plateaus, palsas, bog veneers and fens lacking permafrost. Sandy soils are non-frozen, but loams and clays are frozen with an active layer ranging from 30 cm to in excess of 1 m. Cryoturbation is active in lower slopes and depressions but is sporadic in mid and upper slope positions.

Land Districts - Six Land Districts are delineated and described in the Hayes River area; one in the High Subarctic Land Region, four in the Low Subarctic Land Region and one in the High Boreal Land Region. The location of the Land Districts is shown on the Biophysical Land Classification map of the Hayes River area (Mills *et al.*, 1976) and on Figure 3. The two land systems described in detail in the Appendix occur in the French River Land District in the central part of the Low Subarctic Land Region.

The French River land district is mainly an organic plain, with microrelief provided by scattered occurrence of drumlins and abandoned marine beaches. Elevation varies from 120 m along the eastern border to 75 m in the north. The broad U-shaped channel of the Gods River forms a major topographic break in the landscape. This district includes a large cluster of lakes occupying the western 2/3 of the area; the remainder is dominated by organic landforms. The shape of the lakes reflects the topography of the underlying till which is often covered by a thin mantle of marine deposits.

The organic deposits which dominate the District occur in the form of peat plateaus, bog veneers and fens. The peat plateaus are raised, permanently frozen peat landforms; the bog veneers are thin organic accumulations, which contain a sporadic occurrence of permafrost. The fens consist of moderately deep to deep, very poorly drained organic deposits, which contain no permafrost, except in the case of patterned fens. In such cases, frost is found under some of the better developed ridges.

On upland sites and organic peat plateaus and bog veneers Black Spruce forms the stable tree cover; on the better drained ridges, Black Spruce is often replaced by Jack Pine as a result of fire. On bogs, the Black Spruce is associated with *Sphagnum* spp., lichens and ericaceous shrubs. On upland sites the ground cover consists mainly of lichens and/or feathermosses, with minor components of ericaceous shrubs. The vegetation in the fens is dominantly sedges, Bog Bean, Cottongrass and brown mosses, with, in some cases, a stunted tree cover of Tamarack. In the case of patterned fens the ridges are formed by *Sphagnum* spp. and other mosses which support stunted Tamarack and Black Spruce.

Mesic Organo Cryosols are the dominant soils associated with peat plateaus; Terric Mesisols and Terric Mesic Fibrisols usually occur with some Peaty Gleysols in non-frozen parts of the bog veneer areas. Fens are characterized by dominantly Terric and Typic Mesisols formed on fen peat. The active layer in the organic deposits is about 50 cm and ice content of the permanently frozen materials is high. Medium textured till materials are characterized by Eutric Brunisols on the mid and upper slopes and Peaty Gleysols and Gleysolic Static Cryosols in lower slopes and minor depressions. On beach ridges, the dominant soils are Degraded Eutric Brunisols often associated with Gleyed Degraded Eutric Brunisols on the lower slopes.

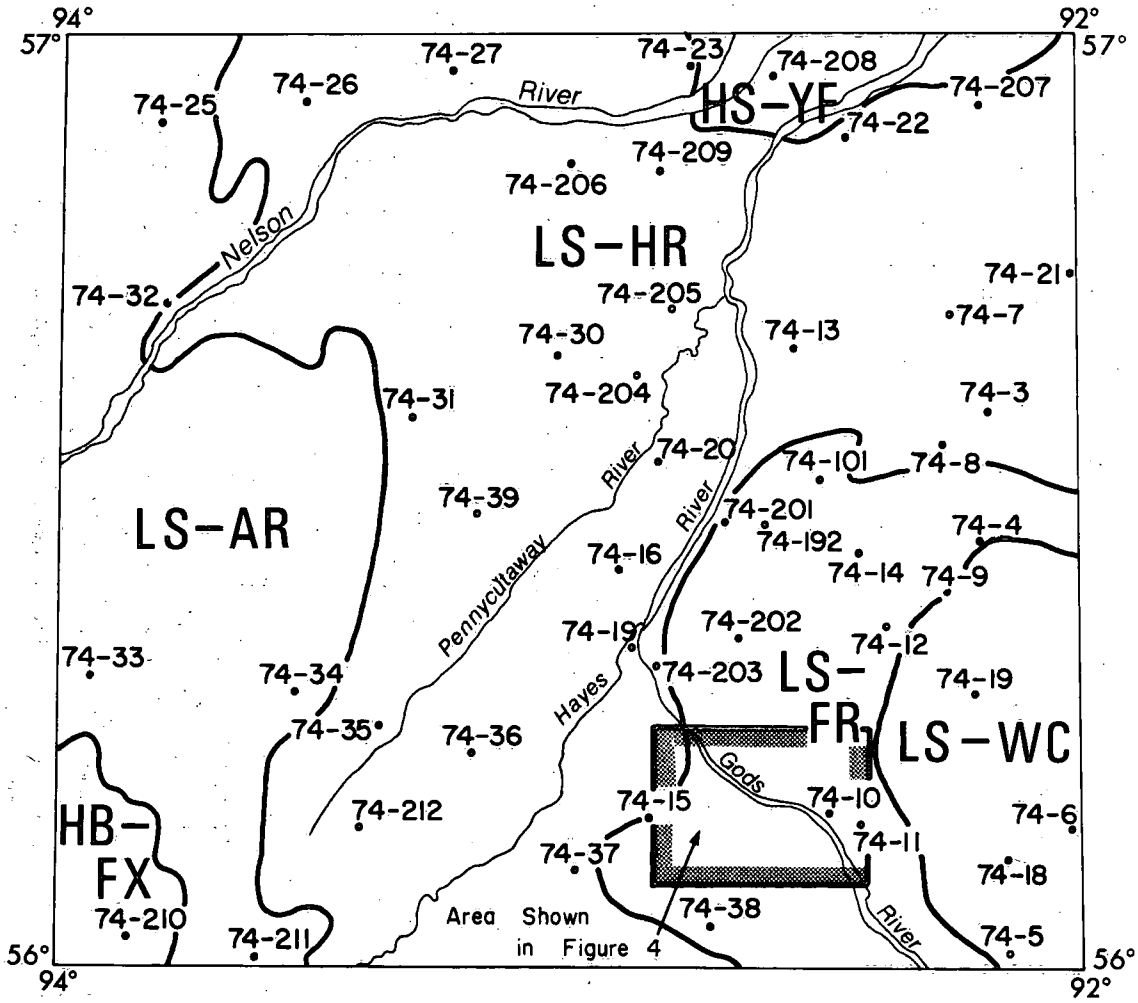
Land Systems - Part of the biophysical map of the French River land district is reproduced in Figure 4. The landform and vegetation pattern characteristic of different land systems is seen in the aerial photograph of the same area (Figure 5). The following symbols describe two land systems located side by side south of the Gods River. They are:

$$b2 \quad \frac{1Mde^{2}}{Sl_{3}} \Bigg| \frac{Bv.t^{6}Fp^{2}}{Dl_{2}Pe_{1}Py_{1}} \quad \text{and} \quad \frac{Bt^{7}}{Pe_{1}} \quad \frac{Fp^{3}}{Py_{1}}$$

$$1. \text{ Land System } b2 \quad \frac{1Mde^{2}}{Sl_{3}} \Bigg| \frac{Bv.t^{6}Fp^{2}}{Dl_{2}Pe_{1}Py_{1}}$$

This symbol reads as follows:

Twenty percent of the land unit consists of loamy till in the form of drumlins or drumlinoid features, which have been eroded by water. The relief of these landforms is from 3 to 5 meters, with most slopes between 6 and 12 percent. The associated soils belong to



Land Regions:	HS	High Subarctic
	LS	Low Subarctic
	HB	High Boreal
Land Districts:	AR	Angling River
	FR	French River
	FX	Fox River
	HR	Hayes River
	WC	Wigwam Creek
	YF	York Factory

Figure 3: Land districts and location of groundtruth sites in the Hayes River Map Area

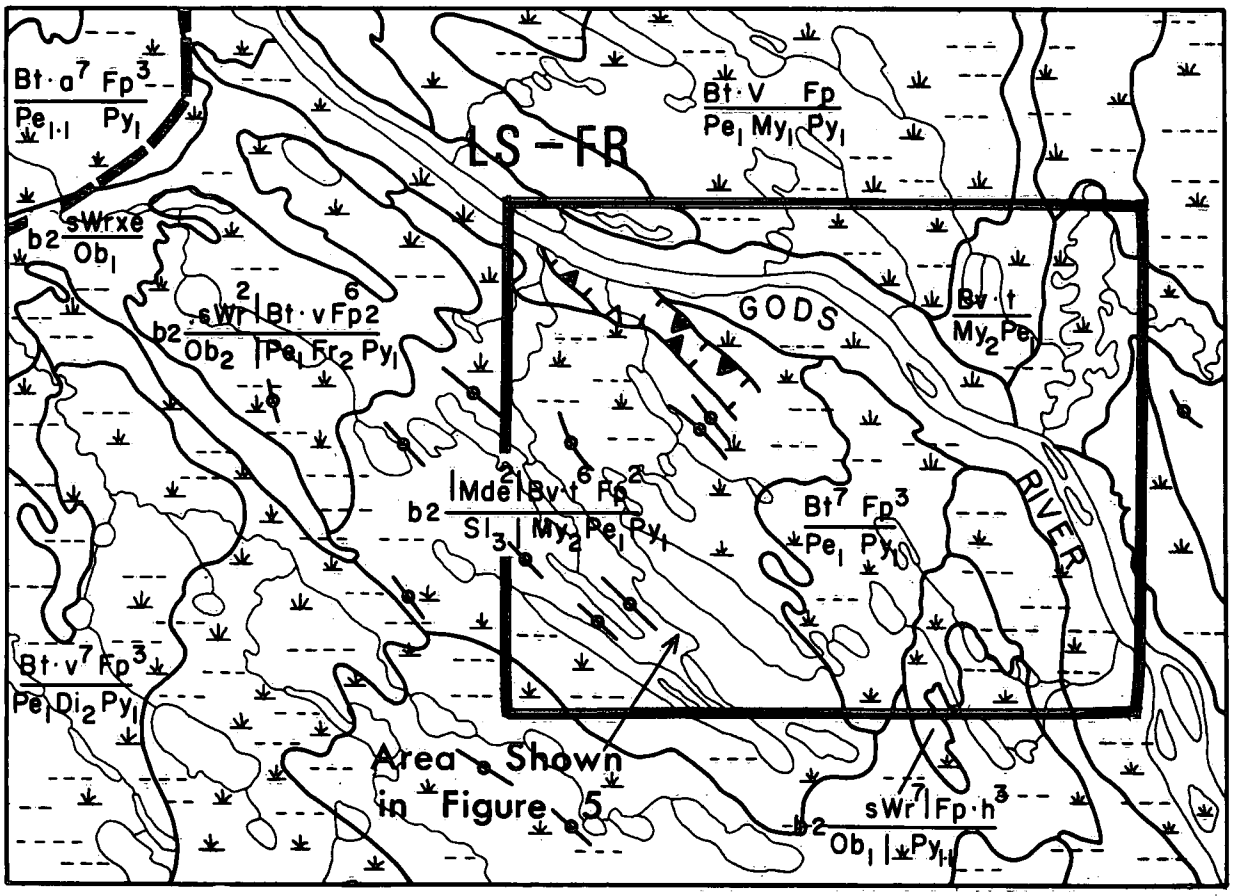


Figure 4: Portion of 1:125,000 scale biophysical map of the Hayes River area

LEGEND - GEOMORPHOLOGY

GENETIC MINERAL LANDFORM CLASS

A alluvial
C colluvial
E eolian
G glacio-fluvial
L glacio-lacustrine
M morainal
W marine
U undifferentiated

BEDROCK CLASS

aR bedrock, acidic
bR bedrock, basic
cR bedrock, carbonatic
uR bedrock, undifferentiated

MORPHOLOGY AND SURFACE FORM CATEGORY

(placed after landform class)

p plain
h hummocky
u undulating
m rolling
d drumlinized
k kettled
r ridged
t terraced
a apron
Δ delta
f fan
b blanket
v veneer

TEXTURAL CATEGORY (placed before landform class)

c clayey
l loamy
s sandy
f fragmental (gravelly, cobbly or bouldery)
-s skeletal (used in combination with clayey, loamy or sandy)

EROSIONAL MODIFIER (placed after morphology & surface form category)

c channeled
e eroded
i dissected
l deflated
w washed

GENETIC ORGANIC LANDFORM CLASS AND CATEGORY

B Bog

a palsa
b bowl bog
f flat bog
l blanket bog
m peat mound
p bog plateau
t peat plateau
v bog veneer
y polygonal peat plateau

F Fen

c collapse scar
f floating fen
h horizontal fen
l sloping fen
m minerotrophic palsa
p patterned fen

S Swamp

RELIEF CLASS (meters)		SLOPE CLASS degrees	%
a 0- 2	1	0- 2	0- 5
b 3- 5	2	3- 7.5	6-15
c 6-20	3	8-15	16-30
d 21-50	4	16-30	31-60
e 51-100	5	>30	>60
f >100	6	complex	

BIO-PHYSICAL BOUNDARIES

Land Region
Land District
Land System

LS-FR

NOTES:
1. See text for explanation of Map Symbol
2. See Table 1 for soil and vegetation
3. See Appendix III for definition of terms

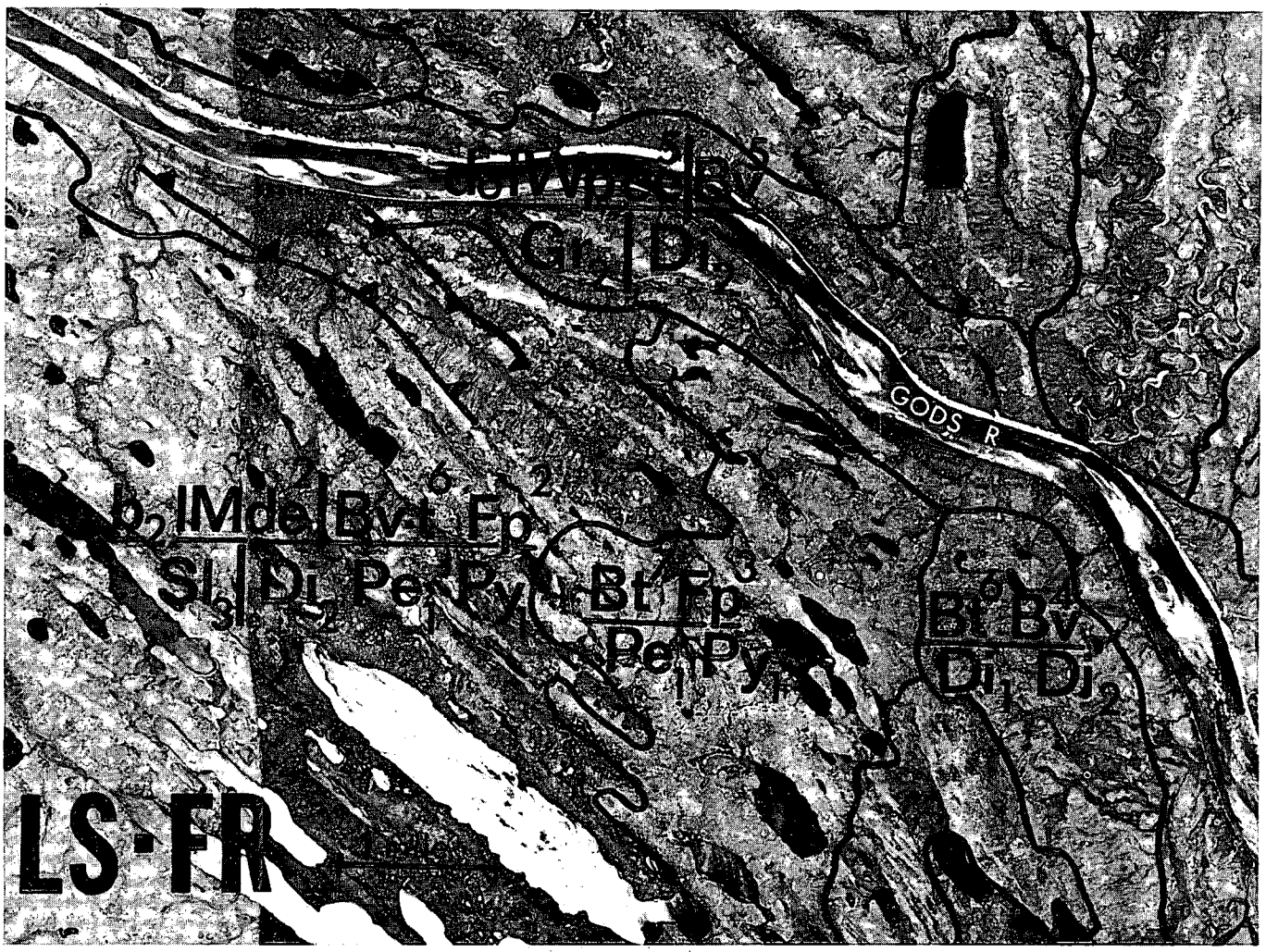


Figure 5: Landform and vegetation patterns of land systems in the French River Land District (see text for descriptions)

Legend for Cartographic Symbols
and Mapping Conventions

MAPPING CONVENTIONS

1. Morphology and surface form categories are applied individually or in combination to the Genetic Mineral Landform or Bedrock Class.
2. Topographic expression applies to both mineral and bedrock landforms and, as well, to shallow organic landforms (bog veneer and blanket bog) which reflect the configuration of the underlying material. The topographic characteristics of all other organic landforms are described in the definition of each landform.
3. Map units may be pure or complex:
   Pure units consist of one component covering >85 percent of the map unit.
   Complex units consist of two or more components, the relative proportion of each being designated in deciles by Arabic numerals placed as superscripts after each landform. The organic landform portion of the map unit is always designated last in the symbol and is separated from mineral and/or bedrock portions by |.
4. Thin veneers or blankets of one geologic material may overly another morphologically dominant unit. Where the overlay is a continuous blanket, the nature of the underlying material is described at the Land District level; if the overlay occurs as a continuous veneer, the underlying materials are described in the definition of the soil association.
5. Areas of dominantly deep organic deposits are designated according to the organic landform only. The underlying materials are described at the Land District level.

CARTOGRAPHIC SYMBOLS

- break of slope (scarp)
- isolated hillock or hummock
- >>><>< esker (direction of flow assumed, uncertain)
- drumlin or drumlinoid (ice direction shown, not shown)
- moraine ridge
- abandoned strandline
- buried strandline
- meltwater channel
- minor intersecting lineaments or grooves

the Strobus Lake 3 association.

Sixty percent of the land system is covered by bogs, which are dominantly of the bog veneer type, while the remainder is in the form of peat plateaus. Twenty percent of the land system is covered by patterned fens. The soil associations are respectively Deer Island 2, Pemichagamau 1 and Pennycutaway 1. Using the soil association as a key, additional information can be found in the extended legend (see Table 1).

2. Land System $\frac{Bt^7 \quad Fp^3}{Pe_1 \quad Py_1}$

This symbol reads as follows:

The unit consists entirely of organic landforms in the form of peat plateaus and patterned fens. Approximately 70 percent of the land system consists of raised peat plateaus occurring singly and as complex associations of peat plateau fields. The associated soils belong to the Pemichagamau association. Thirty percent of the land system is covered by patterned fens characterized by the Pennycutaway soils. Utilizing the soil association symbol as an entry to the extended legend, the user can find additional information on depth and physical properties of the soil materials along with drainage characteristics and associated vegetation types.

APPENDIX III

DEFINITION OF TERMS

(Acton, 1975; Tarnocai, 1974; Flint, 1971)

Genetic Mineral Landform Classes -

Alluvial (A). Accumulation of material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semi-sorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Colluvial (C). Accumulation of any loose, heterogeneous and incoherent mass of material or rock fragments (variable mixture of boulder to clay) deposited chiefly by mass-wasting, usually at the base of a steep slope or cliff.

Eolian (E). Accumulation of deposits (sand and silt) whose constituents were transported (blown) and laid down by atmospheric currents, or of deposits produced or eroded by the wind.

Glaciofluvial (G). Pertaining to the outwash deposits and landforms, produced by meltwater streams associated with and flowing from wasting glacier ice. Such stratified sediments, depending on the depositional environment, are classed as ice contact deposits or outwash sediments.

Ice contact outwash includes kames, eskers and kame moraines deposited upon or immediately adjacent to glacier ice. In addition to a distinctive surface form, ice contact deposits are characterized by extreme range and abrupt changes in grain-size, inclusions of till bodies and marked deformation.

Outwash sediments include stratified materials, mainly well-sorted sands and gravels deposited by streams usually in the form of fans, terraces and valley trains.

Glaciolocustrine (L). Materials deposited in glacial lakes; specifically, landforms and deposits composed of suspended materials transported by streams into lakes bordering a glacier which has since disappeared.

Morainal (M). Accumulations of unsorted, unstratified glacial drift, predominantly till, deposited chiefly by the direct action of glacier ice in a variety of landforms that are primarily independent of control by the surface underlying the drift.

Marine (W). Materials deposited in marine environments. These may form a blanket of deeper-water silts and clays, or occur as a series of marine nearshore features composed largely of gravels and sands and deposited as spits, bars and beaches.

Undifferentiated (U). Deposits whose genesis cannot be determined from the available evidence, or mixtures of deposits resulting from the interaction of several genetic processes.

Bedrock Classes

Acidic (aR). Igneous intrusive or extrusive bedrock having more than 66% SiO_2.

Basic (bR). Igneous intrusive or extrusive bedrock having less than 66% SiO_2.

Bedrock (R). A general term for the rock, usually solid, that is exposed or underlies unconsolidated surficial material. Types of bedrock encountered are grouped into "acidic, basic or carbonatic" classes.

Carbonatic (cR). Sedimentary rocks containing large amounts of calcite and other carbonate materials.

Table 1: Portion of the extended legend, Hayes River Map area, 54C Manitoba

LEGEND FOR SOIL AND VEGETATION

Soil Association Symbol	Soil Association Name	Land Region	Parent Material	Map Unit Symbol	Soil and Drainage[4] Dominant Subgroup[1]	Soil and Drainage[4] Significant Subgroup Inclusions[2]	Landscape Position[3]	Ice Content and Depth of Thaw[3]	Dominant Vegetation[3,5]
Di	Deer Island	LS	Shallow (40-160 cm) deposits of mesic to humic forest peat with alternating subdominant layers of fibric sphagnum peat and/or mesic fen peat underlain by medium to fine textured marine sediments.	Di_1	Terric Mesic Organo Cryosol (i-p)		Raised peat plateaus and palsas	High; 50 cm	bS-Er-Li-Fm bS-Er-Sp-Fm
				Di_2	Terric Mesisol (p)	Terric Mesic Organo Cryosol (p-i)	Gently sloping areas with shallow channels, runnels and depressions	Moderate; 50 cm to 100+ cm	bS-Sp-Er bS-Fm-Er-Li
Pe	Pemichagamau	LS	Deep (>160 cm) deposits of mesic to humic forest peat	Pe_1	Mesic Organo Cryosol (i-p)	Typic Mesisol	Raised peat plateaus and palsas	High; 50 cm	bS-Er-Li-Fm bS-Er-Sp
Py	Pennycutaway	LS	Deep (>160 cm) deposits of mesic fen peat or very thin (15-60 cm) discontinuous fibric sphagnum peat overlying fen peat.	Py_1	Typic Mesisol (v)	Typic Mesisol, sphagnic phase (v)	Level to depressional fens, water track fens	Non-frozen	Cx-Dp-Co
				Py_2	Typic Mesisol, sphagnic phase (v)	Typic Mesisol (v)	Level to depressional fens	Non-frozen	tL-Cx-Dp-Sp
Sl	Strobus Lake	LS	Very strongly calcareous, medium to moderately fine textured stony till.	Sl_1	Degraded Eutric Brunisol (w)	Orthic Grey Luvisol (w) Gleyed Degraded Eutric Brunisol (i)	Apex and upper slopes	Non-frozen	bS-(jP-tA)-Fm-Al
				Sl_2	Gleyed Degraded Eutric Brunisol (i)	Rego Gleysol, peaty phase (p) Gleysolic Static Cryosol, peaty ph. (p)	Mid to lower slope	None to moderate; 50 cm to 100+ cm	bS-Fm-Er-Al
				Sl_3	Rego Gleysol, peaty phase (p)	Gleysolic Static Cryosol, peaty ph. (p)	Depressional to level	None to high; 50 cm to 100+ cm	bS-Sp-Er-Fm

Notes:
1. Dominant subgroup comprises more than 40 percent of soil association.
2. Significant subgroup inclusions are 20 to 40 percent of soil association. Minor subgroups are listed in order of dominance.
3. Landscape position, ice content, depth of thaw and dominant vegetation refer to the dominant subgroup.
4. Drainage classification
   - e - excessively drained
   - w - well drained
   - i - imperfectly drained
   - p - poorly drained
   - v - very poorly drained
5. Vegetation: species abbreviation
   - Dp - Drepanocladus
   - bS - black spruce (Picea mariana)
   - wS - white spruce (Picea glauca)
   - wB - white birch (Betula papyrifera)
   - Bi - dwarf birch (Betula glandulosa)
   - tL - tamarack (Larix laricina)
   - Wi - willow (Salix sp.)
   - Al - alder (Alnus sp.)
   - tA - trembling aspen (Populus tremuloides)
   - bPo - black poplar (Populus balsamifera)
   - Cx - Sedge (Carex sp.)
   - Co - Cottongrass (Eriophorum sp.)
   - Li - Lichen (Cladonia sp.)
   - Sp - Sphagnum (Sphagnum sp.)
   - Er - Ericareae (Ledum, Chamaedaphne, Kalmia, etc.)
   - Fm - Feathermosses
   - jP - Jack Pine (Pinus banksiana)

Undifferentiated (uR). A bedrock material where differentiation into a specific class is impractical or impossible.

Morphology and Surface Form Category

Apron (a). An extensive, continuous, gently sloping and blanket-like deposit of unconsolidated material derived from an identifiable source such as the edge of a large esker or along fault scarps.

Blanket (b). An extensive area of relatively thick (>1 m) surface deposits which subdue but do not completely mask the configuration of the underlying bedrock or deposit.

Delta (Δ). Usually a triangular shaped area composed of stratified materials (ranging from coarse to fine) deposited by streams into large bodies of water.

Drumlinized (d). Elongated, smooth, streamlined ridges with long axes parallel to the direction of ice movement.

Fan (f). A gently sloping, fan-shaped mass of detritus forming a section of a very shallow cone, commonly at a place where there is a noticeable change in gradient.

Hummocky (h). Terrain having a broken, irregular surface with distinct knobs or mounds and depressions.

Kettled (k). An area of glacial drift pitted with numerous steep-sided, bowl- or basin-shaped depressions that often contain lakes; surface drainage is generally deranged.

Plain (p). An area of comparatively flat, smooth, and level land having few or no prominent surface irregularities, but sometimes having a considerable unit tilt.

Ridged (r). Terrain characterized by long, narrow elevations which may occur independently or in parallel or intersecting patterns. Ridges usually have sharp crests and steep sides.

Rolling (m). Terrain having a smooth, regular surface with broad topographic highs. Slopes are usually 1 km or greater in length.

Terraced (t). A long, narrow, relatively level or gently inclined surface bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope; a large bench or step-like ledge breaking the continuity of a slope.

Undulating (u). Terrain having a smooth, regular surface with broad shallow topographic lows and broad medium to subdued topographic highs. Slopes are usually less than 1 km in length.

Veneer (v). An extensive area of thin (<1 m) unconsolidated surficial deposits which mask little of the configuration of the underlying bedrock or deposits.

Erosional Modifier

Channeled (c). Modification of a deposit or feature by the cutting of channels and removal of material from along local drainage ways.

Deflated (1). Modification by erosive action of wind.

Dissected (i). A network of gullies, ravines, valleys and remnant flat-topped interstream ridges formed by stream erosion acting on a relatively even topographic surface.

Eroded (e). The production or modification of a landform by the action of streams, waves or glaciers.

Washed (w). Landforms which have been modified in some manner by wave action are said to be washed. The process results in the sorting of surface materials or the formation of scattered minor beaches.

Textural Category

Three categories of texture are utilized to describe the nature of the deposits associated with a landform. The texture classes within each category are estimated in terms of size and the distribution of primary particles. Significant inclusions of very coarse particles (gravel, cobbles and boulders) within a deposit are indicated by adding the term "skeletal" as a modifier to the symbol for a textural category.

Primary Particles

Name of Separate	Diameter, mm
Boulders, stones	>250
Cobbles	250-75
Gravel	75-2.0
Very coarse sand	2.0-1.0
Coarse sand	1.0-0.5
Medium sand	0.5.0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002
Clay	Less than 0.002

Broad Textural Categories

Clayey (c). Material less than 2 mm contains 35% or more clay by weight and particles 2 mm to 25 cm size are less than 35% by volume.

Includes heavy clay loam, heavy silty clay loam, sandy clay, silty clay, clay and heavy clay.

Fragmental (f). Gravel, cobbles and boulders (2 mm to more than 25 cm) containing too little fine materials to fill the spaces larger than 1 mm.

Loamy (l). Material less than 2 mm contains less than 35% clay by weight and includes coarser materials up to very fine sand size. Particles of 2 mm to 25 cm size are less than 35% by volume.

Includes 2 main groups of texture:

(1) Light (less than 18% clay by weight): sandy loam, fine sandy loam, loam, very fine sandy loam, loamy very fine sand, loam, silt loam, silt

(2) Heavy (18-35% clay by weight): sandy loam, fine sandy loam, loam, very fine sandy loam, silt loam, sandy clay loam, clay loam, silty clay loam

Sandy (s). Material less than 2 mm contains less than 18% clay and more than 70% sand exclusive of loamy very fine sand and very fine sand. Particles of 2 mm to 25 cm size are less than 35% by volume.

Includes sands and loamy sands.

Skeletal (s). Modifies the main textural categories containing more than 35% by volume of particles coarser than 2 mm size.

Genetic Organic Landform Classes and Categories

Bog (B)

A bog is a peat-covered or peat-filled area, generally with a high water table. Since the surface of the peatland is slightly elevated, bogs are either unaffected or partly affected by nutrient-rich groundwaters from the surrounding mineral soils. The groundwater is generally acidic and low in nutrients (ombrotrophic). The dominant peat materials are sphagnum and forest peat, underlain at times by fen peat.

Categories of Bogs

Bog Plateau (Bp). The height of these peat landforms varies from 0.5 to 1 m and is due to greater peat deposition as compared to the surrounding wet fen areas. Bog plateaus are often tear-drop shaped.

Bog Veneer (Bv). This type of bog occurs when a shallow peat (generally 40-100 cm thick) covers slopes and to some degree, depressions and uplands. The surface topography is often micro-hummocky (sphagnum mounds). Permafrost is discontinuous in this type of bog, and most often found in the better developed mounds.

Bowl Bog (Bp). This type of bog has developed in topographic depressions and has a concave peat surface.

Blanket Bog (Bl). This type of bog occurs when peat covers the uplands, slopes and depressions alike up to a considerable degree of slope.

Flat Bog (Bf). This type of bog is a level peatland area having only slight differences in the level of its surface. Irregularities or slopes of the substratum are completely or almost completely masked by the peat deposit.

Palsa (Ba). A mound of peat with a frozen peat and/or mineral core, occurring in water-logged, treeless or sparsely wooded fens. The height of a palsa is generally between 1 and 3 m, while the width is in the order of some tens of meters.

Peat Mound (Bm). Permanently frozen treeless mounds (0.5 to 1 m in diameter and about 30 to 50 cm high) which occur in water saturated fens.

Peat Plateau (Bt). Peat plateaus are associated with permafrost and their height (approximately 1 m) is dominantly due to ice lens formation in the frozen core. Their sizes range from several acres to tens of acres.

Polygonal Peat Plateau (By). These frozen organic landforms resemble peat plateaus as they are elevated about 1 m above the surrounding fen areas. The surface of this type of peat plateau is dominated by a polygonal pattern caused by ice wedge formation. The surface morphology resulting from ice wedge formation is expressed as a network of polygons having high, near level or slightly depressed centers. The outline of each polygon is marked by a polygonal trench often containing a wedge-shaped accumulation of ice.

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BIOPHYSICAL LAND CLASSIFICATION OF BANFF AND JASPER NATIONAL PARKS

W.D. Holland

Canadian Forestry Service
Northern Forest Research Centre
Edmonton, Alberta

ABSTRACT

The Banff-Jasper biophysical team accepts the basic concepts of a biophysical land classification system. Modifications to existing biophysical inventory methodology are described, including problems with classification methodology, and recommendations. Four appendices describe operational methodology, results to-date, user contact and anticipated applications, and problem areas.

RÉSUMÉ

L'équipe biophysique des parcs de Banff et Jasper accepte les concepts fondamentaux d'un système de classification écologique du territoire. Le présent document explique les modifications apportées à la méthodologie existante l'inventaire biophysique, y compris les problèmes relatifs à la méthodologie de la classification et les recommandations. Quatre annexes décrivent la méthodologie opérationnelle, les résultats obtenus jusqu'ici, les contacts avec les usagers, les applications prévues et les domaines à problèmes.

INTRODUCTION

At the request of Parks Canada in 1973, a biophysical land classification was planned, in 1974, for Banff and Jasper National Parks and initiated by field activities in the Mt. Eisenhower-Lake Louise area of Banff National Park. The methodology of Lacate (1969) was adopted for trial. Field work was initiated in Jasper in 1975, and continued in Banff, with Lacate's methodology being modified and developed as described in this paper.

Detailed objectives of the Banff-Jasper inventory project are provided by Day *et al.* (1975) and reiterated in Progress Report No. 1 by Holland *et al.* (1975). The objectives of the project may be summarized as follows:

1) To quantitatively and qualitatively describe the landforms, soils and vegetation characteristics of both Parks - in map and report form.

2) To provide interpretation of data for Parks' purposes; eg. land use planning and management of land within the Parks.

The terms of reference (Day *et al.* 1975) thoroughly outlines the basic data requirements in terms of a multi-disciplinary team approach to integrated resource inventory; thus, the adoption of a biophysical land classification system. They also provide for the inclusion of landform classification (Fulton *et al.* 1974); soil classification (Canada Soil Survey Committee 1970, 1973, 1974); wetlands classification (Zoltai *et al.* 1975); vegetation resource description and classification; wildlife resources. User requirements are desribed. Freedom is provided, however, to permit development of integrated land classification methodology; for example, in the vegetation component of the inventory and as dictated by the scale of 1:50,000.

The main emphasis of this paper is on the classification methodology that is being used in Banff-Jasper and the development of the methodology, logistics, problems, etc. is presented in four Appendices to this paper.

CLASSIFICATION METHODOLOGY

A. Background - The basic concept or aim of biophysical land classification--namely, "to

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differentiate and classify ecologically significant segments of the land surface" (Lacate 1969)--is valid and quite acceptable. The hierarchical levels of generalization (Lacate 1969, Jurdant *et al.* 1975) also have merit but problems in applying them in the Banff-Jasper Land Inventory Project arise for the following reasons:

1. Flexibility of application designed into definitions (Zoltai 1970) promotes somewhat variable interpretations of the various classification levels between team members.

2. Variability of mountain terrain and environments is a main problem area. In particular, vertical zonation, produced by altitudinal macro-climates, necessitates more complex and areally smaller separations at highest levels of generalization than have been recognized in several other projects across Canada.

3. The approximate scales as established by Lacate (1969) for a heirachical biophysical system are not entirely adequate in the mountains and do not include the required project scale of 1:50,000.

4. Many ecologists feel that there is insufficient collection of basic environmental data in biophysical inventory projects. These data are generally not available but are necessary to explain ecological relationships and will add integrity to most interpretations. For the most part, these relationships are now explained by hypotheses. In addition, vegetation scientists desire, in biophysical classification systems, more meaningful hierarchical structure in terms of *ecological significance*. Consequently, modification and refinement of land classification concepts to-date have resulted in the Banff-Jasper Biophysical Land Classification System as presented in the following section.

B. Banff-Jasper Biophysical Land Classification System (Table 1) - Table 1 presents a breakdown (hierarchical levels of generalization) of the biophysical land classification system being used, and proposed for use, in Banff and Jasper National Parks. Levels 1, 2,4 and 5 are presently operational (e.g. Lake Louise Study Area, Walker *et al.* 1976). Level 3 is presently under consideration as a means of grouping, at an intermediate hierarchical level, those Land Systems that have apparently similar environments.

The general objective of this system is to promote holistic, repeating, map unit concepts through integration of landscape components (landform, soil, and vegetation) within an ecologically sound framework.

1. *Bioclimate Zone* (Level 1) constitutes the highest level of abstraction in the Banff-Jasper Biophysical Land Classification System. Separations at this level depict macro-climates, as expressed by vegetation, that are controlled mainly by elevation and partly by latitude and general east-west physiography.

2. *Bioclimate Subzone* (Level 2) identifies subdivisions of macro-climate based primarily on elevation differences as reflected by vegetation. For example, Upper Subalpine encompasses Subalpine vegetation types (usually (spruce/fir forests) that reflect, in this structure and species composition, near-Alpine conditions.

3. *Vegetation-Soil 'District'* (Level 3) is under consideration as an intermediate step for differentiating various environmental 'facies' within some of the more broadly defined Bioclimate Subzones. The basic concept for Level 3 was initiated when biophysical map units comprising the Lake Louise Study Area (Walker *et al.* 1976) were grouped for purposes of relating soil and vegetation development to inferred climatic trends existing in that area (see Figure 1). It is felt that adoption of this step for the overall inventory (1:50,000 scale) will add ecological integrity to the Banff-Jasper Biophysical Land Classification System. It must be pointed out, however, that the 'Districts' listed in Level 3 (Table 1) are highly tentative and reflect experience gained over one year in limited areas of both Parks.

Conceivably, Vegetation-Soil 'Districts' will depict trends in soil and vegetation development as influenced by *meso-climate* (or physiographic modification of macro-climate) interacting with latitudinal, elevational, and broad material (reaction and calcareousness) variations. Controlling physiographic parameters are east-west orography (Foothills versus Front Ranges versus Main Ranges) and, to a lesser extent, slope aspect in broad valleys. Specifically, climatic features such as snowfall (amount and duration), total precipitation, evapo-transpiration, and temperature can be qualitatively defined, on a relative basis, through an evaluation of trends in soil and vegetation development.

4. *Land System* (Level 4) is the basic conceptual level in the Banff-Jasper biophysical land inventory because Land Systems are the most consistent, repeating map concepts observable using air photos. Units that group or subdivide (above and below in the hierarchy) Land Systems are interpreted or identified as a

Table 1: Banff-Jasper Biophysical Land Classification (tentative)

LEVEL OF GENERALIZATION	1 BIOCLIMATIC ZONE	2 BIOCLIMATIC SUBZONE	3 VEGETATION-SOIL 'DISTRICT'	4 LAND SYSTEM	5 BIOPHYSICAL MAP UNIT
	ALPINE	Upper	Rock and lichen	Separations at this level are presently made within each Bioclimatic Subzone and are based on landform and major drainage features. Consequently, each Land System encompasses map units: 1. on similar geologic materials (consideration of origin, texture, and reaction); 2. of similar terrain surface form[4,5] (eg. aprons & fans vs. steep & inclined slopes vs. hummocky & ridged, etc.); and 3. having dominant soils of either: a) moderate to very rapid drainage - or - b) imperfect to very poor drainage. More variability is allowed in alluvial (recent) material characteristics than in other geomorphic materials. In addition, alluvial areas dominated by Regosolic soils (resulting from frequent flooding) are separated from alluvial areas with more advanced soils.	Each Land System is subdivided according to variations in soil and vegetation components as follows: - significant landform modifications (eg. inclusions of other materials, erosional processes); - significant variations in the proportions of component soils (phase of subgroups) and representative vegetation types; - significant inclusions of extraneous soils and vegetation types that influence overall use potential
		Middle & Lower[2]	*Cassiope/Phyllodoce*--Brunisol/Regosol		
	SUBALPINE	Upper Subalpine	Spruce/fir-*Cassiope*--Brunisol/Podzol Larch/fir-Brunisol/Podzol Spruce/fir-*Vaccinium*--Brunisol/Podzol		
		Lower Subalpine	Spruce/fir-*Menziesia*--Podzol Spruce/fir-*Menziesia*--Podzol/Brunisol Pine (Spruce) - *Shepherdia*--Brunisol/Luvisol		
	MONTANE	(Middle & Lower)[2]	White spruce/Douglas fir --Brunisol/Luvisol Grassland--Brunisol/Regosol		
	BOREAL	Upper Foothills[3]	?		
BIOPHYSICAL LAND CLASSIFICATION EQUIVALENTS[1]	LAND REGION (?)	SUBDIVISION OF LAND REGION	?	LAND SYSTEM (?)	SUBDIVISION OF LAND SYSTEM

1. Lacate 1969 2. La Roi *et al.* 1975 3. Rowe 1972 4. Fulton *et al.* 1974 5. Acton 1975

secondary stage.

Separations at this level are based on the descriptive landform classification system initiated by Fulton *et al.* (1974) and modified by Acton (1975). Materials category (origin) and terrain surface form are the basic elements of landform classification considered in Level 4. However, texture, reaction, and calcareousness are also considered. Because of use implications in the mountain National Parks, areas dominated by poorly and very poorly drained (wet) soils are also separated, at Level 4, from areas dominated by better drained soils. Table 1 lists the criteria by which Land System separations are made.

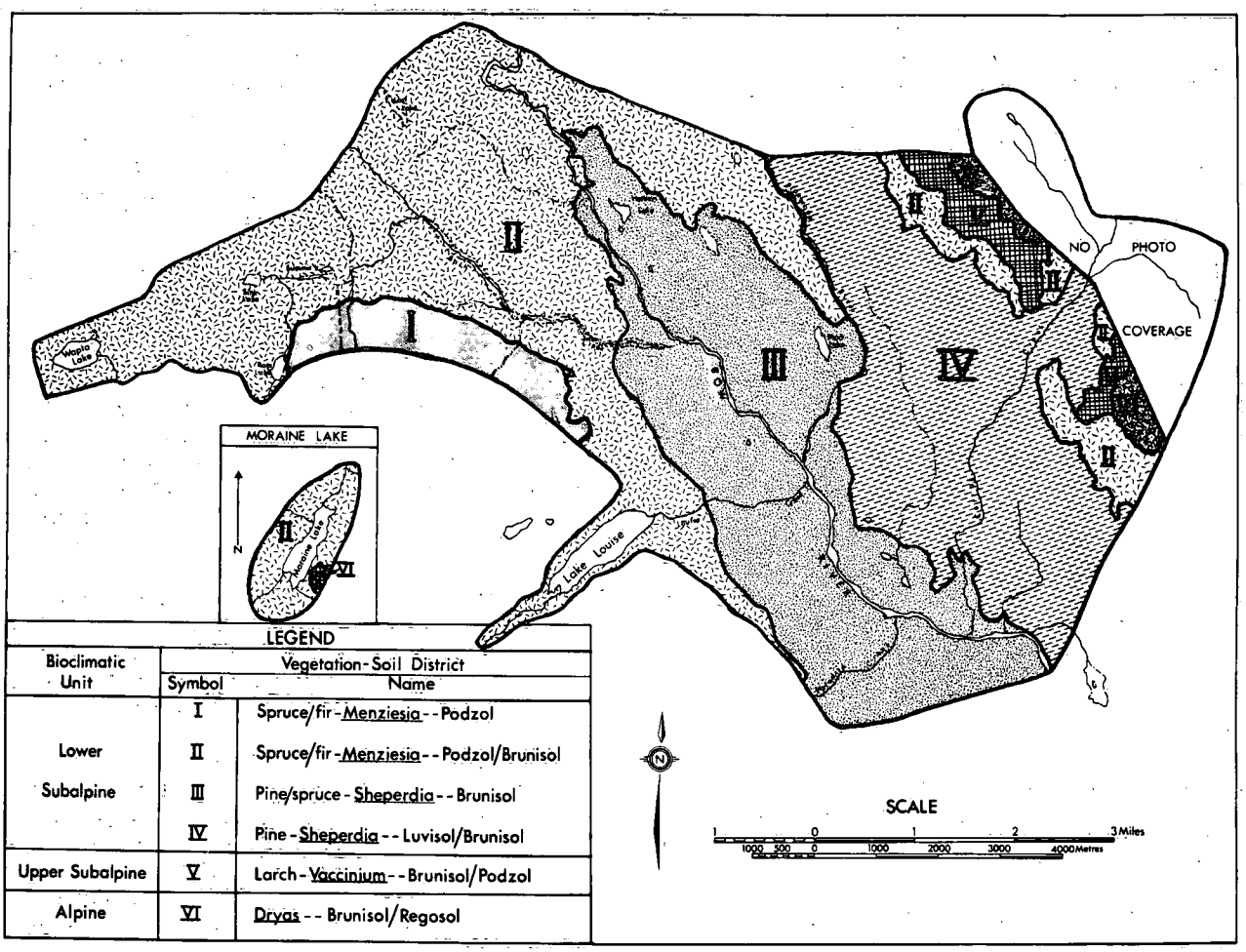
At the present time, Land Systems are differentiated within Bioclimatic Subzone (Level 2) units. If Level 3 is accepted as part of the hierarchy, Land Systems will be defined as occurring within Vegetation-Soil 'District'. Each Land System is identified by a geographic place name and, on maps, by a two-letter symbol.

5. *Biophysical Map Unit* (Level 5) is the main mapping level for the Banff-Jasper biophysical land inventory. Each map unit is identified by a two-letter symbol (indicating the Land System in which it belongs) plus a number.

Each Biophysical Map Unit indicates a pattern of soils and vegetation allowable within the geologic and environmental limits imposed by higher hierarchical levels in the classification system. Table 1 further specifies the criteria used to make map units separations.

The component soil (or soils) of biophysical Map Unit is recognized to be *subgroup phase*.

Figure 1: Vegetation-Soil "Districts" of the Lake Louise Study Area (from Walker et al. *1976)*



Representative vegetation type (or types) constitutes the vegetation element of a biophysical map unit definition and is based on a taxonomic entity - the vegetation type. A vegetation type is the smallest vegetation unit discriminable floristically and environmentally and is comparable to *plant association (sensu* Braun-Blanquet as modified by Krajina 1960) or *biogeocoenosis type (sensu* Sukachev 1958, 1960).

Representative vegetation type is a new concept introduced as a mapping device (legend) in the Lake Louise Study Area (Walker *et al.* 1976). Since most map units are somewhat heterogeneous in terms of vegetative cover, one taxonomic vegetation type is selected to represent or characterize, in the legend, the vegetation of each map unit. This is the representative vegetation type of that unit. In most cases, representative vegetation type is the dominant type providing it is stabilized or mature and reflects model habitat conditions of the map unit. Potential climax types need not be used as representative vegetation types. Short-term early or young succession stages (following disturbances) and introduced vegetation are not used. Types other than the representative vegetation type may in most cases be regarded as inclusions in a map unit. Some map units may be vegetationally characterized by up to three representative vegetation types. These are generally associated with complex landforms and habitats where landscape segments (e.g. north- versus south-facing slopes, dry versus wet portions) are defined in the legend or situations in which more than one vegetation type occupy nearly equal portions of the map unit.

C. Problem Areas - Problems other than logistics problems, but sometimes logistics-related, remain in the Banff-Jasper Biophysical Land Classification System concepts and their application.

1. *Cartographic Problems* - If rock, ice, and permanent snow fields are included within the concept of *Alpine*, Bioclimatic Zones (Level 1) are mappable at a scale of 1:500,000 and, perhaps, smaller scales. However, a major cartographic problem occurs in Level 2 because some bioclimatic subzones--namely Alpine areas exclusive of rock and ice and Upper Subalpine areas--are not mappable at scales smaller than 1:50,000. Nevertheless, bioclimate subzones (Level 2) are ecologically important areas and are used as an organizational tool to group units from lower levels in the hierarchy.

Vegetation-soil 'districts' (Level 3) should be mappable at 1:125,000 to 1:250,000 because they span material and landform boundaries. However, they occur within bioclimatic subzones (Level 2 units), some of which are unmappable at the smaller scales (see preceding paragraph).

The cartographic problem pertaining to Level 2 also descends to Level 4 (Land System). In addition, land systems, as used in the Banff-Jasper biophysical land inventory, are conceptual rather than cartographic groupings of biophysical map units (Level 5 units). In other words, map units belonging to a land system seldom occur together in the landscape but are frequently separated by map units of other land systems.

Biophysical map units (Level 5) are utilized in the mapping and work reasonably well at scales of 1:20,000 to 1:50,000 in the mountain terrain.

2. *Data Requirements* - As previously mentioned in the *Background* subsection, most ecologists express a need for more intensive data gathering for purposes of identifying and explaining ecological relationships. In particular, vegetation scientists desire an intensive sampling program (amenable to statistical analysis) to adequately characterize and define limits for vegetation types. Beyond this, ecological (climate-vegetation-soil-geologic material) relationships, and resulting interpretations, could be more confidently established.

Although intensive sampling and characterization of vegetation is both necessary and desirable, time and monetary constraints limit such an approach and necessitate compromises in sampling intensity.

3. *Waterbodies and Wetlands* - To-date, operational mapping procedures within Banff and Jasper National Parks have not included detailed characterization of lakes and streams. The relatively small areal extent of waterbodies in sections mapped to-date has probably been the main reason for this reduced concern. Recent contact with limnologists, hydrologists, and wildlife biologists suggests that more attention be given to aquatic ecosystems.

Present operational mapping in the mountain Parks recognizes waterbodies and associated wetlands only as accessory features of biophysical map unit (Level 5) definitions. However, guidelines for open water and wetland classification as outlined by Adams and Zoltai (1969) and modified by Jurdant *et al.* (1972) may be tested in the Banff-Jasper Biophysical Land Classification System in the near future.

4. *Classification System Problems* - Main problems in the Banff-Jasper Biophysical Land Classification System center around Level 3 and include naming of this category (use of 'District' may create confusion relative to Lacate's 1969 Land District definition) and its implementation within the hierarchical structure. Regarding the latter problem, several options are under consideration.

a) Level 3 may be retained as a district category as shown in Table 1. Land System separations would be made according to the specified criteria (Table 1) but within each vegetation-soil 'district'.

b) Levels 1,2,4 and 5 (Table 1) may remain operational and Level 3 will be used outside the system's hierarchy to group various soil and vegetation trends for discussion purposes. This option would necessitate mapping of Level 3 units to show climatic and distributional relationships.

c) Levels 2 and 3 (Table 1) may be integrated into a single hierarchical category with less emphasis on the vertical (altitudinal) zonation imposed by Level 2. Such a move may alleviate, in part, the mapping problems associated with the Bioclimatic Subzone Level (see discussion under *Cartographic Problems*).

d) Levels 2 and 4 (Table 1) may be integrated into one hierarchical category. Cartographic problems at such a level would, however, be compounded.

Some of the options will be subjected to testing and evaluation during the 1976 field season. In addition, more stringent criteria for Level 3 separations will be developed in the following year.

D. Summary Discussion and Recommendations - The Banff-Jasper biophysical team accepts the basic concepts of a biophysical land classifi-

cation system. It strongly feels, however, that many definitions of terms, taxonomic criteria, and hierarchical structure be made more rigorous. The trial, and/or adoption, of a restructured hierarchical classification methodology that provides for a category approaching Vegetation-Soil 'District' as described in the above text, is also considered very important.

Recommendations from the Banff-Jasper biophysical team are summarized as follows:

1. Development of more rigorous terms, definitions, taxonomic criteria, hierarchical classification structure throughout the entire biophysical system.

2. The Level 3 concept of Vegetation-Soil 'District' be further developed and adopted for trial.

3. Investigate methods of obtaining extra input from vegetation scientists into biophysical inventory by aiming their efforts towards further development and/or adoption of a unified framework for vegetation classification in Canada.

4. Exploration be made whereby basic data-gathering for vegetation and soils be made more extensive in order to identify and explain ecologically significant relationships that may be used to verify and strengthen interpretations.

5. Efforts be made to develop climatic data input into biophysical land classification methodology in order to assist in differentiation to the Vegetation-Soil 'District' Level (Level 3, Table 1).

6. Biophysical team members continue to develop user contacts and maintain some involvement with site-specific problems and studies as a self-training tool (refer to Appendix C).

7. Efforts be made towards upgrading of user skills in understanding inventory methodology, resource analysis, and interpretative results by development and sale of a *Benchmark Training Manual for Biophysical Land Classification Users* (refer to Appendices C and D).

8. Research requirements be established in order of priority and methods of funding be investigated (refer to Appendix D).

9. Methods of providing publication assistance for biophysical projects be examined (refer to Appendix D).

ACKNOWLEDGEMENTS

The survey of Banff and Jasper National Parks is a joint project involving the Canadian Forestry Service, the Soil Research Institute and the Alberta Institute of Pedology.

Parks Canada is supplying the Major funding. Problem areas, data requirements, advice, and assistance have been, and are being received from Dave Day, C. Zinkan, and P. Benson, Western Region, Parks Canada, Calgary, and from Bruce Wilson, Tom Ross, the Warden Service and others in the respective Parks.

The project is receiving whole-heared support from the Biophysical team members, namely:

Alberta Institute of Pedology:
Dr. Russ Well, Pedologist
Bruce D. Walker, Pedologist
Phil Epp, Pedologist
Ian Corns, Vegetation Scientist
Alan Westhaver, Vegetation Technician
Joe Tajek, Soil Technician

Canadian Forestry Service:
Dr. S. Kojima, Vegetation Scientist
Doug Allan, Soil Technician
Jack Dyck, Vegetation Technician

Soil Research Institute:
Dr. G.M. Coen, Pedologist
Dr. Julian Dumanski, Pedologist

The above personnel are all contributors, in one way or another, to reports emanating from the Banff-Jasper Project. The single name on the front of this document is convenient for referencing and queries.

APPENDIX A

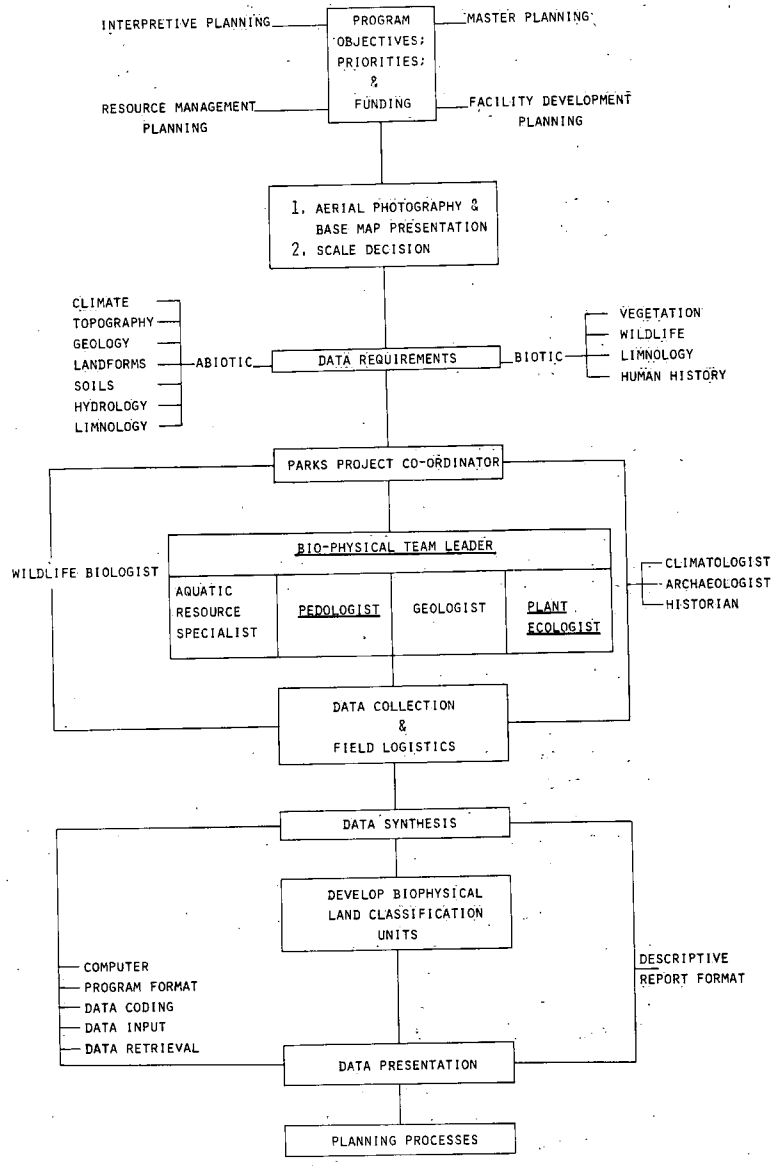
OPERATIONAL METHODOLOGY

Inventory requirements for the overall program (scale 1:50,000) are outlined in the terms of reference (Day *et al.* 1975). The main procedural methodology is given in the Banff-Jasper Bio-Physical Land Inventory Progress Report No. 1:1974-1975 (Holland *et al.* 1975). These two bulky documents have limited availability; their main function is to outline some user requirements, point out the need for a biophysical land classification methodology, relate the biophysical portion of the work to other aspects of the overall Park's inventory program, and provide a documentary reference of project development.

Figure A1 provides an overview of the position of the inventory team within the organizational framework of the entire resource inventory currently in progress in the mountain Parks.

Figure A2 (Holland *et al.* 1975) provides a step-wise view of the inventory procedure.

Figure A1: Biophysical inventory stages (Day et al. 1975)



1. Logistics

The survey requirement is for all of Banff and Jasper, 17518 km^2 (6764 mi^2) at a scale of 1:50,000. The time frame is five years. Logistic problems occur because of:

a) high relief and terrain variability

b) budgetary and Park restraints on use of helicopters

c) slowness of ground access by foot and shortness of survey season

d) limitations in available photography

e) the amount of site-specific work that is requested.

Some of the above restraints have no solutions; however, a serious attempt was made to obtain assistance via new photography.

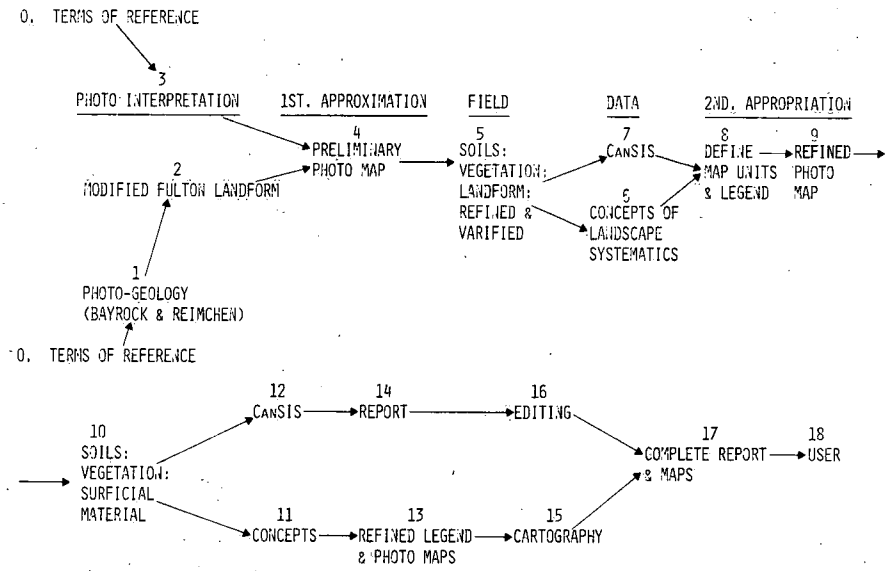
2. Air Photos

The bulk of the air photography is 1972 black and white panchromatic at 1:66,000 and 1:70,000. A number of different flight lines, some of which cross one another, and four different scales (1:15,840; 1:21,120; 1:66,000; and 1:70,000) have been used to-date particularly in the Bow Valley corridor and Lake Louise area. Because of the need for vegetation detail, especially in alpine areas, an attempt was made in 1974, and again in 1975, to obtain full coverage (at 1:50,000) with infrared Ektachrome (film 2443) and infrared Aero neg. (film 2445).

Results of the color photography were disappointing for two reasons:

1. The 1975 flight was flown about July 3, just after a rather vigorous snowstorm, and
2. many of the valley bottom areas are under-exposed while the alpine and other high elevation areas are over-exposed. The project might have benefited from a flight using only one film, but with two cameras and two exposures, one for the valley bottoms and another for the alpine and high elevation areas.

Figure A2: Inventory Methology (Holland et al. *1975)*



3. Team Approach

The concepts of a team approach involve an equal and cooperative input from pedologists and vegetation scientists. The team is split between the two Parks, with major input into Banff in the early stages of the inventory and gradual shift of emphasis to Jasper as the project continues. Improvements in the team approach would involve, firstly, a closer and more continuous contact with the geologists, and secondly, the luxury of enough time to become even more involved with site-specific problems and requirements. The site-specific work in which we have been engaged has been one of the better learning and teaching tools encountered to-date.

The advantages of a team approach are gradually becoming more evident. It broadens the work experience and provides interactions that are most useful in development of methodology. Also, the Banff-Jasper team is small enough that field interactions lead to immediate and systematic integration of geology, vegetation, soil, rather than have each discipline go its own way and then attempt integration at the end of the survey. We feel that generalizations made in the field at the time of ground checking are the best way to integrate two or more disciplines.

4. Field and Laboratory Methods

Soil classification and profile descriptions follow the System of soil Classification for Canada (Canada Soil Survey Committee 1970, 1973, 1974). The project is cooperating with, and contributing to CanSIS, the national soil data bank described by Dumanski and Kloosterman (1973). In addition, we are cooperating with CanSIS personnel in developing vegetation data files. CanSIS is assisting the Canadian Wildlife Service in the development of a wildlife data file.

In situ soils data are recorded in the field and quantitative soils analyses are conducted in the soil survey laboratory at the University of Alberta. Methodology is the same as that used in the soil survey of Waterton Lakes National Park (Holland and Coen, in press).

Plant collections are being made by S.Kojima (1975, 1976) and Ian Corns (1976). Nomenclature is based on "Flora of Alberta" (Moss 1959). All speciments are preserved in the Canadian Forestry Service herbarium, Northern Forest Research Centre, Edmonton. Where necessary, specimens will be provided for Parks' herbaria.

APPENDIX B

RESULTS TO-DATE

Area priorities are determined yearly in consultation with Park's personnel. The areas inventories to-date are the more intensive use areas, and include the Bow Valley corridor and Lake Louise area in Banff and in Jasper, the main Athabasca Valley from about Jasper Lake to Sunwapta Falls (See Figures B1 and B2).

Table B1 provides information on data collected to-date.

Table B1: Vegetation and Soil Observations 1975

	Banff	Jasper
No. of veg. plots	587	103
No. of veg. types	29	53
Vascular plant species	505	400
Vascular plant families	55	48
Vascular plants collected	1000	2000
Bryophytes collected	2000	1500
Soil observation points	558	555
Soil laboratory samples	73	64
In situ soil tests	12	-
Notebook records	65	450
CanSIS soil description sheets:		
Daily forms	475	78
Semi-detailed	1	18
Detailed (sampling sites)	11	9
Area surveyed (mi^2)	600	800
Foot traverse mileage	0	650

The following site-specific work has concerned various members of the biophysical team during 1975:

1. Rehabilitation guidelines for Lakes Edith and Annette area, Jasper (Bull *et al.* 1975).

2. Lake Louise Special Study Area, Banff.

3. Environmental impact study, Mt. Kerkeslin campground, Jasper (Trottier *et al.* 1976).

4. Whistler Mountain rockfall, Jasper.

5. Reclamation planting of old highway between Maligne Canyon and Medicine Lake (about 9 mi), Jasper.

6. Twining of C.P. Railway track in Lake Louise area of Banff National Park.

A separate report and map is being prepared for the Lake Louise area; it is also being used as a pilot test area for CanSIS cartographic file. Interim reports are being prepared for Banff and Jasper, using Itek copies (Alberta Forest Service) of annotated air photos instead of drafted maps.

Some of the results are being utilized almost immediately, or at least within the first year, particularly the site-specific work. Results are also required for the various Planning Units recently established throughout the Parks; eg. the Columbia icefields Planning Unit, the Lake Louise Special Studies Area, etc. To this extent, Parks Planners want our data by September 1 of each year in order that resource analysis and planning functions may be completed by the end of the fiscal year. The complete master planning for the Parks is required at the end of the project.

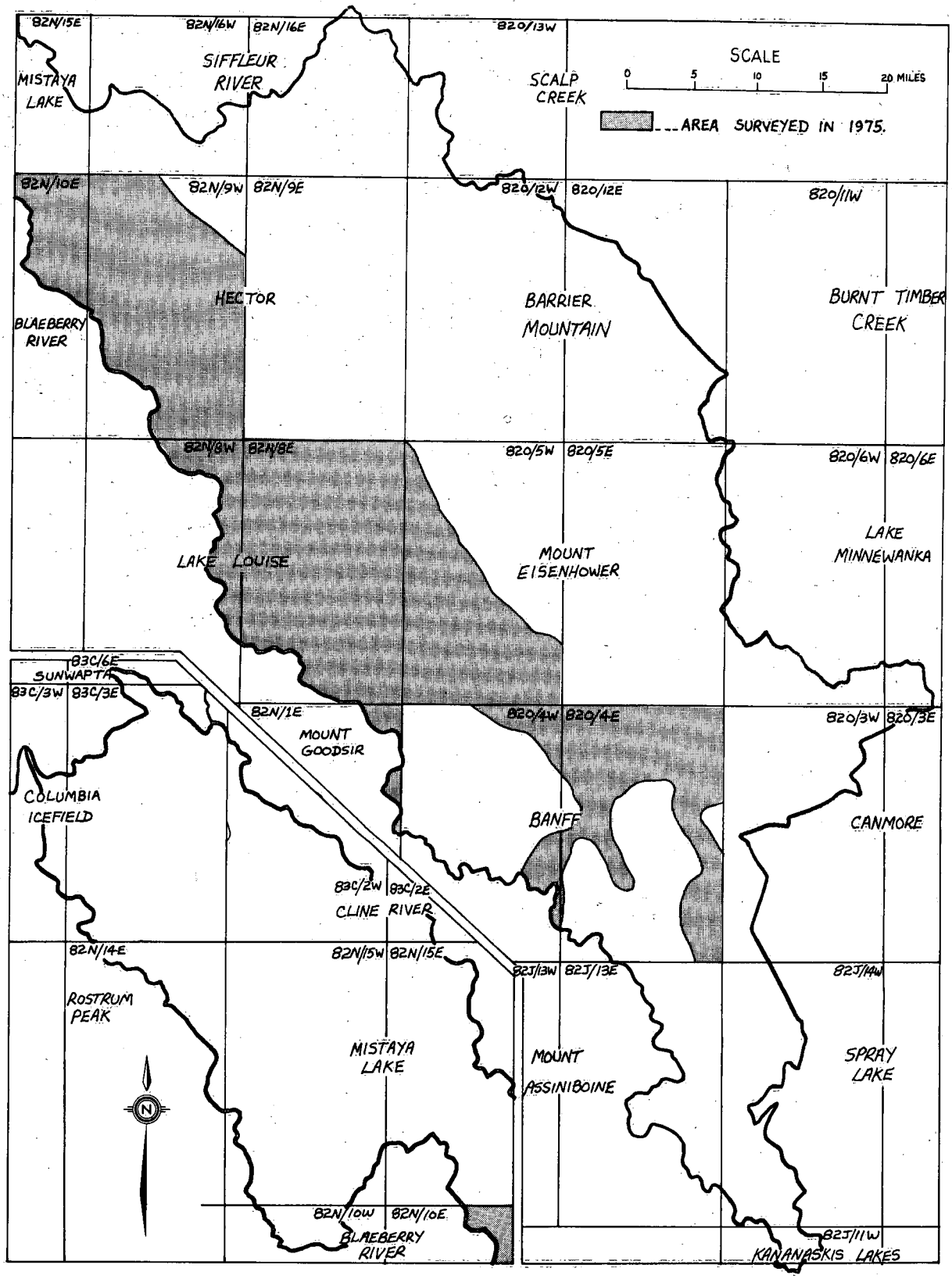


Figure B1: Area surveyed in Banff in 1975

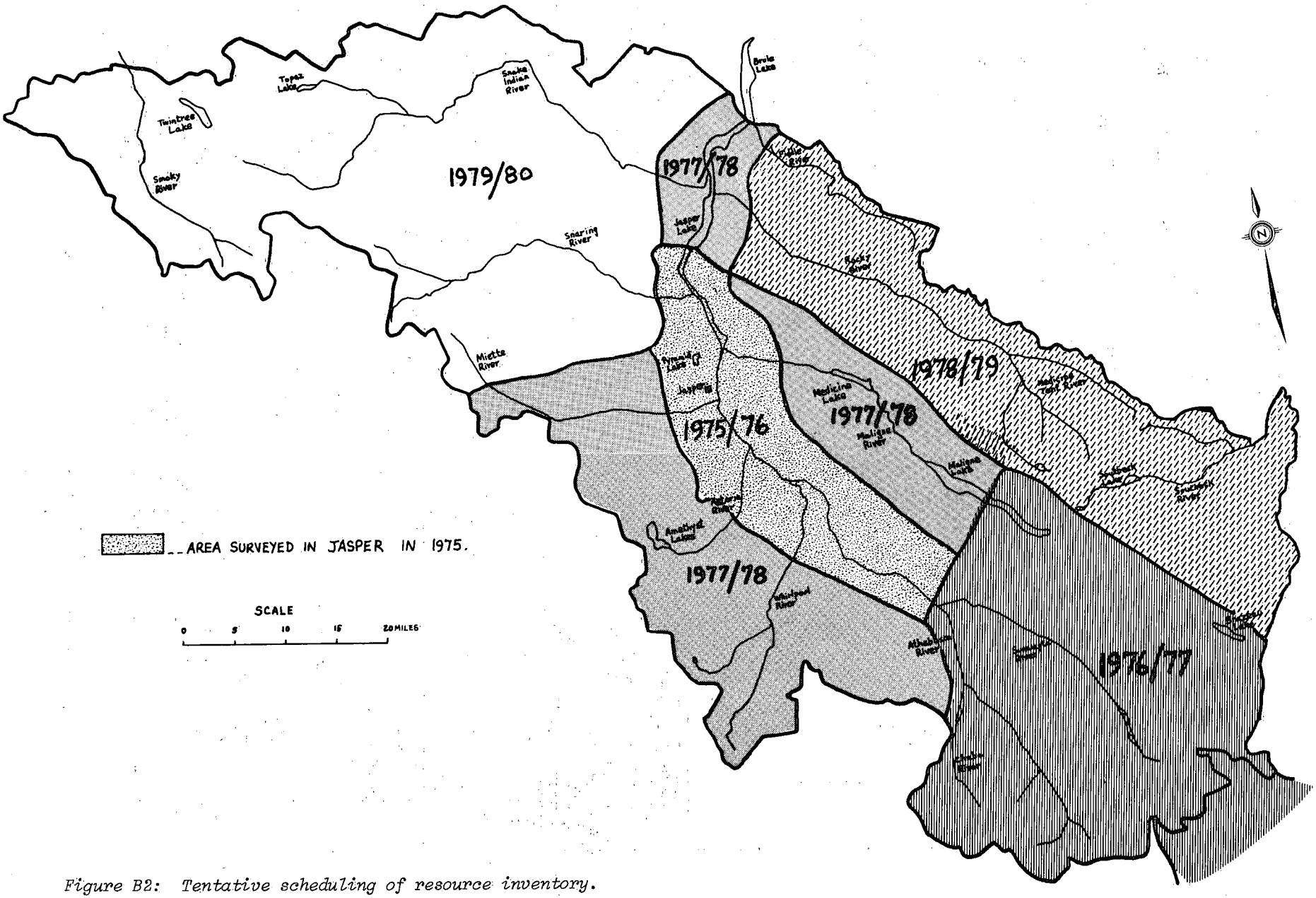


Figure B2: Tentative scheduling of resource inventory.

APPENDIX C

USER CONTACT AND ANTICIPATED APPLICATIONS

USER CONTACT

User contact is excellent; by telephone, personal contact, written reports, seminars, field tours, and workshops. The Park users include various levels of park planners (see top of Fig. A1), park administration, regional administrators, and interpretive personnel. These users are at local and regional Park levels. A number of other users occur within the DOE establishment; eg. fire, regeneration (reclamation and rehabilitation), and Canadian Wildlife Service. Users external to Environment Canada and Parks are consultants, provincial agencies, and various schools. Requests for reports have come from Australia and England. It is interesting to note that the soil map and data used by the master planners during the Public Hearings on Waterton Lakes National Park was displayed before some 45 different agencies in southern Alberta, including Chambers of Commerce, Boards of Trade, University of Lethbridge, etc.

ANTICIPATED APPLICATIONS

The main user, of course, in Parks Canada. Park user requirements are listed in some detail by Day *et al.* (1975). Resource data uses are already being applied; however, a list of uses, including those that are anticipated, may be summarized as follows:

1. Parks want to manage land, or ecological systems; hence the holistic (and integrated) approach to inventory.

2. Master planning of planning units and whole Parks; eg. for conservation zoning, use zoning, potential visitor facility location, resource distribution. In fact, a thorough resource analysis will be required before the master planning can be completed.

3. Resource management and resource operational planning; eg. wildlife management (introduction, protection, reduction censusing), vegetation management (fire protection, regeneration, reclamation and rehabilitation). Resource operational planning becomes very problem-specific, as for example, in grizzly bear management studies.

4. Interpretive themes and coordination, so that people in one Park area receive a unified story during their visit, and so that an interpretation of a certain landform, kind of vegetation, etc. is similar from place to place. Included are audiovisual presentation, exhibits, nature walks, printed pamphlets, or whatever.

5. Visitor services will be using resource data in order to provide wilderness experience to the public while minimizing impact on resources. Areas with high recreational potential for beaches, trails, swimming, canoeing, etc. must be identified. Meanwhile, areas must be identified for potential conflict between use for recreation and preservation. Identification of recource constraints to use must be identified; eg. poorly drained soils, unstable landforms, fragile vegetation, etc. Use of resource data will permit better backcountry management.

6. Site-specific problems and studies; the movement of sand dunes in Jasper, study of caves in Banff, study of intensive use areas such as hotsprings, waterfalls, etc., reclamation and rehabilitation of abandoned roads, campsites, gravel pits, conflicts of use between ungulates and humans, etc. Most of the site-specific uses occur in intensive use areas in the main valley corridor and around townsites and service centres.

7. Upgrading of skills of planners, wardens, naturalists, through familiarization with resource data, maps, air photos. The next five to ten years will see a marked upgrading of skills by many of the Park personnel. It is occurring now.

8. A first-time correlation of wildlife, over large areas, with habitats and other specific environmental situations. The effect on the wildlife approach is already exemplified by the work of Oertli and Stelfox (1975), McGillis *et al.* (1976), and Karasiuk (personal communication).

9. Resource data are expected to be used at public hearings, and by Park administrators, as evidence for decisions on land use assignments or changes, rules etc.

10. Engineering services are also expected to use the resource data.

Other uses, presently occurring and anticipated include:

1. Demonstration of methodology; the Multiple Land Use Section and other sections of the Alberta Forest Service; Alberta Environment, and some people in the Alberta Oil Sands, Environmental Research Program (AOSERP).

2. A teaching tool; seminars to students in forestry and at agricultural schools, inclusion in course work at Hinton Forest Technology school.

3. Reference material; requests by schools, various libraries, and individuals.

Certainly the main uses of demonstrated methodology, interpretative uses, and provision of resource data for planning purposes, could be further developed with more time for external contact.

APPENDIX D

PROBLEM AREAS

A broad range of problems exists with varying degrees of intensity of problem. The following is not necessarily in any particular order of priority, nor does it suggest solutions.

1) Acceptance of biophysical terminology: This, or perhaps the lack of acceptance of terminology by many professionals, including pedologists, causes difficulties in communications. Objections include such items as the use of geographical names for map units. The implication is a weakness in biophysical terminology and definitions, an innate stubbornness in professionals, or a lack of communication between various workers, or a mixture of all three.

2) Differing philosophical approach: There are differences in approach between various professional groups, in particular between the pedologists and vegetation scientists. The pedologist recognizes the mapping problems quite early, develops concepts of modal mapping units, the range and limits of such units, and proceeds with mapping. The vegetation scientist, on the other hand, attempts to sample the entire population before committing any kind of decision. Both approaches have merit, but it does present difficulties with developing and maintaining an integrated biophysical approach.

3) Transfer of knowledge to users: The user audience is extremely variable in its interests and level of training. Thus, we feel strongly about how data are presented; for example, we prefer the use of simple map symbols and an extended legend. However helpful the above techniques may be, they do not solve all of the transfer-of-knowledge problem. We know that the presentation of methodology and resource data must be augmented by interpretative information. Some users possess highly skilled training and require no further assistance with using the inventory data, but others will require very fundamental training before they will be able to use the information. Who is going to provide the necessary training, when, and how?

4) Cartographic problems: Mountainous areas like Banff and Jasper always present problems due to relief and variability of terrain; for example, how does one indicate very small areas of crucial winter range for Rocky Mountain Sheep, when such areas are below the minimum size for symboling, and which virtually disappear when transferred to a planetable map? Also, correction for photographic distortion is still a problem in transfer of data to maps.

The production of generic interpretative maps by CanSIS has not yet become a reality.

One limitation of the present approach of the biophysical land classification is that the prime objective, which is "to differentiate and classify ecologically significant segments of the land surface" (Lacate 1969), cannot always be met. The biophysical approach emphasizes landform base, which enables the rapid delineation of land units. However, landforms may be rather heterogeneous in terms of vegetation, and conversely, one vegetation type may cover several landforms. Thus, segmentation of the land surface on landform alone is undesirable. Mappable (scale dependent), ecologically distinct (as reflected by vegetation) units upon one landform must be separated. We must recognize the difficulty in mapping apparently homogeneous vegetation units which cross landform boundaries. The recognition and mapping of these instances will be dependent upon the mapper's field experience in the area concerned. Where the mapper is not well-familiarized with the vegetation or in areas which have a lower intensity of 'ground truth' information, mapping units will have a stronger landform base - perhaps an unavoidable situation. A problem thus lies in the recognition and mapping of vegetationally uniform, ecologically significant segments of the land surface where landform boundaries are crossed. To partially alleviate this problem, level 3 of the Banff-Jasper Bio-physical Land Classification System (Table 1) will provide improved continuity of vegetation, at a somewhat generalized level, across landform boundaries.

5) Research requirements: The Banff-Jasper project is an operational one, and as such does not have the time or funding for some of the background research that now appears to be desirable. We know, for example, that organic matter content of Park soils varies from virtually zero to highly organic, but we do not know what level of organic matter content is optimal for best results for trail location, campsites, or any area receiving intensive human use. We know that alpine soils are different from subalpine soils, but the extent and significance of such differences are not fully known. Some Park land uses, such as large campgrounds (800 - 1000 acres), can be subjected to rotations (an old agricultural custom), but unique areas such as hotsprings,

waterfalls, etc., cannot be rotated in a management system, yet must be maintained in an aesthetic state for public consumption. Such unique areas require very site-specific research with regard to rehabilitation and/or maintenance of a favourable environment.

Requirements for rehabilitation of sites have every variation imaginable. Much of the vegetative material, rootstocks, and/or seeds, is not available in sufficient quantities for rehabilitation; for example, few vegetative materials are available for rehabilitation of 40-60 acres of bulldozed ski-runs in a Vegetation Type 8 - alpine larch forest in the Upper Subalpine unit. We know much about horticultural stock and our main forest trees, but lack information on many kinds of plants useful to the mountian Parks.

One of the user requirements, mentioned earlier, was for the identification of resource constraints to Park development. Some, such as slope, or impeded soil drainage, are not too difficult to measure, but others are very difficult. For example, the word 'fragility' is frequently used to refer to sites or vegetation types that are sensitive to disturbance. Firstly, it appears as though an overall 'Environmental fragility index' should be developed along the lines of the following formula:

$$\text{Environmental fragility index} = f(\text{soil} + \text{vegetation} + \text{time of use} + \text{intensity of use} + \text{wildlife use})$$

However, such a 'fragility' index cannot be thoroughly developed until we find out what vegetation parameters need to be measured and how.

Measurement of land response to management is another area of concern.

This paper is not a review of research requirements; however, we do know that there is a need for research.

6) Generalization of map units into a hierarchical classification: How is this best accomplished?

7) Logistic problems: These were discussed earlier under "Operational Methodology", Appendix A. The majority of the easily accessible land in the main corridor is surveyed, so the teams are moving into the backcountry areas but have limited helicopter support. There does not appear to be a fully satisfactory solution to the logistics problem.

8) Determination of user needs: The user requirements are gradually becoming known to the biophysical team; production of resource data and interpretation, plus continued user contact will solve these needs as they occur. No doubt some new requirements will appear before the project is completed.

9) Publications: Reports emanating from the project are in limited quantity, usually four or five copies, except for the Lake Louise Study Area (300 maps printed). This problem will be a difficult one to solve unless budgetary constraints are eased.

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BIOPHYSICAL ANALYSIS OF THE YUKON TERRITORY

E.T. Oswald
Canadian Forestry Service
Environment Canada
Victoria, British Columbia

INTRODUCTION

During 1975, a broad-scale biophysical analysis of the Yukon Territory was conducted. The objectives of the project included:

1) to conduct a biophysical survey of the Yukon Territory at a scale of 1:1,000,000
2) to delineate and map broad vegetational, physiographic and climatic zones and major watersheds
3) to assist the Yukon Lands and Forest Service in the use and interpretation of biophysical information and provide for staff training as time permits
4) to develop an information retrieval system capable of storing and displaying data on resource statistics in metric units.

METHODS

The survey was conducted by a three-man crew, consisting of a plant ecologist, a landform-soils man and a technician with some assistance of a second landform-soils man, employing fixed-wing reconnaissance flights followed by helicopter and automobile stops aided by LANDSAT imagery and physiographic maps. Prior to initiation of field work, tentative units were devised by reproducing available physiographic, climatic, geology, forest regions and glacial history data on base-maps at a scale of 1:1,000,000 and overlaying them. With the aid of LANDSAT imagery, boundaries were placed along lines of coincidence of the background data. Climatic and vegetation data were given the most weight.

A pert chart was devised which indicated the orderly flow of tasks and responsibilities to be completed by a specified time. Similarly, a flight schedule was devised for both fixed-wing and helicopter aircraft with approval from the Yukon Lands and Forest Service, who were providing the aircraft in connection with their protection program. Base for the fixed-wing aircraft was Whitehorse; the helicopters were distributed from Watson Lake, Teslin, Ross River, Whitehorse, Carmacks, Haines Junction, Beaver Creek, Dawson City and Mayo.

Meetings were held discussing approach, priorities, responsibilities and product with representatives from Department of Indian and Northern Affairs (Yukon Lands and Forest Service, Arctic Land Use Research Programme, and Water Rights) and Department of Environment (Pacific Forest Research, Lands Directorate and Forest Management Institute).

In the field, reconnaissance flights were made over most of the southern Yukon. Only one flight north of 65°N latitute was possible, during which stop-points for ground checking were noted. Also, general distribution of vegetation types, landforms and wetland surface features were recorded. These flights were followed by helicopter and road stops at as many points as time and logistics allowed.

At each field observation site, data were recorded on landform, vegetation, physical site parameters, soil and occurrence of frozen material according to a previously devised data sheet. Samples were collected of B horizons, (and occasionally of other horizons), at most sites for laboratory analysis. Collections were made of most plant species.

The unit boundaries were modified periodically in light of ground truthing.

Contact with district and regional officers of the Yukon Lands and Forest Service was maintained throughout the field programme. Their assistance was greatly appreciated for discussing situations pertinent to regions and arranging flights and accommodations.

The information retrieval system was developed independent of the survey work. The system was designed to cover the area south of 64°N latitude, essentially the area included in the report of Gairns (1968) on forest resources. It is capable of portraying the available forest statistics and data according to a Universal Transverse Mercator grid matrix and by management regions as defined by the Yukon Lands and Forest Service. For updating

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purposes, the Whitehorse map sheet (105 D) area was used as the primary test area. Ground observations were related to signatures on LANDSAT imagery as portrayed through Image-100 analyses.

RESULTS

Twenty-two ecoregions were recognized for the Yukon Territory (see Map and Legend) through analysis of available information and field survey data. The term *ecoregion* was selected because the units probably do not meet the requirements, in all cases, of Land Regions as defined by Lacate (1969). Rather they are considered to be complexes of Land Regions and Land Districts with a physiographic bias. Primary parameters used for defining the ecoregions were vegetation, climate, landform and frozen soil condition, but time did not permit sufficient ground observations near the boundaries, which necessitated relying on physiographic breaks for placing boundary lines. The northern units were adopted and largely described from the work of Zoltai and Pettapiece (1973) and Hettinger, Janz, and Wein (1973), because no helicopters were available in these areas and roads allowed access to only a very minor portion.

The ecoregions were delineated on a mosaic constructed from LANDSAT imagery at a scale of 1:2,500,000 for publication purposes. The report to accompany the map is near completion.

Six major watershed systems were delineated, although two of these form parts of the Yukon River system and two form part of the Mackenzie River system. Another is the north slope draining directly into the Beaufort Sea, and the other is a small area draining into the Gulf of Alaska.

The information retrieval system is functional, and has been demonstrated, for portraying available forest statistics in metric units south of 64°N latitude. Future expansion of the system to incorporate up-to-date information, fire history and other resource data, to cover the entire Yukon Territory and portray the data according to ecoregions, is anticipated.

DISCUSSION

Approximately 30 man-weeks were spent in the field, working much of the time as two crews. Difficulties in scheduling aircraft, especially helicopter time, were encountered due to weather conditions and incidence of forest fires. Travel distance among bases, along with other commitments for the aircraft, prevented most alterations in flight schedules. The most adversely affected area was the west-central part of the Yukon Territory where several fires occurred. Consequently, few ground observations were made from helicopters in the vicinity of Dawson City, Mayo and Carmacks. Roads in these areas, as elsewhere, mostly follow rivers, and thus do not permit observations of upland sites.

About $11,000 were required for field operations, excluding major equipment, salaries and field aircraft time. Assuming a cost of $250/hr. for fixed wing aircraft and $350/hr. for helicopter time, approximately $23,000 was required for aircraft. The cost of the survey then amounts to about $.16/mi^2 ($.06/km^2). Realistically, the time spent in planning, literature review, pre- and post-data compilation, preparation of data for presentation, and equipment must be considered, bringing the cost up to about $.45/mi^2 ($.18/km^2).

Biophysical mapping of areas the size of the Yukon Territory (207,076 mi^2, 536,327 km^2), and probably considerably smaller areas, should be conducted over a minimum period of two years. This would allow for a familiarization period, for rescheduling flights the second year into areas not surveyed the first year, and for further work in problem areas.

It would also be desirable to have representation of other resource sectors involved with the field work. However, care would be necessary to prevent the field team from becoming too large and cumbersone. Field crews of two members are optimal for logistical reasons, but two or three such crews, each member representing a different discipline, could be set out and periodic coordination meetings arranged. Problems are inevitable with such a procedure, but the final product would be more beneficial.

Contact was maintained throughout the survey with members of the Yukon Lands and Forest Service, one of the principal users. Training programs are anticipated when the final product is made available and as the project continues.

The ecoregion delineation provided a framework within which more detailed analyses of all biophysical sectors, resource research and broad planning and management decisions can be conducted. Integration of these data with the information retrieval system can aid in the definition and interpretation of ecoregions. Utilization of the ecoregion format in this manner will undoubtedly result in boundary modifications so that land regions and land districts can eventually be recognized and delineated.

Future work in the project, beginning in 1976,

will be to concentrate on one ecoregion, initially the Liard River Ecoregion, and delineate land systems. Involvement will be solicited from the Lands, Water and Wildlife sectors so that a broader resource data base can be established.

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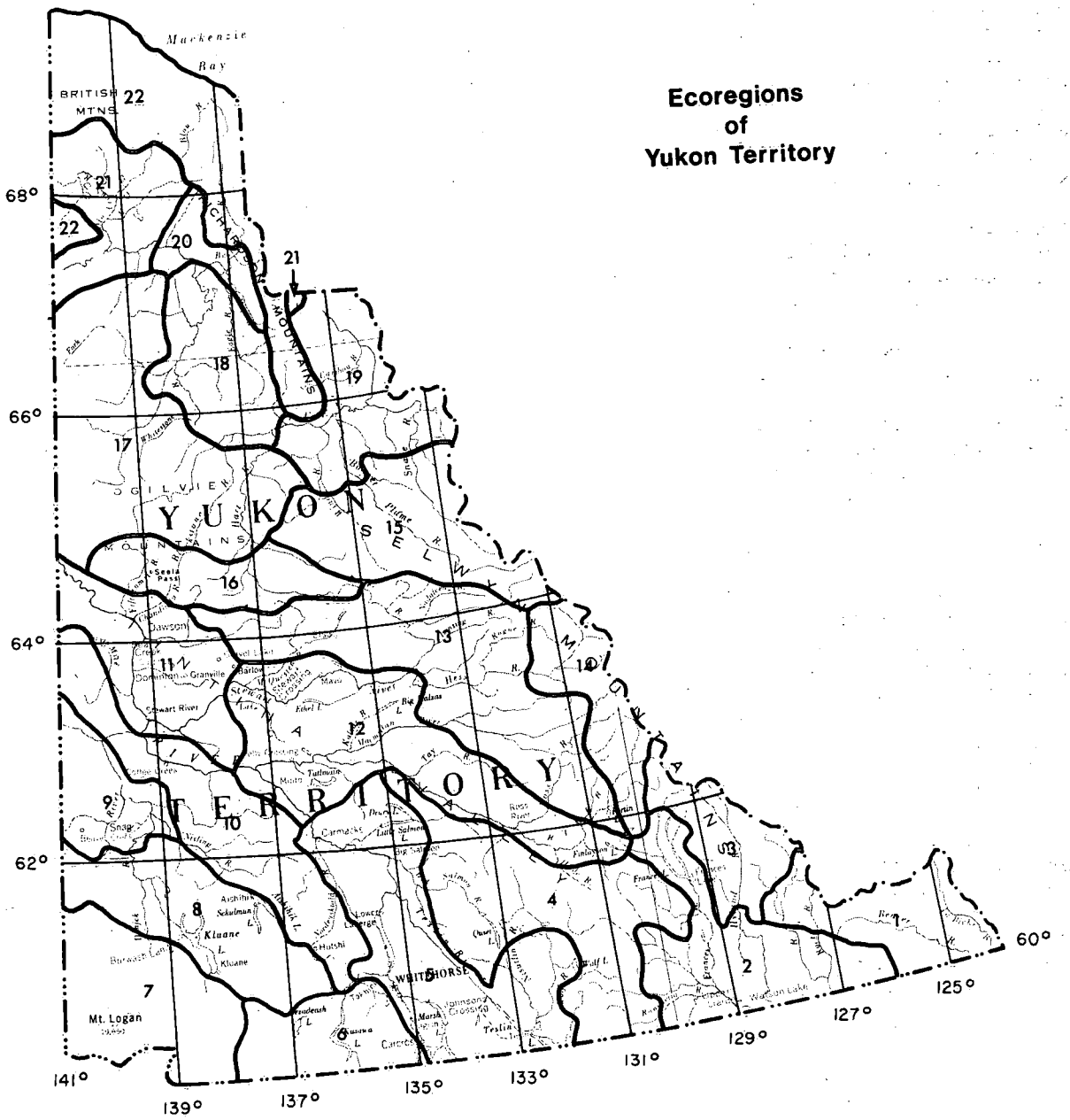


LEGEND OF ECOREGIONS OF THE YUKON TERRITORY

1. Beaver River: 3% of Yukon - 16,350 km^2 (6,310 mi^2). Mostly forested with open black and white spruce and lodgepole pine; lichens prominent on well-drained sites, moss on wet sites; black spruce and larch in bogs, alpine fir and shrub birch-willow-lichen near treeline; treeline at 1200-1350 m; pptn and temp moderate.

2. Liard River: 5% of Yukon - 24,670 km^2 (9,520 mi^2). Forested, with closed and nearly closed stands of black and white spruce and lodgepole pine; understory mostly moss with or without shrubs and forbs; black spruce and larch in bogs, aspen on dry sites, white spruce and balsam poplar on flood plains, alpine fire in subalpine; treeline at 1500 m; pptn and temp moderate.

3. Logan Mountains: 2% of Yukon - 13,190 km^2 (5,090 mi^2). Mostly alpine treeless tundra of shrub birch-willow-sedge, open black and white spruce-lichen in valleys and lower slopes, aspen and lodgepole pine on warmer sites, alpine fir and shrub birch-willow in subalpine; treeline at 1350-1500 m; pptn high, temp moderate.

4. Pelly Mountains: 7% of Yukon - 36,140 km^2 (13,950 mi^2). High elevation treeless tundra common, white and black spruce-moss at lower elevations, white spruce and lodgepole pine on warmer sites, alpine fir and shrub birch-willow in subalpine, sedge tussock in alpine wetlands; treeline at 1350-1500 m; pptn moderately high, temp moderate.

5. Lake Laberge: 7% of Yukon - 37,860 km^2 (14,620 mi^2). Open white spruce and lodgepole pine with moss understory common, black and white spruce on cool sites, aspen or sagebrush-grassland on drier sites, alpine fir present, larch absent; treeline at 1200-1350 m; pptn low, temp moderately warm.

6. Coast Mountains: 3% of Yukon - 15,200 km^2 (5,870 mi^2). Alpine tundra prominent, white spruce-soapberry-moss at lower elevations, white spruce-aspen on warmer sites, shrub birch-willow in subalpine, alpine fir and lodgepole pine absent, black spruce scarce; treeline at 1050-1200 m; pptn high, temp moderate.

7. St. Elias Mountains: 4% of Yukon - 22,370 km^2 (8,640 mi^2). High elevation ice and snow fields, white spruce-moss at lower elevations, black spruce bog and shrub birch-willows on cooler sites, aspen and white spruce on warmer sites; treeline at 1050 m; pptn high, temp cold.

8. Ruby Range: 5% of Yukon - 24,670 km^2 (9,520 mi^2). Open white and black spruce-moss common, black spruce bogs or white birch-alder on cooler sites, white spruce-aspen-moss-forb on warmer sites, lodgepole pine rare; treeline at 1200 m; pptn low, temp moderately cold.

9. Wellesley Lake: 2% of Yukon - 10,900 km^2 (4,210 mi^2). Low elevation open bog, black spruce-*Sphagnum* common, black spruce bog and bog-fen complex on cool moist sites, white spruce-white birch-aspen-moss-alder on warm dry sites, treeline at 1050 m; pptn low, temp moderately cold.

10. Dawson Range: 6% of Yukon - 29,540 km^2 (11,410 mi^2). Mostly treeless, shrub birch-willow common, white spruce on warm dry sites, very open white and black spruce-willow-shrub birch at lower elevations, sedge tussock (black spruce) on cool moist sites; treeline at 1200 m; pptn moderately low, temp moderately cold.

11. Klondike River: 4% of Yukon - 21,510 km^2 (8,310 mi^2). Black spruce and white birch-*Ledum*-*Sphagnum* is common, aspen and white spruce on drier sites with balsam poplar on flood plains, lodgepole pine scarce; treeline at 1050 m; pptn moderate, temp moderately cold.

12. Pelly River: 7% of Yukon - 45,150 km^2 (17,640 mi^2). White and black spruce-shrub-moss is common, black spruce bog in moist cool lowlands, aspen (white spruce) or sagebrush-grassland on warm, dry sites, lodgepole pine common, alpine fir sparse; treeline at 1350-1500 m; pptn low, temp moderately cold.

13. Mayo Lake Ross River: 9% of Yukon - 45,600 km^2 (17,610 mi^2). Open black spruce-moss (lichen) common, white spruce on warm dry sites, black spruce bog-fen in lowlands, aspen, white birch and lodgepole pine sparse, larch absent, alpine fir in subalpine; treeline at 1350-1500 m; pptn moderate, temp moderately cold.

14. Itsi Range: 3% of Yukon - 15,200 km^2 (5,870 mi^2). High elevation tundra, open black and white spruce-lichen on lower slopes, shrub birch-willow common, bog-fen in valleys, alpine fir in subalpine but sparse; treeline at 1350-1500 m; pptn high, temp moderately cold.

15. Wernecke Mountains: 5% of Yukon - 28,390 km^2 (10,960 mi^2). High elevation tundra, black and white spruce-moss (lichen) on protected warmer sites, shrub birch-willow is common, bog-fen complexes, sedge tussock, in wetland; treeline at 1200 m; pptn high, temp moderately cold.

16. South Ogilvie Mountains: 3% of Yukon - 13,900 km^2 (5,430 mi^2). High elevation treeless tundra, sedge tussock bogs in valleys, and shrub birch-willow on slopes, open black and white spruce on protected warm sites; treeline at 1050 m; pptn moderate, temp moderately cold.

17. North Ogilvie Mountains: 9% of Yukon - 47,040 km^2 (18,160 mi^2). Moderate elevation treeless tundra with sedge tussock or shrub birch-willow, white spruce on protected sites, scattered black spruce in low elevation bogs; treeline at 900 m; pptn moderate, temp cold.

18. Eagle Plain: 3% of Yukon - 17,500 km^2 (6,760 mi^2). Very open black spruce-larch-sedge tussock common, white spruce and white birch on well-drained sites, bog-fen common in lowlands; treeline at 750 m; pptn low, temp cold.

19. Peel River: 4% of Yukon - 20,940 km^2 (8,080 mi^2). Black spruce-lichen common, black spruce-larch-sedge tussock on wetter sites, white spruce-white birch on well-drained sites; treeline at 600-750 m; pptn low, temp moderately cold.

20. Berry Creek: 1% of Yukon - 5,450 km^2 (2,100 mi^2). Black spruce-sedge tussock is common, black spruce-lichen and shrub-lichen on cool dry sites, white spruce on warm sites, larch scarce; treeline at 450 m; pptn low, temp cold.

21. Old Crow Basin: 3% of Yukon - 16,630 km^2 (6,410 mi^2). Open white and black spruce-lichen (moss) common, black spruce-lichen or *Sphagnum* on cooler sites, white spruce-lichen (alder) on warmer sites, larch sparse; treeline at 300-450 m; pptn low, temp cold.

22. Northern Mountains and Coastal Plain: 6% of Yukon - 33,340 km^2 (12,730 mi^2). Mostly treeless tussock tundra, scattered black and white spruce on protected sites, shrub heath on many warmer sites; treeline at 0-300 m; pptn low, temp cold.

THE USE OF BIOPHYSICAL ANALYSIS IN LAND USE PLANNING*

P.H. Rennick
Land Use Assignment Section
Technical Division
Alberta Energy and Natural Resources
Edmonton, Alberta

ABSTRACT

This paper describes the land use planning process carried out by the interdepartmental Land Use Assignment Committee which advises the Deputy Minister, Alberta Energy and Natural Resources on the allocation of public lands. Biophysical land classification and use potential ratings play a significant part in this planning process together with public land management agency concerns and present land commitments.

The author identifies areas where improvement is required in the planning process as well as the biophysical methodology.

RÉSUMÉ

Le présent document expose le processus de planification de l'utilisation des terres réalisé par le Comité interministériel des terres, qui conseille le ministre albertain de l'Energie et des Ressources Naturelles quant à l'affectation des terres publiques. La classification biophysique du territoire et les cotes du potentiel d'utilisation jouent un rôle important dans ce processus de planification, de même que les intérêts des organismes de gestion des terres publiques et les utilisations actuelles des terres.

L'auteur souligne les aspects à améliorer dans le processus de planification et la méthodologie biophysiques.

INTRODUCTION

The very real statement that "land is limited but the needs and wants of people are multiplying" is also relevant for Alberta, particularly along the fringe areas of settlement. It could be restated in the vernacular that "quality land is limited and the demands that people are putting on this scarce land resource are unreal".

Alberta recognized this problem in 1948 when an Order-in-Council was passed which identified several major land use concerns. The following points are paraphrased from the 1948 Order-in-Council:

1. It became essential to establish the orderly allocation of lands according to their best use, based on a physical land classification.

2. It became increasingly clear that agricultural settlement should be restricted to lands that were classified as suitable for agricultural development to provide sufficient sustenance for a settler and his family.

3. Since the cost of social services for remote and scattered settlement became increasingly expensive, the government found it necessary to prevent random settlement and squatting in isolated areas.

4. It was recognized that many lands in Alberta had the potential to sustain a valuable forest cover; thus, it was found necessary to prevent land settlement in these areas to allow for the orderly management of forest lands.

Thus, to control land settlement, and for land management purposes, Alberta was divided into three broad areas as follows:

*This paper explains the application of biophysical land analysis carried out by the Land Use Assignment Section of Alberta Energy and Natural Resources (Alta. E&NR) for the Interdepartmental Land Use Assignment Committee (LUAC). Mr. Rennick is Head of the Section.

Proc. 1st Meeting Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ont.

(a) Green Area - This area comprises lands withdrawn from settlement. Any disposition of the right to use the surface of these public lands is for commercial or industrial purposes, or for such other uses as the Minister may consider to be in the public interest.

Today, much of the Green Area is managed for multiple uses such as timber production, fish and wildlife production, and limited domestic grazing, as well as providing opportunities for outdoor recreation.

The sustaining of a quality environment is a key concern in the area and this is provided for by such means as the *ground rules* implemented by the Alberta Forest Service to ensure watershed protection and to reduce soil erosion during and after timber harvesting operations (Forest Service, Alberta Energy and Natural Resources, 1975).

(b) White Area - This is the settled part of the province. Although much of the land in the area is managed for food production under private ownership, significant portions of public land remain which are managed for watershed protection, outdoor recreation, fish and wildlife production, timber production and other purposes.

(c) Yellow Area - This is where most of the land settlement action is taking place . It is also the area where user conflicts are the most intense. Dispositions such as Homestead Sales for agricultural purposes leading to title may be granted. The Yellow Area will utlimately become part of the White Area, although it will contain public lands reserved for the various public requirements noted in the White Area description.

Figure 1 illustrates the current land settlement pattern in Alberta.

Much credit is due to the authors of the 1948 'Green Area' concept. Although it is not a land 'freeze', by restricting settlement to suitable lands, it allows the government to plan for the optimum use of public land.

The same concerns for efficient and effective land use exist today as they did in 1948. They have merely magnified since more people are exerting greater demands on a limited land resource.

Today, we do, however, have a greater awareness and understanding than we did in 1948, of the ecological factors and the importance that they have in the land use planning process.

This early awareness of land use problems together with the initiation during the 1960's of the ecological approach to land analysis has brought us to our present means of advising the Deputy Minister on the preferred use of public lands.

OUR MEANS FOR LAND ALLOCATION

Resource planning should begin by defining the problem to be resolved. Once this is achieved and the problem understood by the participants, the means for arriving at effective solutions become clear.

As stated above, one of the problems to be solved by the Alberta Department of Energy and Natural Resources (Alta. E&NR) is to achieve within a quality environment the optimum integrated use of public land. This means that for such land uses as timber production, fish and wildlife production, domestic grazing and outdoor recreation, the Alta. E&NR must endeavour to allocate land resources to achieve a compatible mix of these uses.

As we all know, this is indeed a difficult task, due to such factors as the physical limitations of the land, the present land commitments, and the uncertainty of future needs. It is further complicated by the need to provide all of these uses and at the same time maintain a quality environment.

The means for solving this problem, although not crystal clear, involve at least two components. Firstly, we require relevent information on which to base decisions. Secondly, we need to bring together the affected people so that effective solutions may be found.

In 1969, the Alta. E&NR (formerly the Department of Lands and Forests) tackled the second-mentioned component by establishing the interdepartmental and interdisciplinary Land Use Assignment Committee (LUAC) which brings together the appropriate public land managers. We are not so naive to suggest that the LUAC is the ideal structure to solve the problem. However, it does allow for a coordinated approach and provides the means for advising the Minister of Alta. E&NR on the preferred uses of public land.

The first-mentioned component, that of providing relevant information, was provided in part by the establishment of the Land Use Assignment Section, presently located in the Technical Division of Alta. E&NR. The section is made up of an interdisciplinary group of resource specialists who describe, classify, and illustrate for the LUAC the ecological character and use potential of the natural land systems

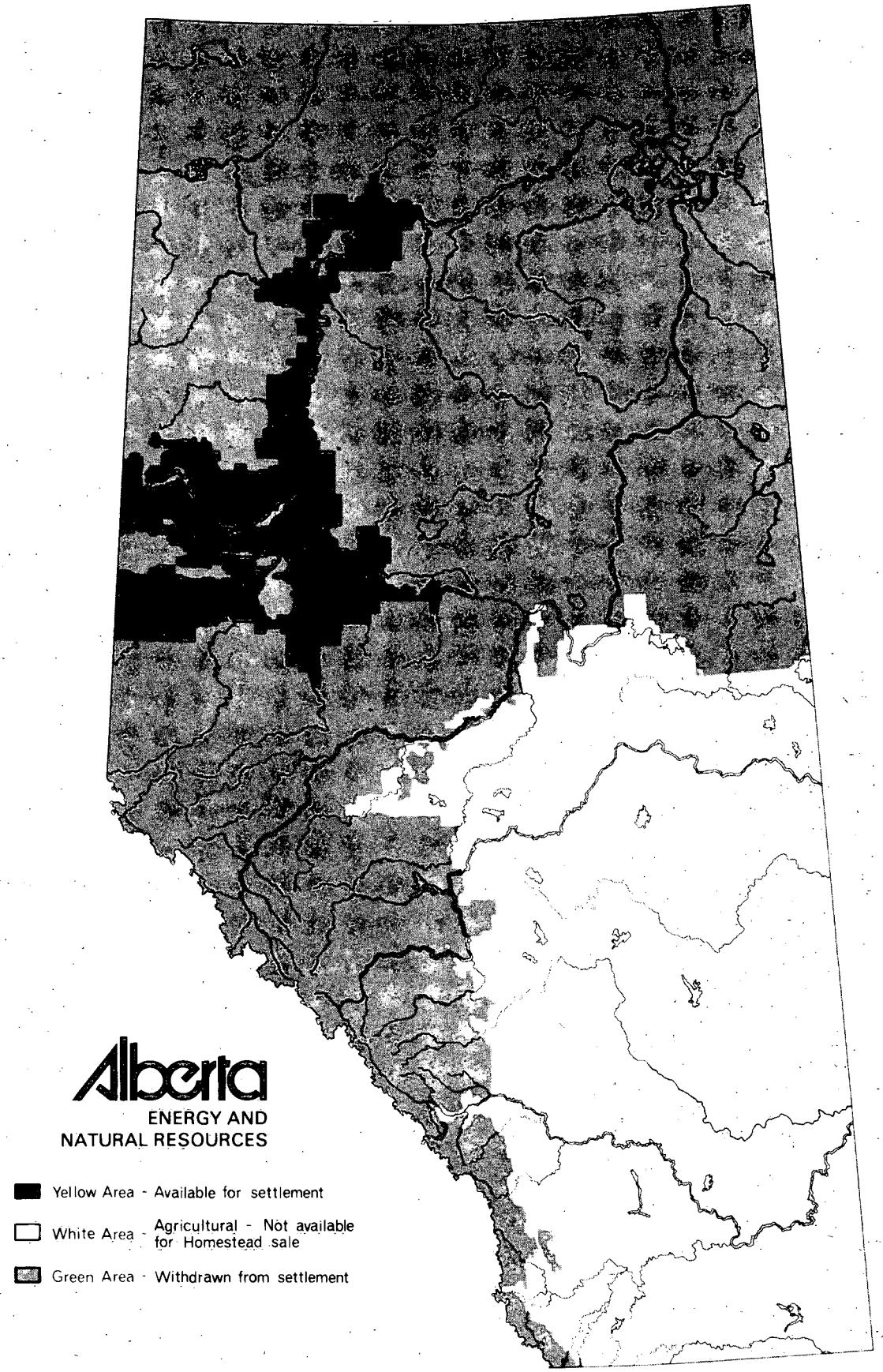

Alberta
ENERGY AND
NATURAL RESOURCES
Yellow Area - Available for settlement
White Area - Agricultural - Not available for Homestead sale
Green Area - Withdrawn from settlement

Figure 1

in the province.

We now then have the means of solving the problems through the consideration of relevant information by a group of involved managers.

ENABLING LEGISLATION AND CURRENT STUDIES

The classification of public lands in Alberta and the designation of their use is the responsibility of the Minister of Alta. E&NR as authorized by Section 12 of the Public Lands Act. The Minister also represents the Crown as the owner and steward of these public lands on behalf of the people of the Province. It is the intent of the Government to ensure that the present and future generations of Albertans obtain optimum benefits from these lands.

The purpose of the LUAC, as stated above, is to advise the Deputy Minister of Alta. E&NR on the preferred uses for public land, including the settlement/non-settlement boundary. Although the main concern is for public lands, the adjacent patented lands are also studied to provide a better perspective.

Figure 2 illustrates the studies currently in progress and those completed by the LUAC since 1969. By comparing Figure 1 and 2, it will be observed that, for the most part, the study areas are located along the interface between settlement and non-settlement lands. For it is here that difficult land use decisions are required to reduce user conflicts and to assure that integrated land use takes place.

THE STRUCTURE

The LUAC is supported by the Technical Division[1] of Alta. E&NR which provides the Chairman, the technical advisor and the secretary, as well as biophysical analysis and mapping services.

The Committee is made up of eight members, one from each of the following Provincial Government agencies: Forestry Division, Alta. E&NR; Lands Division, Alta. E&NR; Energy Resources Sector, Alta. E&NR; Parks Division, Alta. Recreation, Parks, and Wildlife; Fish and Wildlife Division, Alta. Recreation, Parks, and Wildlife; Resource Economics Branch, Alta. Agriculture; Land Conservation and Reclamation Division, Alta. Environment; and Planning Services Division, Alta. Municipal Affairs.

Figure 3 illustrates the relationship between the LUAC and the Technical Division. The solid lines indicate the formal communication channels between the LUAC and the Chairman as well as between the administrative Heads and the Director.

The broken lines indicate other approved linkages such as between the Technical Advisor and the Committee, and the Secretary and the Committee.

The Head of the Section and his professional staff also have access to management agency specialists via their representative on the LUAC.

THE PLANNING PROCESS

The planning process carried out by the LUAC is summarized in Figure 4 and may be described as follows:

Problem Definition - Study requests originate from concerned Provincial Government agencies as well as local citizen groups. Each concern is described, and the area is selected for study according to a priority dependent on the magnitude of the problem. Once an area is selected, the LUAC is requested to undertake a study and to submit recommendations to the Deputy Minister of Alta. E&NR.

Data Collection - Although various kinds of data are collected during all segments of the planning process, the major biophysical data are collected and analyzed during this segment by the Land Use Assignment Section of Energy and Natural Resources. Staff members of this Section prepare a report of the study area with the emphasis on biophysical description, and present land commitments as well as an indication of the productive potential of the land for various uses.

Soon after completion of the biophysical study, each Committee member examines the area in light of the biophysical report and prepares a written report providing additional data related to their particular management interest. At the same time, the particular Regional Planning Commission staff are given an opportunity to comment on the socioeconomic factors.

Policy Consideration - Based on the above data and analysis, the LUAC, as an interdisciplinary and interdepartmental group, examines the proposed land uses for the area and endeavours to resolve conflicts. The Committee then agrees

1. A reorganization of Alta. E&NR is presently underway, and this structure may not exist by the time this article is published.

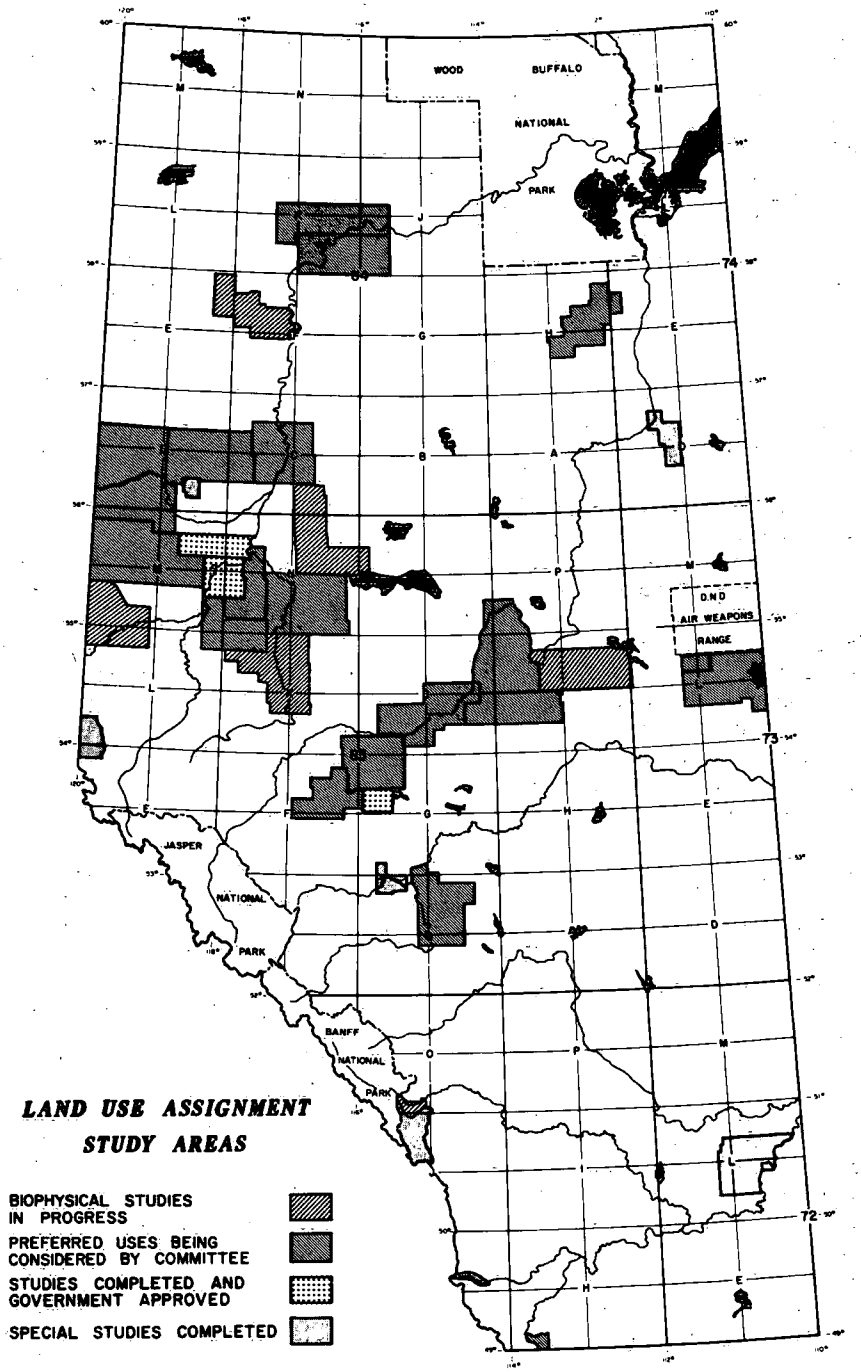
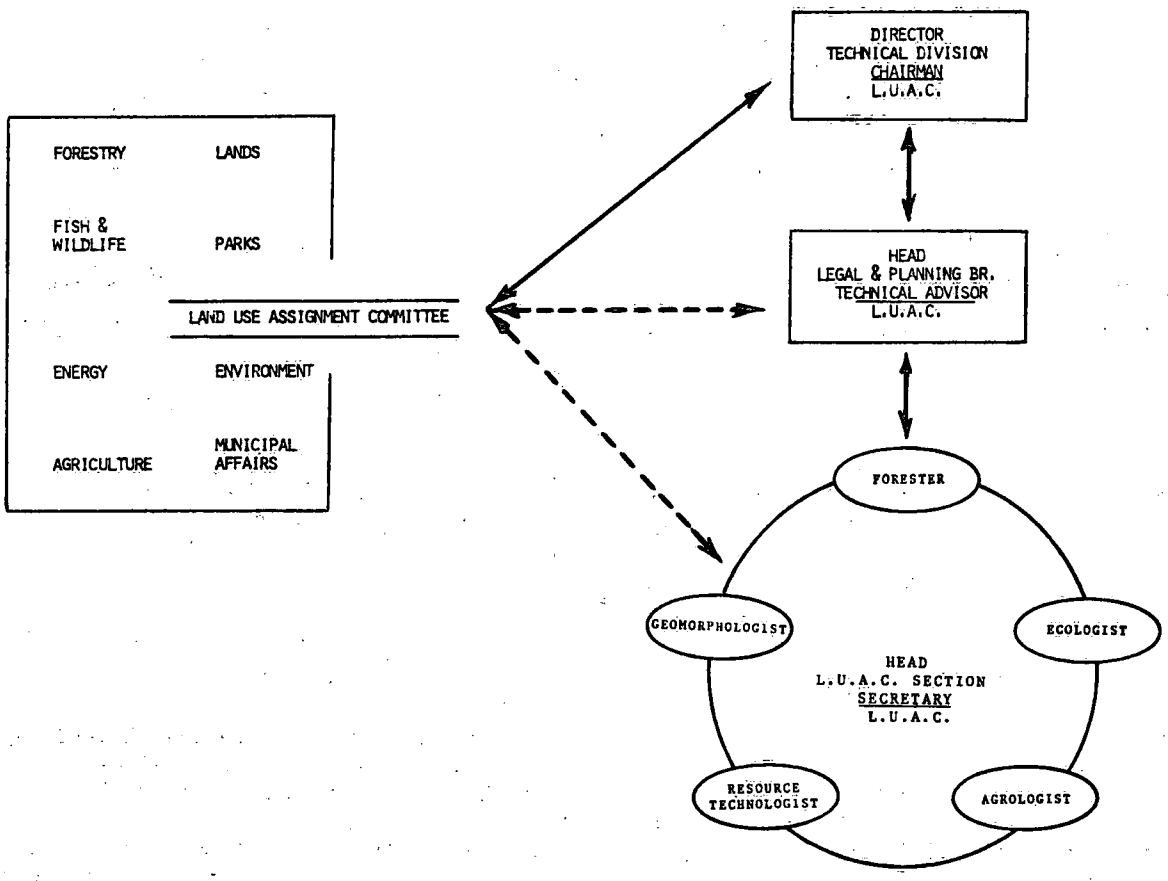

WOOD BUFFALO
NATIONAL
PARK
D.N.D
AIR WEAPONS
RANGE
JASPER
NATIONAL
PARK
BANFF
NATIONAL
PARK
74
73
72
LAND USE ASSIGNMENT
STUDY AREAS
BIOPHYSICAL STUDIES IN PROGRESS
PREFERRED USES BEING CONSIDERED BY COMMITTEE
STUDIES COMPLETED AND GOVERNMENT APPROVED
SPECIAL STUDIES COMPLETED

Figure 2

Figure 3: Relationship Between the Land Use Assignment Committee (LUAC) and the Technical Division, Alberta Energy and Natural Resources.



on a mix of uses compatible with the biophysical analysis and the expressed management concerns.

Consultation - The draft plan is then presented to the concerned parties, such as the local managers, the local Agricultural Development Committee, the Agricultural Service Board and the Regional Planning Commission for their information and to provide an opportunity for them to express their concerns. A method for formal public involvement has not been established, although the LUAC will listen to any public group which asks to be involved.

All of the views expressed during the consultation segment are then considered. The draft may be revised accordingly, and it is delivered to the interdepartmental Conservation and Utilization Committee for their review and comment as to its effect on relevant government policies.

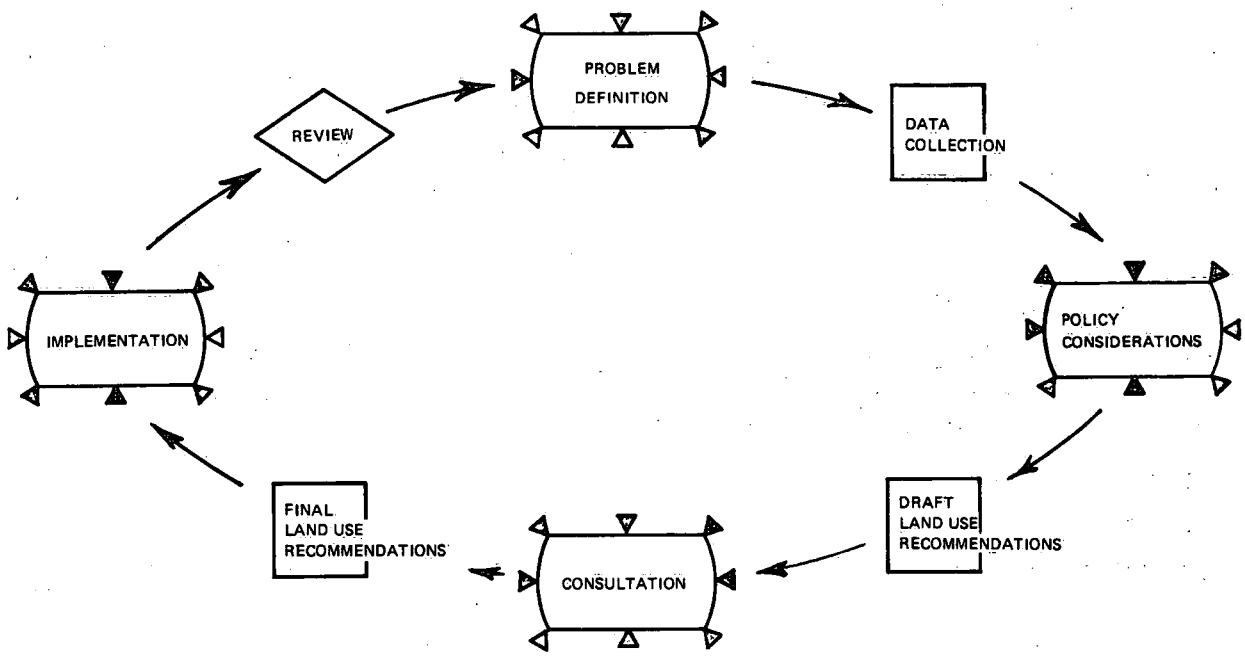
Final Land Use Recommendations - On the basis of the above consultation, the final recommendations are prepared and delivered to the Deputy Minister of Alta. E&NR for his approval.

Implementation - The recommended preferred uses serve to give direction and guidance to the affected Departments for land disposition and land management. The plan also provides a basis for more detailed local management plans.

The information collected and the policies established during this planning process may also be used to guide Regional Planning Commissions and Improvement Districts in the preparation of regional plans.

An important part of implementation is the transferring of approved land use plans into

Figure 4: The Land Use Assignment Committee Planning Process



the Township Registry administered by Lands Division, Alta. E&NR. The natural land unit boundaries are squared off according to the closest legal survey (quarter section) boundary, and the recommended uses for each quarter section are noted.

A four-digit coding system is used to enter all notations and land use reservations in an effort to assure that optimum land allocation takes place.

Review - Each study area is to be reexamined every five years for possible changes in local or regional situations and in light of any new government policies. Preferred uses may then be modified or totally revised to reflect the new circumstances.

THE BIOPHYSICAL METHOD

Based on a four-level planning hierarchy (i.e. Provincial, Regional, Local, and Operational), the level of detail presently carried out by the LUAC approximates a Local land use plan. The published map scale is 1:126,720 which restricts the biophysical detail to the land system level. However, much of the preliminary analysis, including the photo interpretation and the field observations, is carried out at 1:31,600 to better understand the ecological character of the area. Details on the preliminary maps are then lumped together to form land systems and final maps are reduced to the published scale of 1:126,720.

The biophysical details noted during the analysis are not lost since they are noted in the written description of each land system. They play an important role in the use potential ratings.

The biophysical method employed involves dividing and classifying the landscape into definable ecological land regions, land districts and land systems based on distinctive patterns of relief, geology, geomorphology, landforms, characteristic vegetation and climatic factors as defined by Lacate (1969) and Jurdant (1975).

Existing information such as soil surveys, bedrock geology, surficial geology, and climatic data is collected and synthesized for biophysical relevance.

Considerable emphasis is given to air photo interpretation to delineate distinctive biophysical patterns which reflect the ecological nature of the area. This is achieved by careful observation of landform, slope, drainage and vegetative patterns assisted by knowledge of soils and parent materials.

To illustrate the biophysical method, let us assume that we are dealing with a large expanse of landscape defined as a *land district* (Lacate, 1969). A closer examination of this land district through aerial photograph interpretation and field observation reveals that it is, in fact, composed of a number of separate *land systems* (Lacate, 1969), each system having its own pattern of landform, soils, drainage, and associated natural vegetation.

Due to its inherent physical makeup, each land system has a measurable ability for growing biotic crops and for providing opportunities for outdoor recreation. For instance, river terraces and sand dunes, two commonly ocurring systems, have different abilities to sustain habitat for moose or to provide opportunities for outdoor recreation.

Each land system identified is described including the following basic information: physiography and soils - including landform, slopes and drainage pattern, soil texture, soil moisture, soil order and association; natural cover - the major tree species, indicator shrubs and characteristic lesser vegetation; present use - indications of the present cultural practices, amount of cleared land, and management activities; use potential ratings (Hills *et al.*, 1970) - for agriculture, forestry, ungulates, recreation and waterfowl, including a general discussion of the potential for each use.

At the same time, the sensitivity of the landscape to development and surface disturbances is indicated such as observations of soil stability, hazard lands, and important headwater areas.

Once the natural land systems are studied, mapped and described, a report is prepared called "Biophysical Analysis and Evaluation of Capability". The report also includes current information on land dispositions such as patents, leases, licences, agreements and other present land commitments since these are very important considerations in any planning process. The report is then delivered to the LUAC for their information and as a base for the remainder of the planning process.

A comment on the 'use potential rate' methodology is warranted. During the biophysical study, the existing Canada Land Inventory (CLI) capability ratings are used. However, they are 'proportioned' according to Hills' (1970) method to fit the biophysical land system base and they are checked in the field for accuracy. Where questions arise as to a particular rating, the appropriate resource specialist is contacted for verification. Every effort is made to provide realistic use potential ratings for each land system. It is indeed unfortunate that a common biophysical base was not used by the various agencies who carried out the CLI programme. It is recognized that Forestry and Agriculture did use similar landform information.

THE PLANNING PRODUCT

Using the land system map[2] as a base, the LUAC then decides on the preferred uses for each land system based on the biophysical analysis, management agency concerns, and present land commitments. The recommended land uses are symbolized according to the land use codes illustrated in Figure 5.

Codes that appear in the numerator indicate that the uses may take place throughout the land system. Codes that appear in the denominator indicate that the uses may take place in that part of the land system biophysically suitable for the activity in consideration for the other uses noted.

When the LUAC completes the land use coding exercise and reaches consensus on the uses, an agreement is prepared advising the Deputy Minister on preferred land uses for the area.

This document contains the purpose of the study, a brief recap of the physical character of the area, the conclusions, and recommendations of the LUAC including the recommended uses for each coded land unit[3]. Sensitive areas and nonconforming dispositions are also included as additional information for the concerned managers.

Included with the recommendations are four maps which summarize the preferred uses as follows:

1. Land Use Coding Map showing the preferred uses for each land unit.

2. Permitted Agricultural Use Map showing land units where agricultural practices are allowed as well as the proposed settlement/non-settlement boundary.

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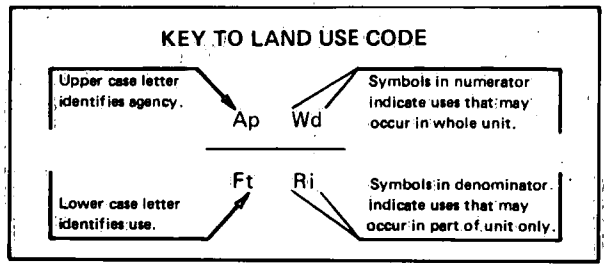
2. We call it the Land District Map since it is colour-separated in published form by land districts.

3. The separations on this map can no longer be called 'Land Systems' since land systems given the same codes are joined together into larger land units where the same uses are allowed.

Figure 5



BLUEBERRY MOUNTAIN

LAND USE CODING MAP

WEST OF THE SIXTH MERIDIAN

SCALE: ONE INCH EQUALS TWO MILES 1: 126,720

Miles 1 ½ 0 1 2 3 4 5 Mi.

Kilometres 1 ½ 0 1 2 3 4 5 6 7 8 km.

Universal Transverse Mercator Projection

ENVIRONMENT

Eh HEADWATERLANDS
Eb RIVERBREAKS
Ew WATERCOURSES
Es SHORELANDS
Er RECHARGE AREA
Ed DISCHARGE AREA
Ef FLOOD PLAIN

AGRICULTURE

Aa ARABLE
Ap IMPROVED GRAZING
Ag UNIMPROVED GRAZING

FORESTRY

Ft TIMBER
Fa WOODLOT
Fw WATERSHED
Fe EROSION CONTROL

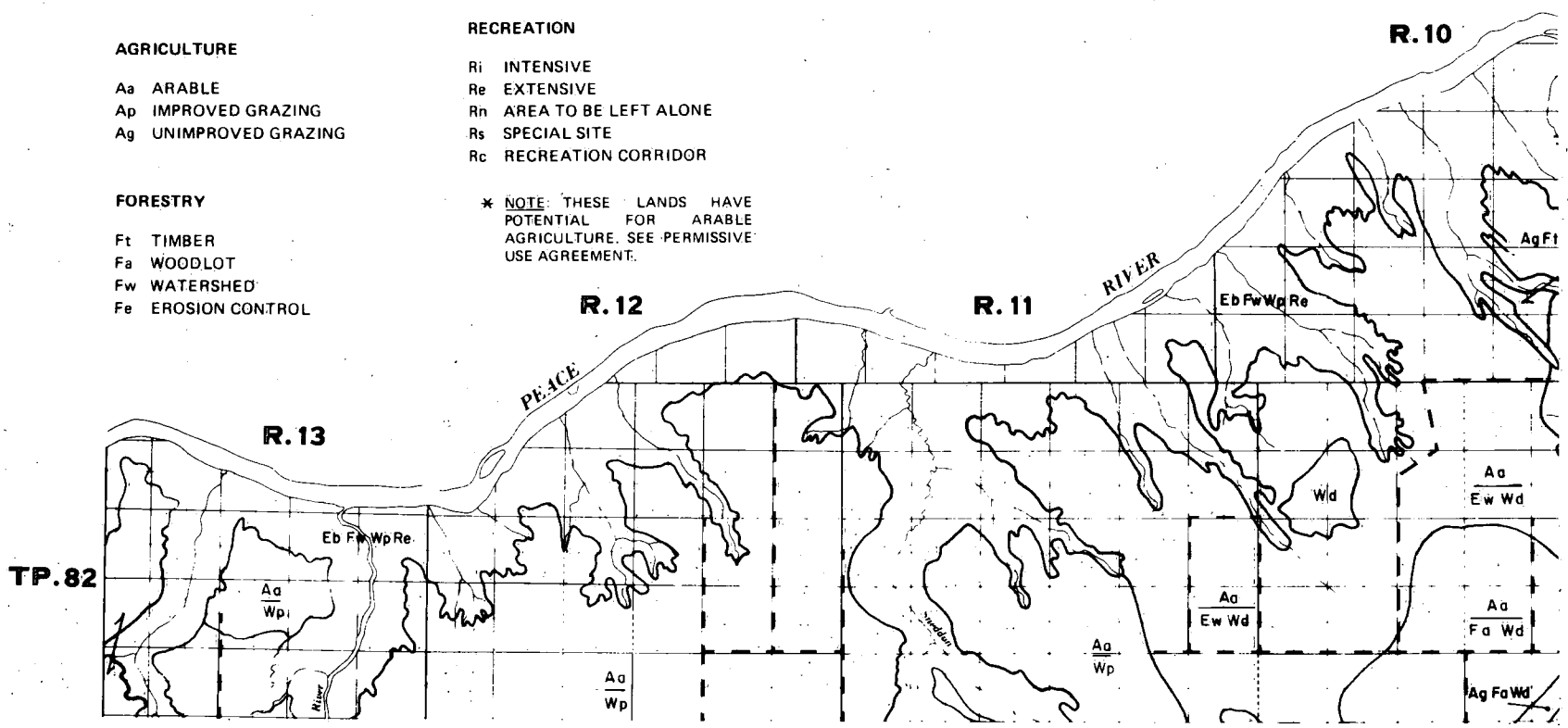
WILDLIFE

Wp PRIME HABITAT
Wd DISPERSAL AREA
Wn NESTING
Ws STAGING
Wf FISHERIES
Wm MISCELLANEOUS INTERESTS

RECREATION

Ri INTENSIVE
Re EXTENSIVE
Rn AREA TO BE LEFT ALONE
Rs SPECIAL SITE
Rc RECREATION CORRIDOR

* NOTE: THESE LANDS HAVE POTENTIAL FOR ARABLE AGRICULTURE. SEE PERMISSIVE USE AGREEMENT.



3. Land Disposition Map showing the current land commitment situation.

4. Areas for Land Conservation Practices showing sensitive areas within and adjacent to river breaks requiring protection.

The recommendations prepared by the LUAC are broad in scope. When approved by the Deputy Minister of Alta. E&NR, they serve to give direction and guidance to the agencies responsible for the disposition and management of the natural resources in the study area.

IMPROVEMENTS REQUIRED

There is good evidence from the many land use planning processes carried out in different jurisdictions that improved government policies may be formulated for complex natural resources when the people involved are placed in participative structures, when they use two-way communication skills, and when they are allowed to focus on the problem. Such an atmosphere encourages mutual learning and thus a greater chance that the resultant land use plan will be understood and accepted by the management and the users.

With that in mind, we in Alta. E&NR have been endeavouring to improve the planning process. Following are some of the areas viewed by the author where improvement is required:

1. A greater commitment by Government of staff and funds for integrated natural resource planning to provide guidelines for management operations. The big push in the past and the present is to staff and fund single-sector management planning and operations (e.g. forestry and parks). The government is providing lip-service to the philosophy of integrated planning. However, no substantial commitment has been made.

Land use planning is to operational management as pre-engineering is to road construction--without it, we have little hope of a sound structure or a realization of the ecological significance of the land.

Much of this could be done by a redistribution of existing funds, programs and staff rather than the infusion of new funds. To do this, senior administrators and politicians must be convinced that such a shift will provide better information as a basis for management.

2. Integrated natural resource policies may be achieved via a comprehensive planning process by approaching the problem through a hierarchy of planning areas. A predetermined level of detail and decision-making is required for each level.

For instance, an overview provincial plan will indicate in broad terms how the department proposes to use or to influence the use of the lands and waters of Alberta to achieve its objectives.

On the other hand, a local plan will indicate in greater detail the type and amount of uses that may take place for specific local areas.

The following summarizes this approach to the planning task:

Area	Planning Product	Level of Detail	Plan Responsibility
Province of Alberta Natural Planning Regions	Provincial Plan	Provincially significant, broad	Management agencies together with the Planning unit (LUAC)
Natural Planning Regions Strategic Areas	Regional Plan	Characteristic to Region, Comprehensive	
Strategic Areas Local Zones	Local Plan	Specific to area, Comprehensive	
Local Zones Administrative Units	Operational Management Plan	Specific Single use in consideration of other uses	Management agencies

3. A participative planning structure and style within government is essential for the development of effective policies. Those who will be required to carry out the plan must be part of the designing of the plan so that they understand the concepts.

4. Equal emphasis should be given to socio-economic factors and biophysical factors. Those who will be directly affected by the plan must be recognized and given the opportunity to become involved throughout the planning process through such means as community awareness programs, group workshops, advisory committees, and the Media.

5. Relevant study area boundaries are required considering both natural boundaries and administrative management concerns, to focus on the problem. All too often, the only rationale used to delineate a study is the possible extent of suitable agricultural lands or an area small enough so that one person can handle the work in one year. These are only two of many parameters that must be considered for establishing the study area boundaries for a land use plan. The hierarchy of planning areas illustrated above will solve much of this concern. Without the hierarchy of areas, a good planning principle is to examine a larger area than actually required to solve the problem, so that external influences may be noted. Although these external influences may not be dealt with in detail in the plan, at least they will give a better perspective to the decision-making process.

6. Problem-oriented biophysical studies are required where the methodology is designed to facilitate the solutions required by the particular management agencies. All too often, we, as scientists with rigid scientific methods, fail to provide relevant information. We are not flexible enough in our means and we lose interest in the application. We need to be more pragmatic and problem-oriented in our means to provide the information required. If we do not, managers will be reluctant to give credence to our trade.

7. Considerable improvement is required in the biophysical method carried out by the Land Use Assignment program. At the moment, for instance, the physical attributes of the landscape are adequately described, but the biological parameters are only given a cursory treatment. The characteristic vegetation, including trees, shrubs and lesser plants, requires greater consideration in the methodology as well as the characteristic fauna of the units described.

Improvements are also required in the structure of the organization. At present, one person carries out most of the biophysical analysis. He has the opportunity to consult with his peers and other agency specialists. This is only partially successful since the other people are fully occupied in their own work and unable to devote adequate time to the task.

A team approach is required where each member of the team has sufficient time and funds to properly analyze the ecology of the area. They should also work together in the field to fully understand the ecological linkages so that an adequate biophysical analysis may be prepared.

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INTEGRATED SURVEY OF BIOPHYSICAL RESOURCES IN NATIONAL PARKS

P. Gimbarzevsky
Forest Management Institute
Environment Canada
Ottawa, Ontario

ABSTRACT

The biophysical surveys conducted by the Forest Management Institute in national parks involve the mapping of land, vegetation and water, as primary natural resources at a reconnaissance (general or detailed) or a management intensity level. The working procedures and classification methods used in the acquisition, presentation and interpretation of resource information are described and illustrated with selected examples.

RÉSUMÉ

Les études biophysiques effectuées par l'Institut d'aménagement forestier dans les parcs nationaux comportent la représentation cartographique du sol, de la végétation et de l'eau, en tant que ressources naturelles primaires au niveau de la reconnaissance (générale ou détaillée), ou à celui de l'importance de l'aménagement. Les méthodes de travail employées dans l'acquisition, la présentation de l'interprétation des données sur les ressources sont décrites puis illustrées à l'aide d'exemples choisis.

INTRODUCTION

As a part of its research and development program during the past decades, the Forest Management Institute (FMI) has conducted numerous studies dealing with the appraisal of forest resources in various parts of Canada. These studies were usually initiated at the request of government agencies to provide basic information on forest resources in selected areas to plan and control anticipated forest activities, or to assess the environmental impact of potential development in the north (e.g. pipelines from the Arctic to Southern Canada). From a systematic analysis of aerial photographs and ground information collected during the field inspections, some 300 maps have been compiled covering an area of over 10,000 mi^2 (160,000 km^2) at the scales of 1:15,840, 1:63,360 and 1:125,000, mainly in the Yukon Territory and the Mackenzie District of the Northwest Territories. This work, in addition to supplying the requesting agency with the information they needed, provided FMI researchers with an opportunity to develop and test survey methods based on an intensive application of remote sensing technology and photo interpretation techniques.

The forest is one of the living components of the earth's surface and its occurrence, structure and growth are intimately linked with the physical character of the landscape. Due to the dynamic nature of the forest and its interrelationship with other landscape components, the proper management of the forest resource requires a firm ecological base where the forest cover is viewed as an integral part of the environment. To provide such an ecological base, management planning would require not only the factual information on the amount, quality and areal extent of forest cover, but also a comprehensive knowledge of the physical characteristics of the land, its biological capability or limitations, past and present land use practices, distribution of wetlands and water bodies, etc. Such information may be acquired through additional surveys, or the original survey may be organized to integrate the collection of basic resource data, thus eliminating costly duplications.

In 1971, FMI was requested and subsequently agreed to assist the National Parks Service in the appraisal of the biological and physical environment in National Parks. Following discussions with the Applied Research Division of National Parks, FMI undertook the survey of several national parks as pilot studies with the objectives:

a) To provide factual data on primary natural

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resources of the physical and biotic environment for immediate use by the parks managers and planners;

b) To undertake developmental work on a multi-level approach to integrated resource classification and survey using a combined application of remote sensing technology and field verification; and

c) To develop comprehensive guidelines for the integrated method of resource data acquisition and presentation based on demonstrated validity of research results.

The hierarchical classification system proposed by the National sub-Committee on Bio-physical Classification (Lacate, 1969*) is used in the evaluation of land, vegetation and water resources, and the surveys are referred to as *biophysical* or *integrated survey of biophysical resources*.

To meet the users' requirements and to test the classification method, the work extended over eight national parks ranging in size from 78 km^2 to about 5,000 km^2, and located in several physiographic provinces and regions:

Atlantic Uplands of Nova Scotia, New Brunswick Highlands and Newfoundland Coastal Lowlands of the Appalachian Physiographic Region (Kejimkujik, Fundy and L'Anse aux Meadows national parks);

Central St. Lawrence Lowland and Western St. Lawrence Lowland of the St. Lawrence Lowlands Physiographic Region (St. Lawrence Islands and Georgian Bay Islands national parks);

Saskatchewan Plain of the Interior Plains Region (Prince Albert National Park); and

Mackenzie Mountains, Liard Plateau and Selwyn Mountains of the Cordilleran Physiographic Region (South Nahanni National Park).

The acquisition of resource data is based largely on the application of remote sensing technology - interpretation of conventional aerial photography and LANDSAT, Thermal IR and SLAR imagery combined with field investigation. The intensity of field work depends upon the complexity of the area, access, amount of required detail, and the presentation scale. Several scales, ranging from 1:5,000 to 1:100,000, are used for resource data presentation and compilation of resource maps and overlays. The St. Lawrence Islands and Georgian Bay Islands national parks are mapped at the scales of 1:10,000 and 1:5,000, L'Anse aux Meadows at 1:10,000, Kejimkujik and Fundy national parks at 1:12,500, Pukaskwa and Prince Albert national parks at 1:25,000 and 1:50,000, and South Nahanni National Park at 1:50,000 and 1:100,000.

Cooperation with Parks Canada, frequent consultation and exchange of information with the regional staff, training seminars and workshops provide an excellent opportunity for developmental work and demonstration of how the research results can be put into practice.

METHODOLOGY

The approach presently used at FMI for the classification and survey of primary natural resources in national parks is based on a systematic stratification of the land surface and delineation of ecologically significant segments of the landscape composed of a pattern of landforms, vegetation and open water bodies. Since distribution and growth of natural vegetation is closely associated with the physiography of the area, the land features are mapped first to provide a physical base relatively independent of successional or man-introduced changes for the evaluation of biological and water resources. The hierarchical structure of this classification method, where the work proceeds from the recognition of general landscape patterns toward the classification of specific components of this pattern, has several advantages. It allows the most effective use of remote sensing technology, reduces or eliminates unnecessary and costly duplications and has a 'built-in' provision for subsequent more intensive investigations in selected areas.

For practical purposes, the resource evaluation is conducted at three intensity levels:

Reconnaissance level provides a quick overview of broad landscape units and associated vegetation, delineated as land districts or land regions, usually presented at the scales smaller than 1:100,000.

General working level or *detailed reconnaissance level* shows the recurring patterns of landforms, soils, drainage conditions and vegetation or land systems, mapped as components of a land district and presented at intermediate scales.

Management level is delineation of land types or land units characterized by a relatively homogeneous combination of soils, topography, drainage conditions and origin of parent material. The vegetation associated with a land type

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* Lacate, D.S. 1969. Guidelines for bio-physical land classification. Can. For. Serv. Publ. No. 1264.

(forest cover and non-forest plant communities) in most cases occurs as a single forest cover type, or as several subtypes, or plant associations. The land types are presented at scales larger than 1:25,000.

WORK PHASES

Regardless of the intensity level, the integrated survey of principal natural resources involves three main work phases (Figure 1):

Resource data acquisition
Resource data presentation, and
Resource data interpretation

1. Resource Data Acquisition

The acquisition of resource data is the most important phase in the integrated survey. Based on actual working experience at FMI, it has been found convenient to follow a sequence of major activities:

a) *Preliminary work* - The preliminary work consists of gathering and reviewing existing information on the area to be surveyed. Available background material on bedrock geology, geomorphology, vegetation, soils, land use, climate, hydrology, aerial photography, mapping and on other related aspects are carefully studied, sorted by specific subjects, and indexed for future reference.

b) *Systematic Air Photo Analysis* - Small scale aerial photographs, mosaics and LANDSAT imagery are extremely useful for a general familiarization with the study area and a quick overview of landscape patterns. A preliminary stereo-

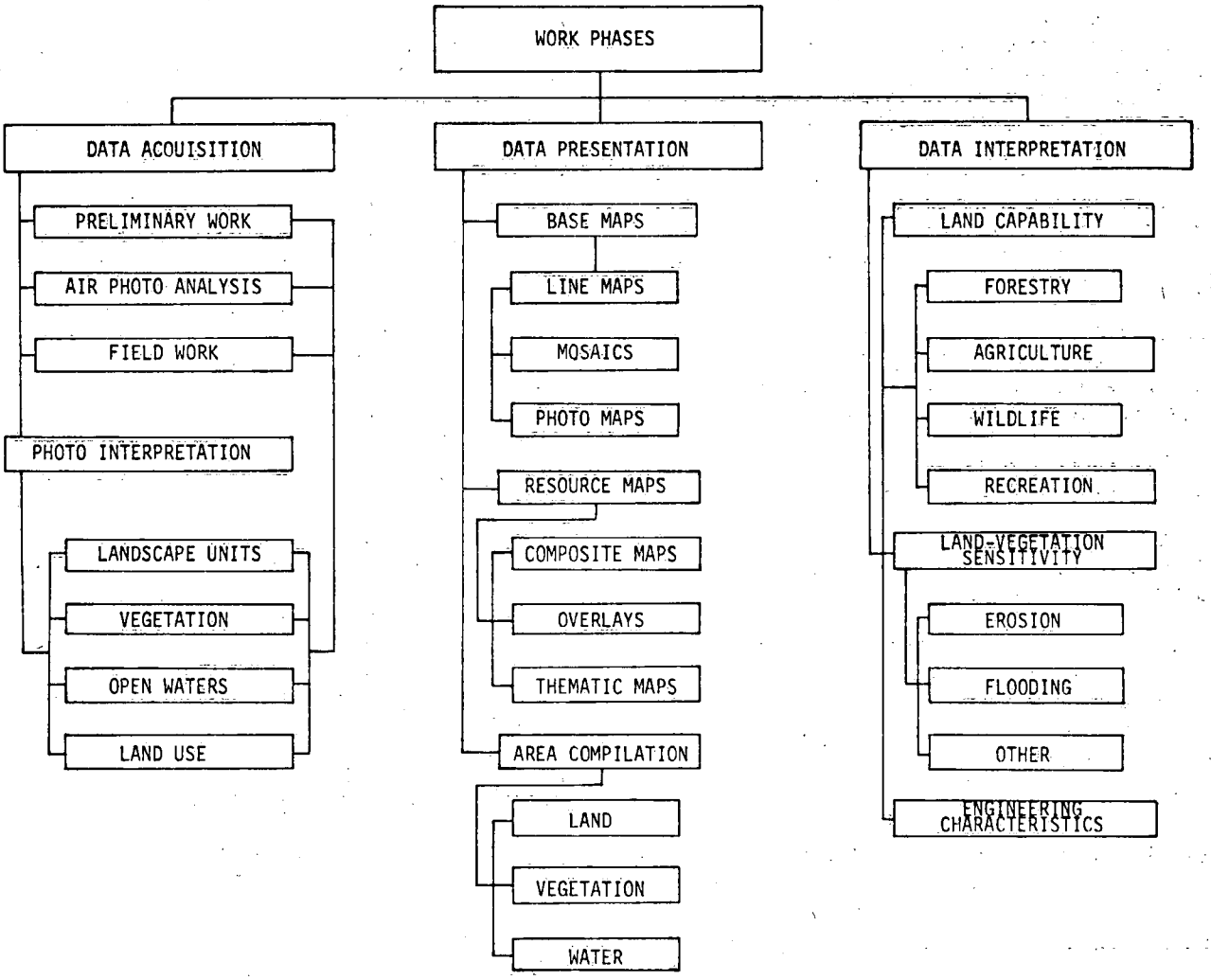


Figure 1: Integrated resource classification and survey

scopic analysis of small scale imagery also provides better understanding of geomorphic processes while establishing a broad framework for detailed survey. It is often necessary to go over small scale photography several times before commencing systematic interpretation on a larger scale, which will be used for final mapping.

The pre-field photo interpretation, with or without a brief field reconnaissance, and transferring of land and vegetation information to preliminary maps has been found quite convenient for planning the field work.

The land, vegetation and water may be delineated on the same set of photographs using different ink colors and outlining, for example, the land systems or land types in red, the forest cover types in black and the water (small lakes and ponds, intermittent streams, etc.) in blue ink. This assures more consistency of the boundaries, and considerably reduces the number of prints to be handled while transferring to the base maps.

c) *Field Verification* - The field work or collection of *ground truth* information, is usually the most expensive part of any survey and requires proper planning and preparation. As there is no substitute for the field experience, the interpreter who worked on the preliminary classification usually takes part in the field verification. All essential field observations on physical land characteristics, forest cover, non-forest plant communities, water bodies, shorelines, etc. are recorded either along predetermined transects or in selected localities. Samples of plants and soils, ground photographs, slides, strip aerial photography from helicopter, and other field notes on some specific aspects of the area provide a valuable support for the final classification and analysis of resource data.

d) *Classification* - After the field verification and a thorough analysis of field data, the preliminary photo interpretation is reviewed; revisions or corrections are made, where necessary, keeping in mind the size of individual map units at the presentation scale.

A resource map is intended to provide the user, resource manager or planner with factual survey data expressed by conventional cartographic symbols. For ease in reading and understanding, the selection of appropriate symbols should be compatible with the survey intensity level and the mapping scale. In a reconnaissance survey, for example, involving mapping of extensive areas, the essential information that can be presented at a small scale will be of a general nature. The resulting map units (land regions, land districts or land systems) are identified by a simple map symbol - a numeral, abbreviation of letters and numerals, or geographic names, and the essential aspects of topography, geology, geomorphology, vegetation, drainage, land use, etc., briefly described.

In detailed surveys for management purposes, the survey information is more specific and the map symbols should be selected accordingly. The symbolization developed at FMI, for example, shown in Figures 2 and 3, has been found quite convenient and practical for mapping at the land type level.

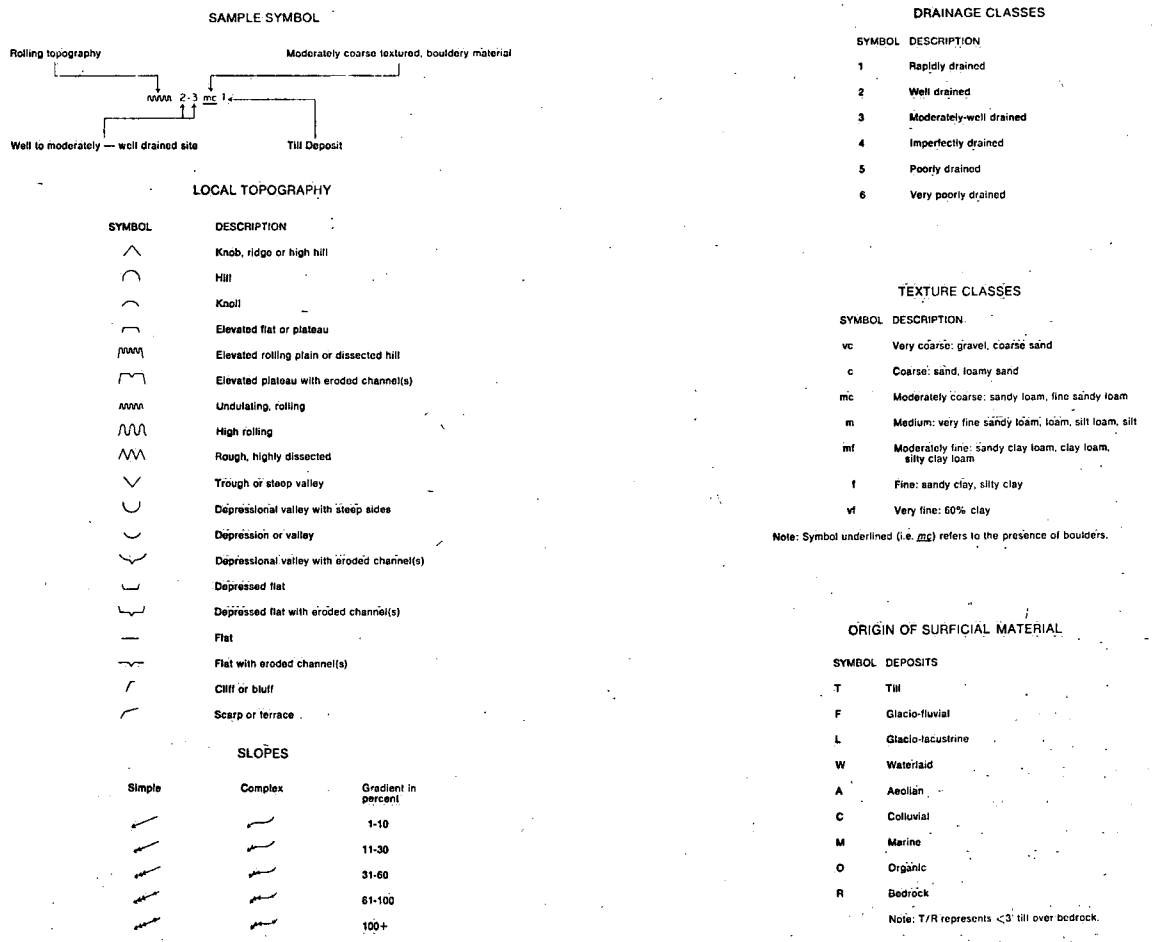
The physical characteristics of a land type are expressed as predetermined classes of local topography, moisture conditions, soil texture, origin of surface material and depth to underlying bedrock.

Local topography is presented graphically by a symbol derived from a cross-section profile of terrain model resembling the shape of a particular surface configuration. The seven texture classes (very coarse, coarse, moderately coarse, medium, moderately fine, fine, and very fine) are expressed as lower case abbreviations (vc, c, mc, m, etc.). The soil moisture conditions based on the consideration of local climate, surface run-off and permeability are expressed as six drainage classes, indicated with numerals from 1 to 6. Class 1 expresses a rapid runoff and/or permeability and generally dry moisture conditions, while class 6 indicates saturated conditions. Classes 2 to 5 indicate drainage conditions from *well drained* to *wet*. The geomorphic origin of a land type is expressed by upper case letters indicating the main processes of deposition and erosion performed by the glaciers, water, wind and gravity, or by a combination of these forces (e.g. T - glacial till; F - glaciofluvial; A - aeolian or windlaid; R - bedrock; etc.). The depth of surficial material to underlying bedrock where estimated as being less than 1 m is indicated by placing the bedrock symbol (R) under the geomorphic origin symbol (e.g. T/R = thickness of till deposit less than 1 m).

The vegetation types (forest cover types and non-forest plant communities) are presented by a symbol consisting of letters and numerals to indicate the stratification by height and density classes, species composition, stand structure and present growing conditions.

The average height of a forest cover type is expressed by numerals in 20-foot or 5-m height classes, and the percentage of crown closure as density classes 1 to 4. The species composition is indicated by conventional abbreviations of common tree names listed by the order of their

Figure 2: The FMI land type legend



dominance within the map unit. The *condition classes*, indicating the successional stage and vigour of the type, are expressed by numerals 1-5 placed under the cover type symbol. To indicate a specific structure of some complex vegetation types (e.g. a two-storey forest stand), a combination of conventional symbols is used to express a particular situation.

Figure 4 shows delineated land types (white lines) and their biotic components, the vegetation types (black lines).

Open waters - rivers, permanent and intermittent streams, lakes and ponds - are delineated on aerial photographs during the analysis of land types. Water bodies, often as small as a fraction of a hectare, are shown as separate map units where technically possible. A detailed delineation of microdrainage features is a relatively inexpensive exercise. Such a drainage map (Figure 5), in addition to being a comprehensive physical inventory of water resources, provides an excellent base for future hydrological and engineering investigations - stream analyses, determination of drainage basins, classification of lakes, shoreline studies, etc.

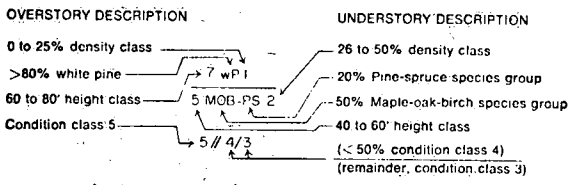
2. Resource Data Presentation

The final product of a resource survey is usually a map of the area investigated showing the geographic location and areal extent of a particular resource as map units. This work phase involves the preparation of *base map(s)* at a suitable scale, transferring of resource details from interpreted aerial photographs to the base or *compilation of resource map(s)*, and *area determination* and tabulation by resource classes.

Base Maps - The selection of adequate scale for presentation of resource data depends upon the intensity level of the survey. The average size of resulting map units - (land regions, land districts, land systems or land types) may be used as a reliable guide. A 2000 km^2 land district, for example, when placed on 1:1,000,000 or 1:500,000 scale map will have a size of 20 cm^2 and 80 cm^2 respectively, while a 10 km^2 land system at these scales will appear as a dot. The same 10 km^2 land system at the scale

Figure 3: Forest cover type legend.

SAMPLE SYMBOL



SPECIES

SYMBOL	COMMON NAME	SYMBOL	COMMON NAME
P	Pine	wB	White Birch
wP	Eastern White Pine	M	Maple
rP	Red Pine	sM	Sugar Maple
S	Spruce	rM	Red Maple
bS	Black Spruce	Be	Beech
F	Fir	wA	White Ash
bF	Balsam Fir	O	Oak
L	Tamarack	X	Undifferentiated
H	Hemlock		hardwood species
eH	Eastern Hemlock	U	Upland clearing, grassland
Po	Poplar	M	Marshland
B	Birch		

HEIGHT CLASSES

SYMBOL	HEIGHT CLASS IN FEET
1	1-20
3	21-40
5	41-60
7	61-80
9	81-100
11	101+

DENSITY CLASSES

SYMBOL	PERCENTAGE CROWN CLOSURE
1	<25
2	25-50
3	51-75
4	>75

CONDITION CLASSES

SYMBOL	CLASS DESCRIPTION	SYMBOL	CLASS DESCRIPTION
1	Regeneration following a disturbance, <10 years, height class 1	1A	No regeneration following a disturbance
2	Young, normal growth, 11 to 30 years, height class 1 or 3	2A	Young, retarded growth due to poor site and/or overstocking, height class 1
3	Young to mature, normal growth, 31 to 60 years, height class 5	3A	Young to mature, retarded growth due to poor site and/or overstocking, height class 3
4	Mature, good growth, healthy, 61 to 80 years, height class 5 or 7	4A	Forest cover affected by exposure, shallow soils, exposed bedrock, and/or other site factors. Height class 3 to 7
5	Mature, good growth, healthy, 81+ years, height class 7 to 11	5A	Overmature, showing signs of decadence, height class 7 to 11

of 1:250,000 will cover less than 2 cm^2, and 10 cm^2 at the scale of 1:100,000. The selection of proper scale base maps becomes more critical in the presentation of detailed resource information at the land type level, where the map units measure often less than 10 ha; at the scale of 1:25,000 a 10-ha land type will measure less than 2 cm^2, and about 10 cm^2 at the scale of 1:10,000.

In pratical application, three general scales are used for an effective presentation of resource data: *small scale* base maps (1:500,000 and smaller) for the reconnaissance mapping (land regions and land districts), *intermediate scales* (1:50,000 to 1:250,000) for general working level or detailed reconnaissance (land systems), and *large scales* (1:25,000 and larger) for a detailed or management level mapping (land types).

The base maps at a desired scale, usually on a stable, transparent material, may be compiled as *line maps* or *photo maps*.

Line Maps - The most commonly used base for presentation of resource data is the National Topographic System (NTS) maps, available for all or most of Canada at the small and intermediate scales (1:1,000,000, 1:500,000, 1:250,000 and 1:50,000). A limited coverage in this series is available at the scale of 1:25,000, but only for some densely populated areas. The small and intermediate NTS series maps provide a quite suitable and economical base for presentation of resource information at the reconnaissance and land system levels. The required map sheets may be obtained on transparent stable material which would allow the reproduction of additional paper prints.

A base map at the scale of 1:25,000 or larger for a relatively small area may be produced by photographically enlarging a 1:50,000 NTS map sheet and then simply redrafting the required portion on a stable transparent base.

For a detailed survey of extensive areas involving several map sheets, the compilation of base maps at the scales 1:25,000 or larger should comply with the NTS subdivision to ensure a consistency for any future mapping and to retain a convenient size of produced map sheets.

Figure 6 exemplifies the method developed at FMI for the compilation of base maps at the scales of 1:25,000, 1:12,500, 1:10,000 and 1:5,000. The large scale maps are derived from the NTS base drawn on the Universal Transverse Mercator projection (UTM) and the size of produced map sheets is approximately the same as the size of an average 1:50,000 NTS map (80 cm by 56 cm).

A standard 1:50,000 NTS map sheet, which is a sixteenth of a 1:250,000 sheet, covers an area of 30' longitude and 15' latitude. To produce a base map at the scale of 1:25,000, the 1:50,000 NTS map is divided into eight sections and referenced as sections a,b,c,d,e,f,g and h. To maintain the same size of individual maps, it has been found convenient to place two adjoining sections on one 80 cm by 56 cm sheet and to reference the four maps as a-b, c-d, e-f, and g-h.

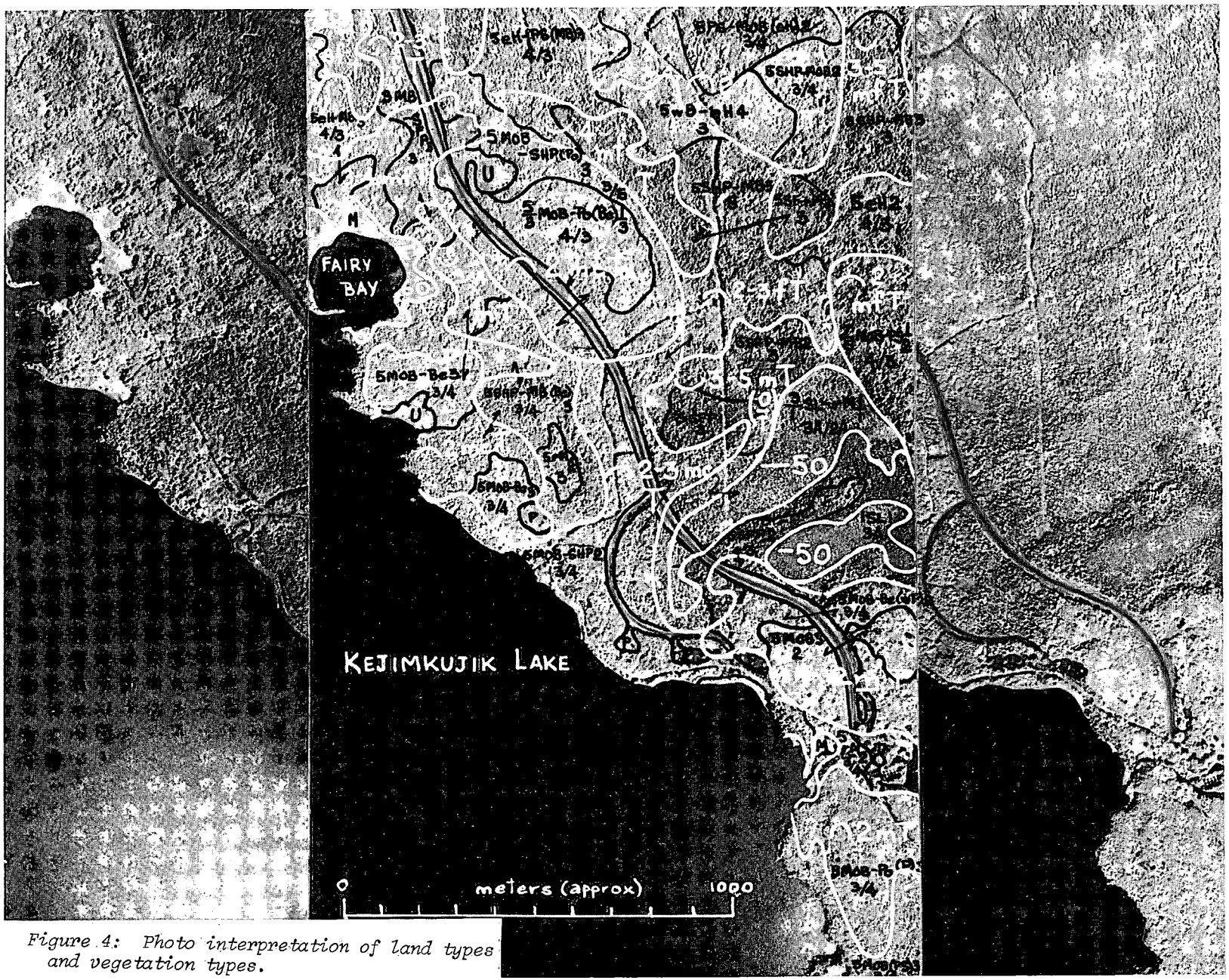


Figure 4: Photo interpretation of land types and vegetation types.

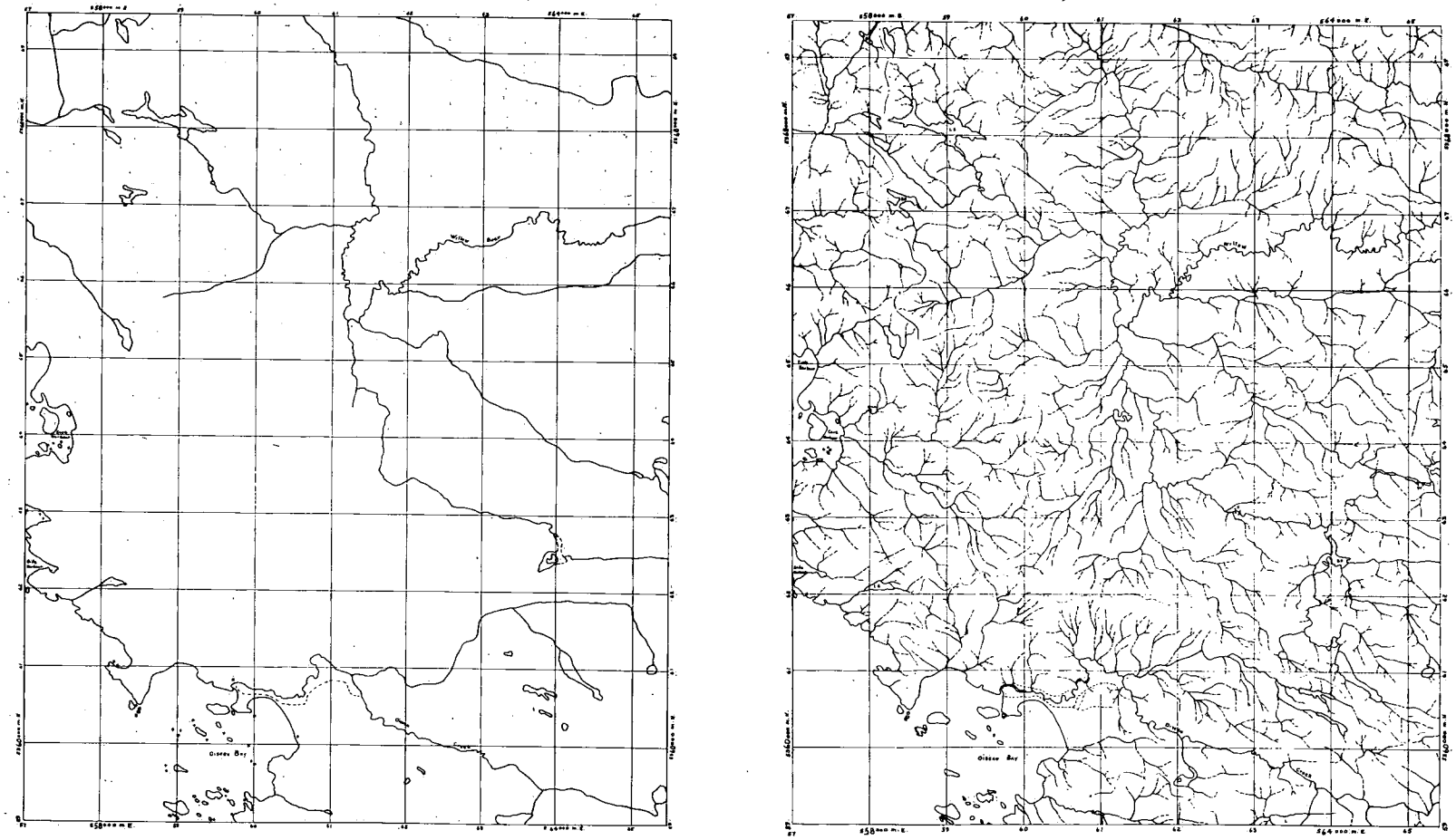
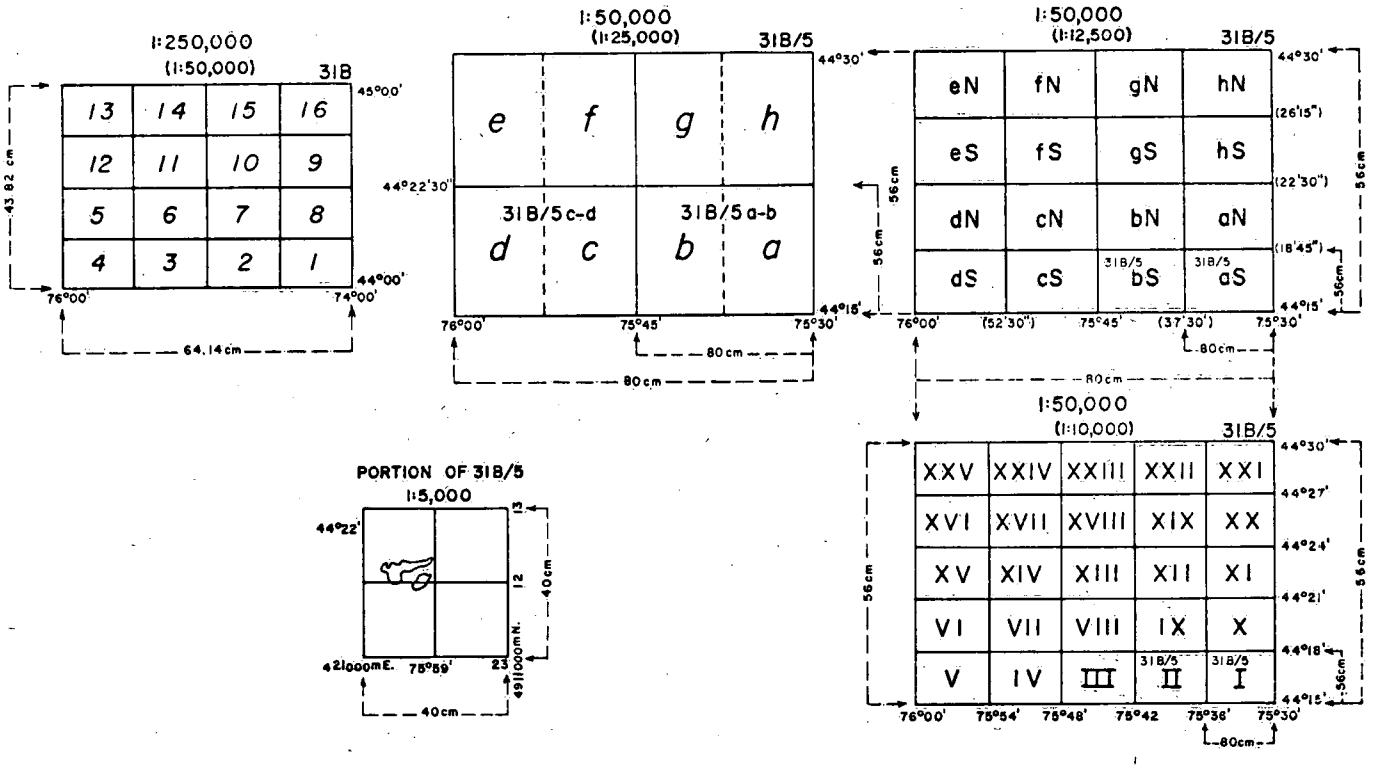


Figure 5: Portion of a planimetric base map without (left) and with the micro-drainage features interpreted from aerial photographs.

Figure 6: Subdivision of NTS sheet for compilation of large scale base maps



Each of the four 1:25,000 scale maps covers an area of 15' longitude and 7'30" latitude.

A similar method is used for the compilation of base maps at the scales of 1:12,500 and 1:10,000. For the construction of 1:12,500 scale base, the 1:50,000 NTS map sheet is divided into 16 quadrangles, 7'30" longitude and 3'45" latitude each, and referenced as map sheets aS(south) aN(north), bS, bN...hS and hN.

For compilation of base at the scale of 1:10,000, the 1:50,000 NTS map sheet is divided into 25 quadrangles, each covering an area of 6' longitude and 3' latitude, and referenced with Roman numerals commencing with I in the south west, and ending with XXV in the northwest corner.

The 1,000 m UTM grid which is included on all large scale base maps has been found a convenient feature for referencing of specific map units, and for compilation of base maps larger than 1:10,000.

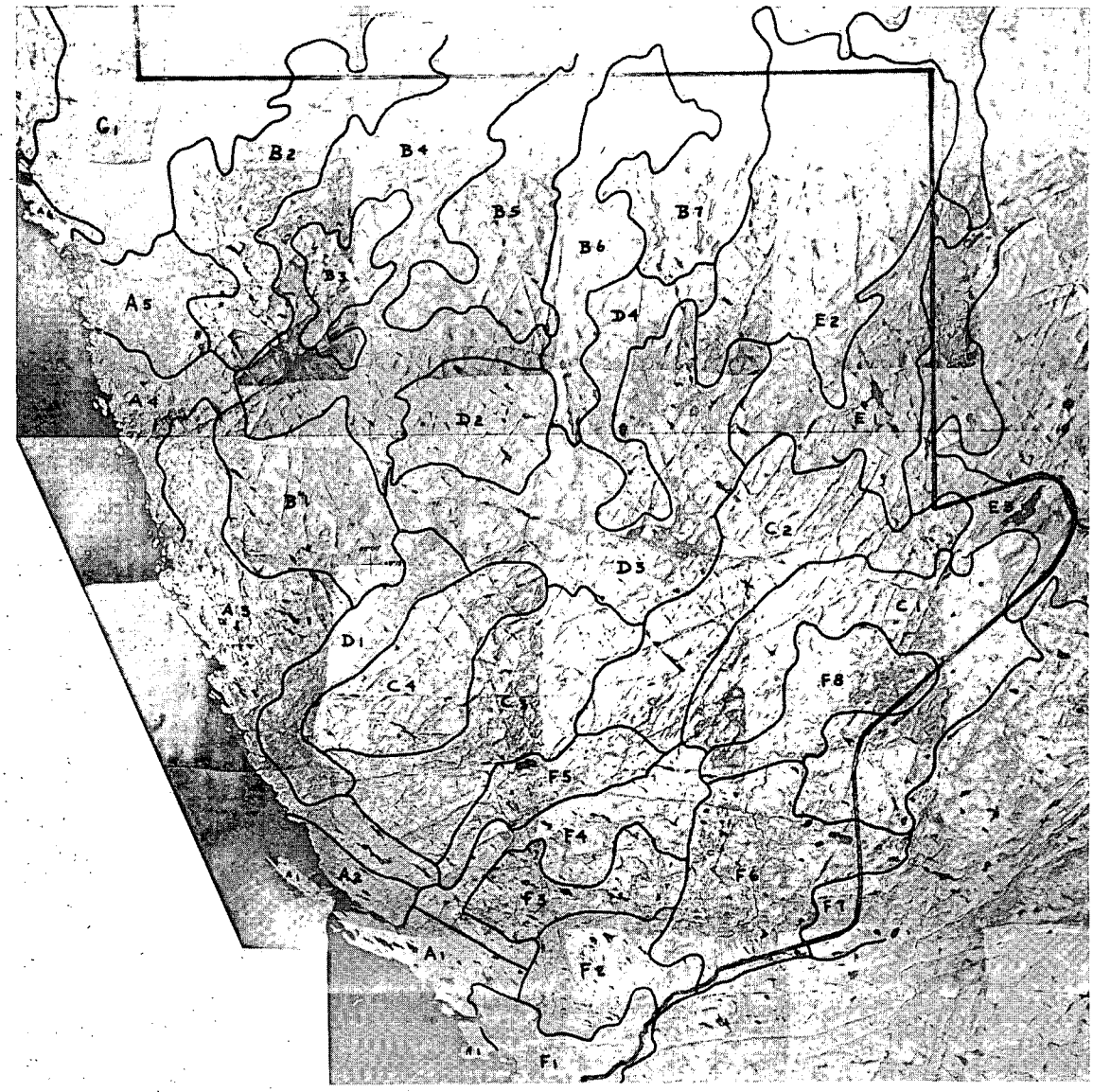
Photo Maps - Occasionally the resource information may be presented on a photographic base - aerial photograph, LANDSAT image, air photo mosaic or orthophoto maps reproduced on a stable transparent material which would allow a duplication of the compiled resource map by photography, or by a less expensive dry process.

Air photo mosaic - uncontrolled or semi-controlled, as well as selected small scale photographs or LANDSAT frames enlarged to a required scale, often provide a convenient base for resource data presentation of the areas that are relatively small or lack adequate NTS coverage. Such a base is relatively inexpensive and simple to construct (Figure 7).

The controlled photo mosaics and orthophoto maps combine the advantages of a line map and the photographic terrain features corrected to a true scale. Although they provide an excellent base for large scale mapping, their use is limited by a relatively high cost and terrain slope limits (maximum slope for orthophoto maps is 50% for 152 mm focal length photography).

Compilation of Resource Maps - A resource map is a cartographic display of the survey results. Its compilation involves transferring of resource details interpreted on aerial photographs to a base map, determination of the area of all map units for preparation of summary tables, and

Figure 7: Semi-controlled photo mosaic as a base map for presentation of land systems



a subsequent construction of required resource maps and overlays for management or planning.

The transfer of resource information from interpreted aerial photographs and the plotting of the map units on the base are performed by relatively simple instruments or by stereo plotters. For mapping low relief areas, the use of simple instruments such as a reflecting projector or sketchmaster has been found quite satisfactory. However, for a correct plotting from aerial photographs of a hilly or mountainous area, a stereo plotter which allows the use of paper prints (e.g., Radial Kail Plotter, or 'Stereotop') provides much better results.

From a checked and edited map manuscript, a paper copy is produced for the area determination of each map unit. For this work, a suitable dot grid or a planimeter may be used. The sizes of all map units (in km^2 or ha), numbered in a consecutive order, or referenced to the UTM coordinates of the map sheet, are listed with their appropriate classification symbols and coded for computer processing and preparation of summary tables.

Standard cartographic procedures are used in the construction of final resource maps. They may be drafted on the same planimetric base as the map manuscript, or scribed and subsequently reproduced as composite land-vegetation maps (Figure 8). In addition, a series of thematic overlays may be produced to show some specific features such as contour lines, plant communities, land use, outstanding or unique features, drainage, open water, shoreline classification, etc.

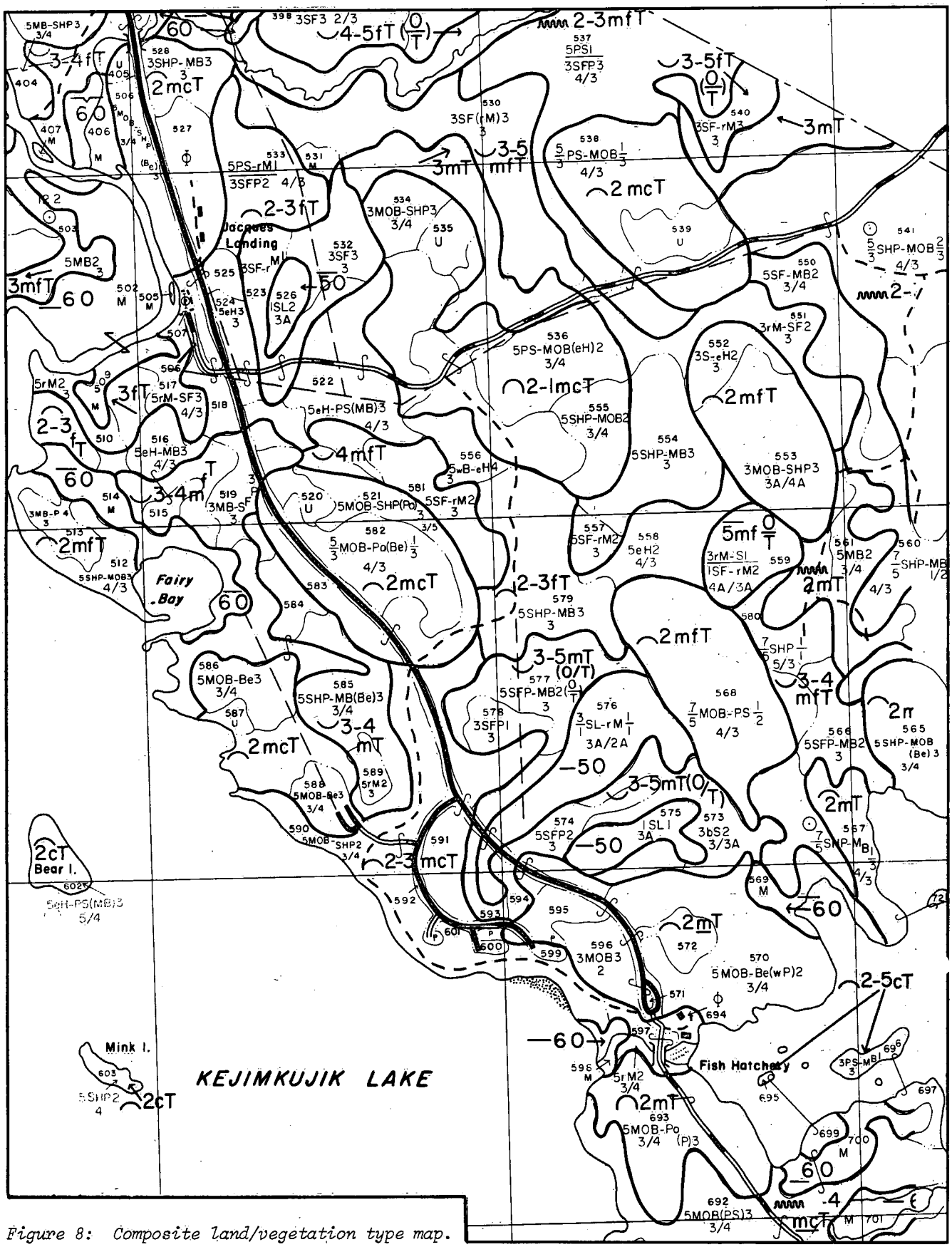


Figure 8: Composite land/vegetation type map.

3. Interpretation of Resource Data

The completed resource maps - land type and vegetation cover type - provide in a simple form factual information required for management planning and general operation of the park. The kind, location and areal extent of primary biophysical resources are expressed by conventional symbols which indicate basic characteristics of map units. These characteristics and their positive or negative effect on the suitability of the map unit for a particular purpose may be interpreted from the resource maps and expressed as capability classes for biological productivity or suitability for recreation and other purposes, such as engineering soil properties, or sites having some unique characteristics.

Land Capability for Biological Productivity - A biological productive capacity of the land surface is a function of climate and physical properties of the land, mainly its topography, drainage conditions, texture of the soil and origin or parent material. The land types, which are fairly homogeneous segments of a landscape and reflect these physical characteristics, may be grouped by their physical properties and limitations and expressed as capability classes for agriculture, forestry, wildlife or recreation.

Engineering Soil Characteristics - Physical aspects of land types may also be interpreted to provide data required for the construction and maintenance of roads, location of granular deposits or for selection of building sites and detailed field investigations involving specific engineering problems.

The susceptibility to erosion on various land types may be determined from the analysis of specific topographic positions, inherent soil characteristics and associated vegetation and expressed as high, moderate or low erosion hazard classes.

Outstanding Features - These are sites or locations having some unique or unusual characteristics related to biotic or physical aspects of the park environment, as for example a prominent landform, waterfall, unusual vegetation type or a site associated with the past history of the area. The recognition of such features is important in planning developmental work and in setting up an interpretative program for the park. Such information may be interpreted from the completed resource maps and presented as a separate thematic map or overlay indicating their location and classification.

DISCUSSION

The practical value of remote sensing technology in integrated surveys is its versatility to cope with the highly dynamic nature of biophysical resources. A combination of several sensors is a particularly suitable, rapid and economical tool for the hierarchical classification approach of natural resources.

For a traditional photo interpretation, the conventional aerial photography is still the most dependable and widely used sensor at FMI. Small scale (1:50,000 and smaller) black and white and color photography provide a reliable and inexpensive means for a reconnaissance survey, while the intermediate and large scales (1:25,000 to 1:10,000) are used for intensive surveys at the land type level. The large scales (1:1,200, 1:2,400 and 1:5,000) flown along preselected transects have been used successfully in inaccessible areas to reduce the intensity of field work.

The LANDSAT imagery, particularly enlarged to 1:250,000 scale, provides an excellent overview of extensive areas and is being used together with conventional photography in the reconnaissance surveys and for monitoring the dynamic character of the biotic components.

The application of SLAR and thermal IR imagery has great potential value, but its use in biophysical studies has to be fully explored.

The cost of a biophysical survey is directly related to the complexity and size of the area, accessibility, required amount of detail and form of data presentation. Generally over 50% of the cost is for the acquisition of resource data, about 30-40% for data presentation and the remaining 10-20% of the total cost for the data interpretation phase.

Continuous cooperation between FMI researchers and park personnel as the user of resource information is mutually beneficial. Members of the regional staff, for example, often participate on the survey with the FMI team and become familiar with the general techniques of data collection. The user is often given advance survey data of a high priority area for an immediate application and this provides an opportunity to test the classification system and its suitability for the intended use. As a part of this cooperation and technology transfer program FMI is organizing and conducting special workshops related to a particular study (e.g. Halifax, N.S., Cornwall, Ont. and Winnipeg, Man.), as well as training seminars for technical staff (e.g. St. John's, Nfld., Halifax, N.S.

and Whitehorse, Y.T.). The research data are often used in scientific papers presented at national and international conferences (e.g. Canadian Remote Sensing Symposium, Guelph, Ont., Symposium of IUFRO, Freiburg, W. Germany and North American Soil Conference, Quebec City).

For those interested in further details, FMI has published numerous reports and papers.

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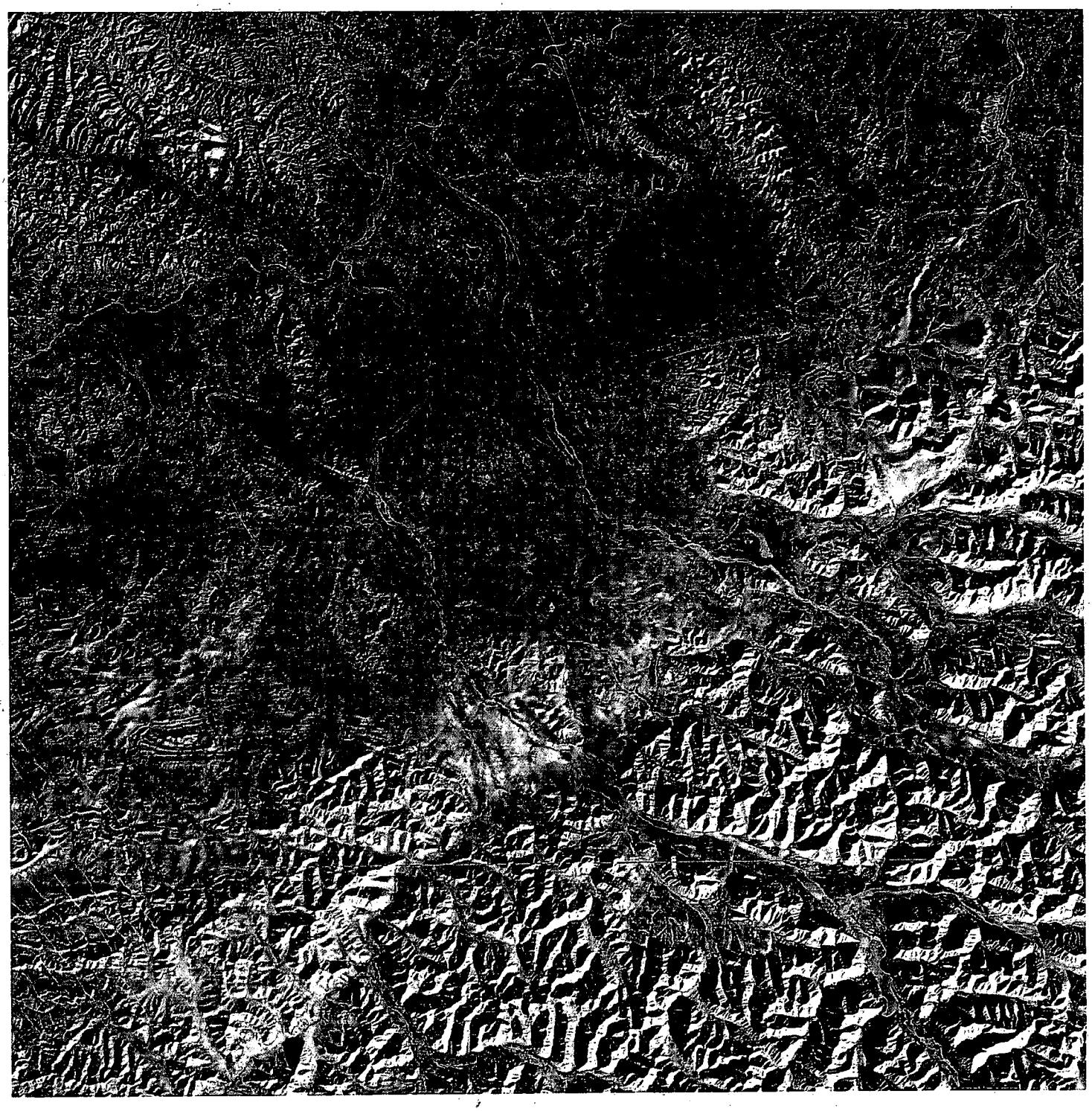
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