CONSEIL CANADIEN DES
AIRES ÉCOLOGIQUES
CCEA
CANADIAN COUNCIL
ON ECOLOGICAL AREAS

OCCASIONAL PAPER NO. 13

CANADIAN COUNCIL ON ECOLOGICAL AREAS FRAMEWORK FOR DEVELOPING A NATION WIDE SYSTEM OF ECOLOGICAL AREAS

PART 2 ECOREGIONAL GAP ANALYSIS

D. GAUTHIER, K. KAVANAGH, T. BEECHEY, L GOULET, AND E. WIKEN
EDITORS

JULY 1995

YPAS Library
CCEA
7

OCCASIONAL PAPER NO. 13

CANADIAN COUNCIL ON ECOLOGICAL AREAS

FRAMEWORK FOR DEVELOPING A NATION-WIDE SYSTEM OF ECOLOGICAL AREAS
PART 2 - ECOREGION GAP ANALYSIS

July 1995

D. Gauthier, K. Kavanagh, T. Beechey, L. Goulet and E. Wiken
(editors)

CCEA MISSION STATEMENT

The Canadian Council on Ecological Areas (CCEA)[1] was established in 1982 **to facilitate and assist Canadians with the establishment and maintenance of a comprehensive network of protected ecological areas representative of Canada's terrestrial and aquatic natural diversity.**

Council draws its membership from federal, provincial and territorial governments, non-governmental organizations, universities and private citizens. The objectives of CCEA are to:

- provide scientific advice and guidance in the systems design and development of management practices for a nation-wide network of terrestrial and aquatic ecological areas and the selection of sites to complete it;
- assist in determining the ecological requirements and institutional arrangements for the securement and protection of unique and representative ecological areas;
- advance sound stewardship practices for protected ecological areas including their management, restoration and use for biodiversity conservation, science, education and heritage appreciation;
- promote the value of protected ecological areas for the environmental, social and economic well-being of all Canadians;
- serve as a national forum for ecological areas meetings, research and reporting;
- facilitate inter-agency funding by governments, non-government agencies, private industry and the public for initiatives, programs and research in support of the above; and,
- establish useful relationships with international organizations and organizations in other countries having similar interests and concerns.

---

[1] CCEA is a registered charitable organization.

ACKNOWLEDGEMENTS

This report is based on three case studies[2] conducted on behalf of the Canadian Council on Ecological Areas by Katherine Enns (British Columbia), David Gauthier (Saskatchewan), and Daryl Cowell and Mirek Sharp of Geomatics International Inc. (Ontario). In addition, Geomatics International Inc. synthesized material from the three case studies in a summary report to CCEA (Geomatics International 1994) from which material in this paper is drawn.

This work was generously supported by funding from IBM Canada Ltd., State of Environment Reporting (Environment Canada) and provincial government contributions to the Canadian Council on Ecological Areas (CCEA).

It is not possible to recognize every person who contributed to this final product. Many individuals are recognized in the separate background reports and case studies from which this occasional paper is derived. In addition, the editors acknowledge Arlin Hackman (World Wildlife Fund Canada) for his guidance in developing the case studies. Additional guidance and input was provided by Tony Turner (Environment Canada) and Claude Mondor (Parks Canada). The following individuals provided valuable comments on an earlier draft: Dys Burger, Bill Crins, Don Cuddy, Paul Gray and Peter Quinby. Responsibility for the acceptance or interpretation of comments and the expression of views and opinions rests with the editors.

---

[2] Enns 1993, Gauthier 1993, Geomatics International 1993. Copies of individual case studies are available through the CCEA Secretariat.

PREFACE

Establishing a comprehensive network of protected areas which are representative of Canada's ecosystem diversity is a central goal of the CCEA. The success of Canadian efforts is largely dependent upon answering a number of fundamental questions:

1. What is currently protected?
2. What is Canada's ecosystem diversity?
3. What strategy should be taken to identify major gaps in a comprehensive network of protected ecosystems?
4. What methods can be used to assess ecosystem integrity and sustainability?

Responding to the first two questions primarily involved building a foundation of basic knowledge. The Council initiated the first national registry of ecological areas and, since then, has produced regular, yearly jurisdictional reports to support an expanded National Conservation Area Data Base. The Council also actively supported the Canadian Committee on Ecological Land Classification(CCELC) and related groups which classified and characterized both the terrestrial and marine ecosystems of Canada.

In addressing the third question, the Council sponsored the **Ecological Areas Framework for Developing A Nation-Wide System of Ecological Areas: Part 1 - A Strategy**[3] (Gauthier 1992). That publication established the basic approach and principles to be undertaken in the sense of assessing ecosystem representation. It endorsed the methods and concepts of the CCELC. As well, it discussed the basic concepts that should be used in assessing ecological integrity and sustainability.

This paper addresses the fourth question. It synthesizes the work of three case studies that provided three practical applications based on significantly different ecosystem settings: the Southern Interior of British Columbia; the Prairies of southern Saskatchewan; and the Canadian Shield uplands of north-eastern Ontario. This report draws heavily upon the regional provincial case studies and from the summary document of those studies (Geomatics International 1994).

The primary purpose of this report is to formally present a national approach to gap analysis based on the ecoregion level of generalization. Specifically, it presents a generic methodology along with accompanying area assessment forms which will permit the systematic determination of:

1. the representativeness of ecoregions;
2. the adequacy of existing protected areas; and,

---

[3] Hereafter referred to in this report as the "Strategic Framework".

3. a means to guide the selection of additional protected areas.

The methodology is intended as a "coarse filter" analysis. Because of the vital importance of the "physical" base of ecosystems and the availability of ecosystem data , the methods emphasize the use of "enduring features". This approach places an emphasis on initially using landform and soil landscape features. It is not intended to replace more detailed analytical methods employed by individual jurisdictions, nor does it exclude using biological features. Rather, it should be considered as complementary analyses geared to support a finer scale of work that identifies "local or unique" features.

The guide allows small scale comparative assessments and gap analysis at scales of between 1:250 000 to 1:5 000 000. This level and associated methodology are particularly useful for providing an overview of protected areas on a national level. It also allows comparison of areas selected among individual provincial and regional jurisdictions. This approach should be viewed as complementary to analyses geared to a finer scale that identify "special or unique" features of the landscape for inclusion in a protected areas network.

Together, Part 1, offering the **Strategic Framework** (Gauthier 1992), and Part 2, providing the **Ecoregion Gap Analysis**, provide a refined view and approach for selecting representative ecological areas beyond that provided in Council's earlier guidelines on area selection in CCEA Occasional Paper No. 5 (Beechey 1989).

It is important to note that this report deals primarily with gap analyses for terrestrial representation. The **Strategic Framework** (Gauthier 1992) also acknowledges the importance of representing aquatic and marine systems, and special areas to protect other aspects of biodiversity, such as vulnerable, threatened and endangered species, old growth ecosystems, and other features as called for in the Canadian Biodiversity Strategy (Biodiversity Working Group, in prep.). Through subsequent projects, as set out in Council's Business Plan 1994-1997 (CCEA 1994), Council aims to pursue these complementary thrusts.

Ed Wiken
CCEA Chairman

TABLE OF CONTENTS

Page

CCEA MISSION STATEMENT i

ACKNOWLEDGEMENTS ii

PREFACE iii

TABLE OF CONTENTS v

1.0 INTRODUCTION 1

1.1 CCEA STRATEGIC FRAMEWORK FOR PROTECTED ECOLOGICAL AREAS 1
1.2 CONCEPT OF ENDURING FEATURES 2
1.3 ECOREGION GAP ANALYSIS 3

2.0 ECOREGION GAP ANALYSIS CASE STUDIES 4

2.1 BRITISH COLUMBIA GAP ANALYSIS 5
2.2 SASKATCHEWAN GAP ANALYSIS 9
2.3 ONTARIO GAP ANALYSIS 13
2.4 SUMMARY OF KEY FINDINGS 16

3.0 GENERIC METHODOLOGY FOR IDENTIFYING REPRESENTATIVE AREAS 18

3.1 PART A - DETERMINATION OF REPRESENTATION 20
3.2 PART B - DETERMINING AREA REQUIREMENTS 22

4.0 SUMMARY AND CONCLUSION 24

5.0 REFERENCES 24

APPENDIX 1. GENERIC MATRICES FOR ANALYZING REPRESENTATION 26

APPENDIX 2. EXAMPLES OF MATRICES ILLUSTRATIVE OF NATURAL AREA AND LANDSCAPE ANALYSIS 35

1.0 INTRODUCTION

Early in its work, the CCEA identified the need to construct a nation-wide map and inventory of protected ecological areas. This information needed to be set against a backdrop of an ecological classification system. Existing information was used as a starting point in developing CCEA's National Registry of Ecological Areas[4]. Subsequently, the Natural Conservation Areas Data Base (NCADB) was created by State of the Environment Reporting (SOER) in cooperation with CCEA. Parks Canada (formerly the Canadian Parks Service), Forestry Canada and many provincial and territorial agencies provided further input and guidance. NCADB directly contains information on 3,500 government holdings including parks, wildlife sanctuaries, forest reserves and other categories of conservation or heritage areas. Information on protected ecological areas within this data base is categorized according to the World Conservation Union's (IUCN) management categories as well as many other variables. The NCADB is comprehensive for most jurisdictions. It also contains information on over 10,000 protected areas of various types which are held by non-governmental groups such as the Nature Conservancy of Canada and Ducks Unlimited.

In addition, an ecosystem classification has been created under the auspices of the Canada Committee on Ecological Land Classification (Wiken *et al.* 1993; Wiken 1986) for all of Canada. The Terrestrial Ecoregions framework encompasses 5,500 Ecodistricts contained within 217 Ecoregions which are in turn aggregated into 45 Ecoprovinces and 15 Ecozones. The Terrestrial Ecoregions, currently under review, were delineated using a consistent methodology to characterize Canada's terrestrial ecosystems in a systematic, hierarchical fashion which lends itself to designing a nation-wide system of ecological areas. Similar work has been completed for the marine ecosystems of Canada.

1.1 CCEA Strategic Framework for Protected Ecological Areas

The establishment of a nation-wide system of rigorously protected ecological areas is the primary focus of CCEA. CCEA believes that such a system is essential to ensure the maintenance of Canada's biodiversity and ecosystems. In July, 1992, CCEA released its **Strategic Framework** for developing a nation-wide system of ecological areas (Gauthier 1992).

The objectives of the **Strategic Framework** are to promote and to stimulate thinking about an approach to establishing and conserving a comprehensive range of ecological areas. To complement representation the framework also advocates maintaining ecological integrity to preserve ecosystem composition, structure and function, which is an important underlying goal of conserving biodiversity (ecosystem diversity, species diversity and genetic diversity). To that end, the **Strategic Framework** prescribes

---

[4] See Gray and Rubec (1989).

representation of each of the 217 Terrestrial Ecoregions of Canada as a minimum level of completing a Canadian system of representative protected areas. To achieve these ends, CCEA encourages jurisdictions to adopt the ecological classification scheme most appropriate for their needs and accepts the mosaic of systems plans for ecological areas already in place in the various jurisdictions across Canada. In addition, CCEA encourages the jurisdictions to establish the completion of their systems plans and targets as a high priority. The framework also recognizes the need for a spectrum of mechanisms to achieve protection including the following: legislation, private stewardship, and aboriginal support; the need for replicate representative areas given the small size of many existing areas; the need to adopt larger sizes in existing and planned ecological areas; and the need for a management authority to prepare management plans with goals, defined ecosystem boundaries, a management strategy, and a monitoring program.

The **Strategic Framework** further specifies that **representation should be the fundamental basis on which areas are established followed by maintenance of their ecological integrity**. Representation should be judged initially in relation to enduring features of the landscape such as landforms and physiographic conditions that significantly control regional ecosystem development and patterns. From this, jurisdictions are encouraged to develop ecosystem representation targets and corresponding site evaluation procedures employing some form of gap analysis.

To demonstrate the application of the **Strategic Framework** and provide guidance to jurisdictions and other relevant organizations, CCEA conducted the pilot Ecoregion Gap Analysis reported in this Part 2 document. The project employed three case studies representing widely differing settings in Canada that illustrate how existing efforts correspond with Council's generic methodology for selecting and evaluating ecological areas.

1.2 Concept of Enduring Features

As set out in the **Strategic Framework**, the principles and criteria for analyzing the level of representation achieved by protected areas within Canada's diverse ecoregions was developed and reported on by Peterson and Peterson (1991). That paper provided a review of the literature and a synthesis of author's opinions and interviews with other persons knowledgeable about protected area systems.

A fundamental conclusion of that work was that representation be judged in relation to enduring features of ecosystems and not in relation to themes that can change rapidly or are in high public profile at any given time. Examples of ecosystem features that can change rapidly are micro-climate and populations of certain species of plants, birds and mammals that adjust to major natural and human induced disturbances.

Consequently, landforms and soils and the ecological patterns that they control, are viewed as the most enduring feature of ecosystems and one on which the degree of representation can be evaluated best, at least at a "coarse filter" level of analysis. Plant and animal assemblages can change with time, as can ecological processes, so they are not the best features to capture the most stable ecological basis of Canada's ecosystems. Further, in adopting this "coarse filter" level, it is recognized that regionally based survey data should be employed rather than site-specific or species-specific data. Selection of actual candidate areas should focus on acquiring, whenever possible, undisturbed and natural ecosystems associated with the characteristic enduring feature(s).

The implicit assumption underlying the enduring features concept is that if the variation in landform and physiography as well as soils are adequately represented in terrestrial ecosystems, then the environments and site conditions that support representative plant and animal species and communities will also be captured. Landform/physiography, in combination with climate and hydrology, provides and controls the essential ingredients which determine the biotic response. For example, the soil composition of landform mainly controls nutrient regimes and soil moisture, whereas its form and elevation largely affects drainage conditions and micro-climate. In addition, landform is much more stable than biota, which can change dramatically over short intervals of time as a result of natural and human induced alterations. As Rowe (1992) notes so elegantly:

> *"geomorphology - landform, its composition and structure - is genetic for landscape ecosystems through its influence on local climate, drainage, soil formation and the recruitment of plants and animals...is the indispensable foundation of terrain analysis world-wide."*

Effectively, this mirrors the approach more generally referred to as Ecological Land Classification (ELC).

1.3 Ecoregion Gap Analysis

Building on the principles and approach set out in the **Strategic Framework**, the Ecoregion Gap Analysis involved the development of a methodology with which to develop a nation-wide system of ecological areas. This methodology would provide a means to assess representation of ecoregions as well as incorporate the concept of ecological integrity.

Four main tasks were identified as follows:

1. identify natural enduring abiotic features and biotic assemblages within three ecologically distinct areas of Canada using principles of representation adopted by CCEA;
2. develop a methodology which can be used for the development of a nation-wide system of protected areas;

3. identify the constraints imposed by data available for these regions relative to the diagnostic criteria and propose a minimum data set required to address such diagnostic criteria; and,
4. recommend design principles for protected areas based upon representation criteria and to ensure ecological integrity is maximized.

The Terrestrial Ecoregions of Canada was used by CCEA as the fundamental basis to determine generic representation requirements since it met the immediate needs for a nation-wide classification system (Gauthier 1992). Terrestrial ecoregions are regarded as the most comprehensive ecosystem framework and the CCEA notes that this is the coarsest scale at which candidate ecological areas should be evaluated and established (Gauthier 1992). The primary task of the Ecoregion Gap Analysis was to develop the methodology by which the ecological representation requirements for each ecoregion could be assessed systematically using a broad physiographic and landform framework as recommended by Peterson and Peterson (1991) and adopted by CCEA (Gauthier 1992).

To develop the methodology, three case studies representing distinctly different terrain and climate regions were undertaken. Each case study was framed with the foregoing tasks with the aim of developing principles and criteria relating to representation and ecological integrity based on available data. This report represents a synthesis of the three case studies (Enns 1993, Gauthier 1993, Geomatics International 1993). Guided by Council's **Strategic Framework**, these case studies provide the basis for the gap analysis methodology proposed in this report.

2.0 ECOREGION GAP ANALYSIS CASE STUDIES

National systems of mapping and classifying landforms through to ecosystem units exist. On a regional basis many other systems of mapping and classifying have been used. Unfortunately, this results in a plethora of terms which are applied inconsistently from jurisdiction to jurisdiction. Some of these differences are in name only, while others reflect fundamental differences in approach. It is not the intent of this paper to reach a consensus on, or even fully explain, terminology and the application of methods; however, it is important that the reader be aware of these complications. It is particularly important that those who attempt to apply the proposed methodology be cognizant of the situation to understand how best to use and manipulate the data.

This situation is improving and there have been a number of past and recent attempts to reconcile differences in both terminology and the boundaries concerning ecological units. For purposes of this paper, the standard ELC terminology and scale concepts, as developed by the Canadian Committee on Ecological Land Classification, have been adopted (*e.g.*, Environmental Conservation Task Force 1987). To this end, the methodology presented in section 3.0 and the data summary matrices in Appendices 1 and 2 attempt to cut across the morass of terminology and provide a generic system focusing on broad terms associated with the descriptions of physiography and landform, and the databases available to describe them.

Probably the most important element in understanding this approach and, ultimately applying the methodology, is relating information detail (map units and associated attribute data) to presentation scale. The ecoregion level in the classification hierarchy reflects areas which are defined primarily on the basis of their regional biophysical characteristics and mapped at scales ranging from about 1:1 000 000 to 1:5 000 000. More detailed levels of the hierarchy, for mapping purposes, equally emphasize local landform, soils and hydrology which, along with micro-climate, define response by vegetation and wildlife. Hence, the ecoregion level is particularly suitable as a framework within which enduring features based on stable regional landforms can be identified for assessing representation at a coarse filter level.

The following sections provide a brief summary of the key results from each of the three case studies: i) the Southern Interior of British Columbia; ii) the Prairies of Saskatchewan; and, iii) the northern Great Lakes-St. Lawrence Forest region in Ontario (Figure 1). While any number of ecoregions across Canada could have been chosen for study, the CCEA Gap Analysis Committee selected these three regions since they reflected a variety of landscapes and data suitable for developing the methodology. Thus, the committee felt that a case study in each of these regions would exemplify the difficulties in applying representation issues to regions of varying fragmentation, level of impact and data quality.

2.1 British Columbia Gap Analysis[5]

British Columbia is a leader among Canadian jurisdictions in attempting to develop and apply protected areas strategies and gap analysis on a province-wide basis. The vision, goals and methodologies developed to identify and select new protected areas are detailed in many documents, with the "A Protected Areas Strategy for BC" (1993) policy document and the "Gap Analysis Workbook for Regional Protected Area Teams" (1993) providing the most comprehensive reviews. Two primary goals are identified to complete the BC protected areas system, that of establishing a comprehensive system of viable representative protected areas, and that of protecting areas with special natural, cultural and/or recreational features.

The concept of representation forms the fundamental approach to identifying and evaluating areas for inclusion in the protected areas system. BC has adopted a mapped ecological framework based on two complementary classification systems; the ecoregion and the biogeoclimatic ecological classification systems. This mapped ecological framework forms the foundation for user gap analysis and is applied at both a provincial and regional level. The ecoregion classification system integrates landforms and climatic processes, encompasses both marine and terrestrial environments, and provides a rational

---

[5] Based on Enns (1993), with commentary by L. Goulet.

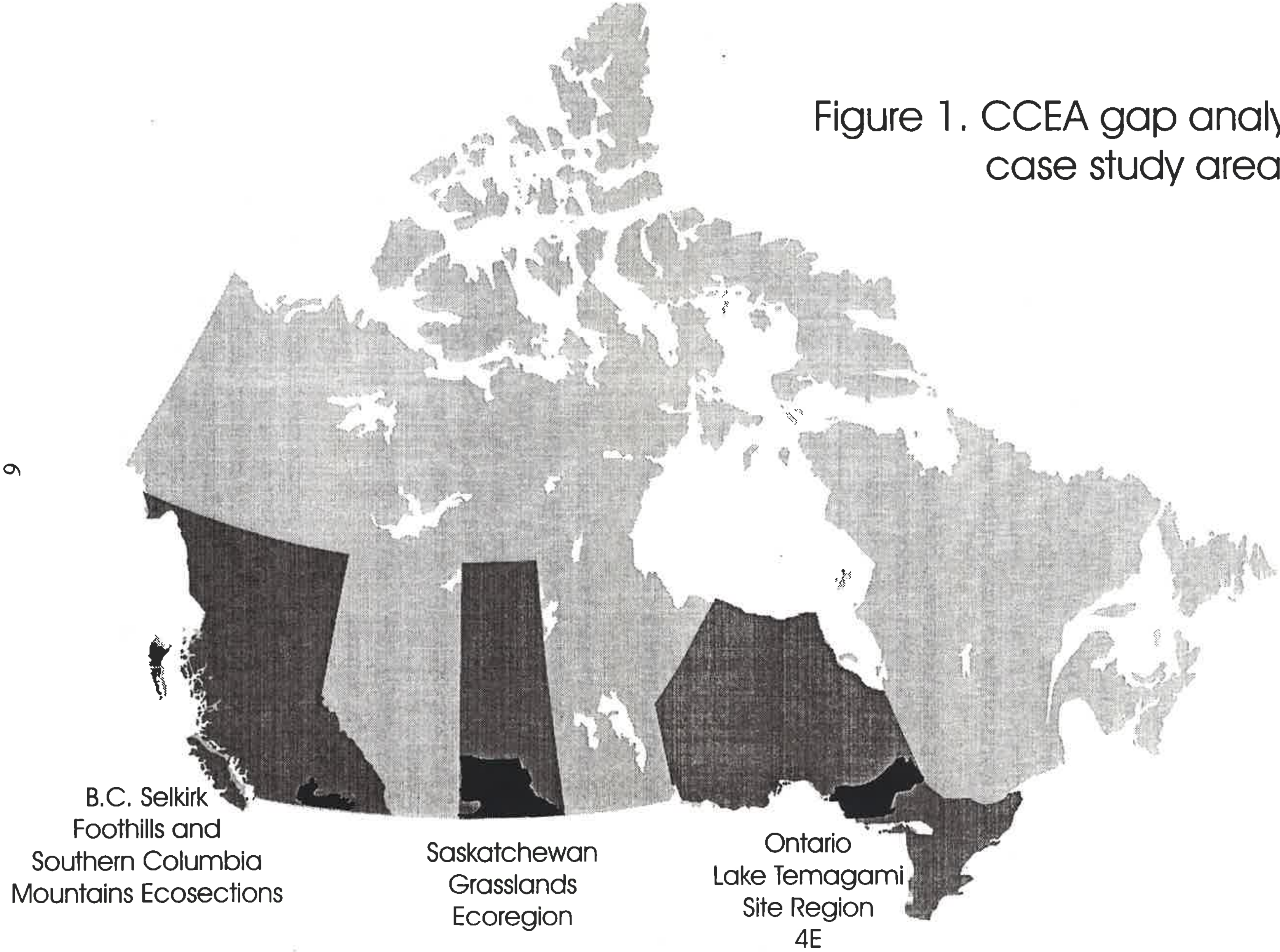


Figure 1. CCEA gap analysis case study areas.

basis for the first level of a framework for planning for a system of representative ecological areas. This system is comprised of 100 terrestrial and ten marine ecosections (equivalent to ecodistrict using Environment Canada's Terrestrial Ecoregion Classification).

In recognition that individual ecosections may possess considerable internal variation, the biogeoclimatic ecological classification system, which delineates ecosystem units based on a synthesis of vegetation, soil (including topography and parent materials) and climatic data, is used to divide the ecosections into finer units (*i.e.*, variation in plant communities). Also, the biophysical variation within these ecosystem units is further described and analyzed using a standard worksheet. The "target" is to represent each of the biogeoclimatic units within an ecosection in relative proportion to its occurrence in that ecosection. Further, the intent is to capture and represent characteristic sequences (topographic variation) of biogeoclimatic units within protected area proposals for each ecosection.

Employing these two ecological classification systems in combination is considered as the minimum approach to gap analysis in BC. As time and data constraints permit, other factors such as bedrock geology, landforms, physiography, hydrology, wildlife requirements and specific habitats of known importance (*e.g.*, old growth, wetlands, grasslands) must also be considered.

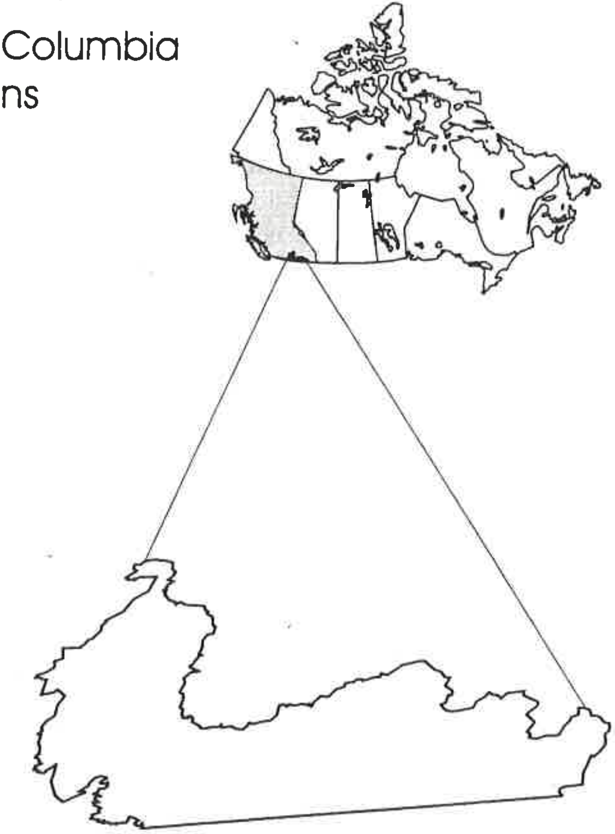
This basic methodology to identify and select representative protected areas is being applied province-wide through the multi-agency efforts of seven regional protected areas teams. However, it should be noted that various approaches have been used in different regions within the confines of the broad methodology outlined above. This flexibility is required to respond to three factors: 1) short timelines dictated by the various land use planning processes currently underway in BC (*e.g.*, the CORE Vancouver Island, Cariboo and Kootenay Regional Planning tables); 2) varying levels of data and resources available in different areas of the province; and, 3) regional differences in the nature and level of disturbance of the landbase.

Enns (1993), based on the information available at that time, reviewed the current state of the art in BC from the standpoint of objectives, methods, approaches to determining representation, and the process of selecting potential protected areas. In particular, Enns (1993) provides a summary of specific data types and gap analysis approaches employed in three ecosections: Kootenay, Kamloops and Chilcotin (see Figure 2).

As used in these studies, the actual selection of areas relative to determining representation was based on biogeoclimatic variants (forest type based), and/or employing a wide range of attributes including vegetation cover, hydrology, physiography, geology, degree of naturalness, old growth and other special habitats and wildlife within the biogeoclimatic variants.

Figure 2. B.C. Case Study Area

Selkirk Foothills and Southern Columbia Mountains Ecosections



Alplands in BC. Thin soils overlying bedrock in combination with changes in slope aspect and drainage patterns results in a mosaic of vegetation communities.
Photo: WWF Canada/Ric Careless

Cane Lake represents a subdued mountain relief dissected by wide valleys and trenches that is typical of most of the Selkirk Foothills. At mid-elevations the dense forest cover may be interrupted by small wetlands and lakes.
Photo: Province of BC, Ministry of Environment, Lands and Parks

Dry interior valleys characterize south-central BC. This photo depicts a landscape with rolling hills. Lower precipitation and higher temperatures result in a semi-arid vegetation complex.
Photo: WWF Canada/Jeff Shatford

Enns (1993) notes that the Protected Area Strategy (PAS) Workbook currently in use in BC is being applied at more detailed scales than that required for CCEA's **Strategic Framework**. One of the common elements of the BC protected areas strategy is its use of biotic and abiotic assessment forms to determine the composition or make-up of ecosections. Generally these assessment forms are very detailed and as such, are most useful at very detailed levels of study (*e.g.*, 1:50 000 to 1:250 000 scales).

Enns (1993) provides a set of design principles and recommendations for protected areas strategies. The use of coarser scales (*e.g.*, ecoregion), emphasizing landform and physiography, was considered by Enns (1993) as a useful approach to assist the BC strategy in terms of setting priorities and determining an overall framework within the more detailed assessments already under way. Enns (1993) expresses concern about the range of gap analysis approaches being used in BC to identify gaps in the protected areas system, especially regarding the ability of the methodologies to appropriately address representation targets. In particular, Enns (1993) indicates that a key shortcoming of the BC strategy is the inconsistent use and interpretation of landforms and hydrology. Enns (1993) concludes that the current presentation of biophysical factors with the PAS Workbook does not provide "a clear vision of what constitutes representation or where priorities should be applied on the list of criteria".

Some of her views are not shared by BC ecologists and protected area planners who are associated with the BC PAS. However, they readily recognize that the methodologies being developed have some weaknesses and are still evolving as more is learned about the fine "art" of selecting representative protected areas.

2.2 Saskatchewan Gap Analysis[6]

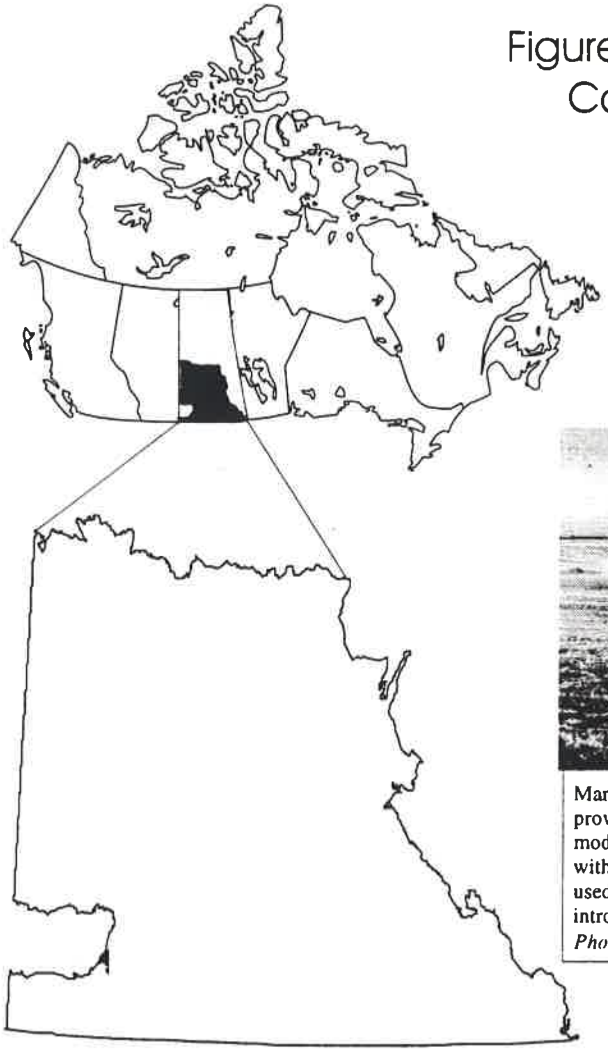
Saskatchewan is comprised of four ecozones (plains, boreal plains, boreal shield, taiga shield) and 11 ecoregions. The CCEA Gap Analysis Committee felt that a case study in the Grassland Ecoregion of Saskatchewan would exemplify the difficulties in applying representation issues to a fragmented, heavily impacted, data-poor region. Gauthier (1993) outlines two major tasks undertaken in the Grassland Ecoregion case study (Figure 3).

1) To delineate and define the Grassland Ecoregion of Saskatchewan and hierarchical classes within that ecoregion that can be used for protected area planning according to criteria specified by CCEA in its systems framework document. A review of existing ecological classification schemes for Saskatchewan led to selection of Agriculture Canada's agro-ecological scheme. It was decided that the soil landscape should be used as the basis for defining a grassland landscape region in Saskatchewan. Evaluation of these data resulted in a Grassland Ecoregion comprised of two land

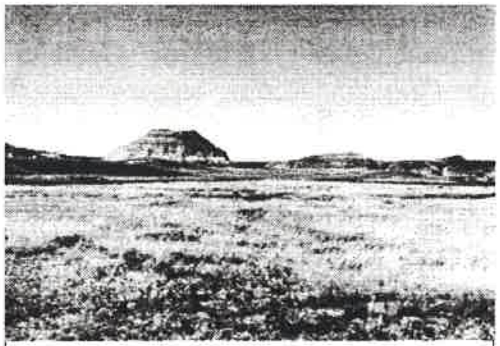
---

[6] Based on Gauthier (1993).

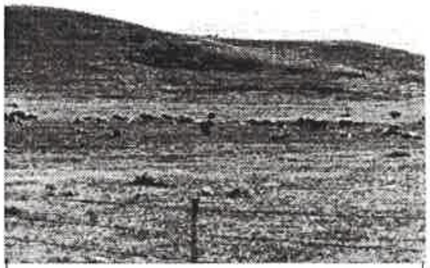
Figure 3. Saskatchewan Case Study Area.



Marking the northern extension of grasslands in the province, the landscapes of this ecoregion are heavily modified. Agriculture is by far the dominant land use with about half of the area cultivated and the remainder used for extensive grazing of livestock on native or introduced grasses.
Photo: Government of Saskatchewan.



The mixed grassland is the driest area of the province with diverse landscapes that include level, glacial lake plains; dune-covered, sandhill areas; hilly, pothole country; and rolling expanses of native grassland and intermittent "badlands".
Photo: Government of Saskatchewan.



Most landscapes in the moist, mixed grassland are comprised of glacial till with short, steep slopes and numerous undrained depressions or sloughs.
Photo: Government of Saskatchewan.

resource areas (ecodistricts), nine land areas (ecosections) and 397 soil landscape units for which there are over 25 specific attribute characteristics. Four of those attributes were selected as the criteria to be used at the coarse filter level to define landscape boundaries: soil development, soil texture, surface form (macrorelief), and topography (elevation).

2) To develop criteria based on the guidelines in CCEA's systems framework to categorize the extent to which existing protected areas are representative of landscapes and to apply those criteria to the Grassland Ecoregion. Using the abiotic criteria (soil development, soil texture, surface form, and topography), four variables defining the grassland landscape were identified: regional land form, surface land form, soil parent material and slope. An ecosystem matrix approach was developed using those four variables to define representative, broad physiographic types. Dominant combinations in the Grassland Ecoregion are morainal plain and lacustrine plain, which comprise 61% of the total area. Other common combinations are morainal-hill-land and morainal-tableland, which together comprise 19% of the total area. The extent of protected areas in the Grassland Ecoregion was assessed for each of the nine ecosections in the region relative to four variables defining the landscape: regional land form, surface land form, soil parent material and slope. That analysis indicated that for any of the major variables used to define landscapes, existing protected areas are not proportionately representative of those landscape variables, *i.e.*, protected areas in the Grassland Ecoregion are not representative of major landscapes at the coarse filter level used in this study. Gauthier (1993) also compared the proportional representation of selected abiotic variables in the Grassland Ecoregion to their proportion within protected areas. That analysis showed a bias in existing protected areas towards particular landscapes, and that existing protected areas do not proportionately represent[7] the full diversity of landscapes within the region. The assumption behind using abiotic factors to define enduring landscapes was that by capturing representative portions of those landscapes, the biota on those landscapes would also be represented. That assumption remains to be tested in the Grassland Ecoregion.

Biotic criteria pose a special problem in this ecoregion. The best, available comprehensive information merely categorizes areas as dominant or subdominant vegetation relative to grassland, cropland or shrubland. Furthermore, there are no land use maps for this region that identify the status of land cover. As surrogates for these attributes, assessments of the extent of cultivated and non-cultivated land and grazed and non-grazed land were made. There are no soil landscape units within the region that have not been cultivated or grazed for less than 20% of their area. Given the coarseness of the database, that result suggests that what remains in a relatively undisturbed state is very small and heavily fragmented. There is also a paucity of information on animal species at the coarse filter level. Ideally, each landscape unit should be assessed in terms of its faunal dynamics and composition. There is no information to allow that to be done. It seems clear that if a policy is adopted in the region to protect relatively large areas of representative landscapes based on abiotic features, that large amounts of disturbed biotic communities will be captured in the process. While these can by no means be considered to be representative

---

[7] Proportional representation in this case study refers only to numerical proportion. It does not refer to **adequacy** of representation in the context of maintenance of biodiversity and ecological integrity.

of previous native vegetation communities, they may offer significant opportunities for restoration.

Conclusions

There are substantial data gaps that need to be filled to adequately assess representation for protected ecological areas at even the coarse level in the Grassland Ecoregion. Gauthier (1993) detailed data constraints in terms of five issues: (1) temporal/spatial coverage; (2) accuracy/precision; (3) attribute characteristics; (4) data access; and, (5) general issues related to study design, "meta-data" (data about the data) and information systems management. A list of minimum data sets needed to assess representation for the Grassland Ecoregion were identified.

Gauthier (1993) concluded that prospective sites for protected area designation in the ecoregion should be assessed in relation to the degree to which they capture representative portions of enduring landscapes, and then in terms of: (1) the occurrence and extent of representative native biota, *i.e.*, protect remnants; (2) the capability of the landscape for restoration of native biota; and, (3) the occurrence and status of rare, threatened or endangered species. Site selection will ultimately also have to consider, in an explicit integrated fashion, demographic, social and economic variables.

The situation in the Grassland Ecoregion provides a practical rationale for supporting the need to focus on indicator or focal taxa at the coarse landscape level. Ingram (1992) proposes a three-tiered analysis related to focal taxa at the landscape level:

step 1 - determination of focal taxa;
step 2 - determination of the types of minimum requirements for each focal taxon; and,
step 3 - translation of minimum requirements into tangible elements which can be surveyed, inventoried and monitored across the landscape units.

Ingram (1992) suggests that for biota, the following constitute a workable set of landscape indicators: population size; number of populations; area; environmental gradients (*e.g.*, soil, elevation, precipitation, aspect, salinity); habitat features and associated species; successional phases with disturbance factors; characterization of minimum requirements in terms of protected area cores (takes into consideration, size, shape, contiguity); characterization of minimum requirements in terms of protected area buffers (considers edge, size, land use); characterization of minimum requirements in terms of protected area corridors; and characterization of minimum requirements in terms of protected area barriers. The specific criteria used by experts to delineate areas that should be protected include: biodiversity/ecodiversity; genetic diversity; ecological functions; rare, threatened and endangered species (as indicators of ecosystem loss); potential for restoration; inaccessibility; corridors for linkages; spatial separation, distance, spatial orientation; physical/geological values; archaeological, paleontological; benchmark for evaluating condition; aesthetics; and spiritual value. The criteria outlined above provide a basis for continued work to apply CCEA's framework for developing a system of protected areas based on representation and integrity in the Grassland Ecoregion.

2.3 Ontario Gap Analysis[8]

In Ontario, the concept of ecological representation has been adopted as a central principle in selecting nature reserves, other provincial parks and areas of natural and scientific interest. In order to demonstrate CCEA's approach utilizing enduring features in an Ontario context, an independent case study was conducted on a segment of the forested Canadian shield in north-eastern Ontario (Figure 4).

The Ontario case study, conducted by Geomatics International, utilized the Lake Temagami Site Region 4E (approximately equivalent to the Chapleau Plains Ecoregion) which represents a part of the northern Great Lakes-St. Lawrence Forest region (Rowe 1972). The analysis was focused specifically to determine the broad physiographic composition of the region using both ELC databases and single theme abiotic databases. This case study was designed to clearly establish what broad physiographic complex(es) characterize Site Region 4E, the boundaries of which are defined using temperature and precipitation, <u>at the scale of ecoregion delineation (*i.e.*, approximately 1:1 000 000)</u>; the relationship of these abiotic data to biotic data; and how ecological integrity could be maximized in this Boreal-Great Lakes transitional ecosystem.

Site Region 4E has been divided into five site districts (Hills 1961) or four Ecodistricts (Wickware and Rubec 1989) primarily on the basis of landform and physiographic variables. From an analysis of the abiotic data, it was determined that the physiography of Site Region 4E was best characterized by two broad complexes relating approximately to the central shield uplands, and the Cobalt clay plain. Thus, to obtain adequate protected area representation of Site Region 4E, both of these physiographic complexes will need to be captured, including the full range of variability associated with each complex (*i.e.*, with respect to slope, drainage, moisture and topographic setting).

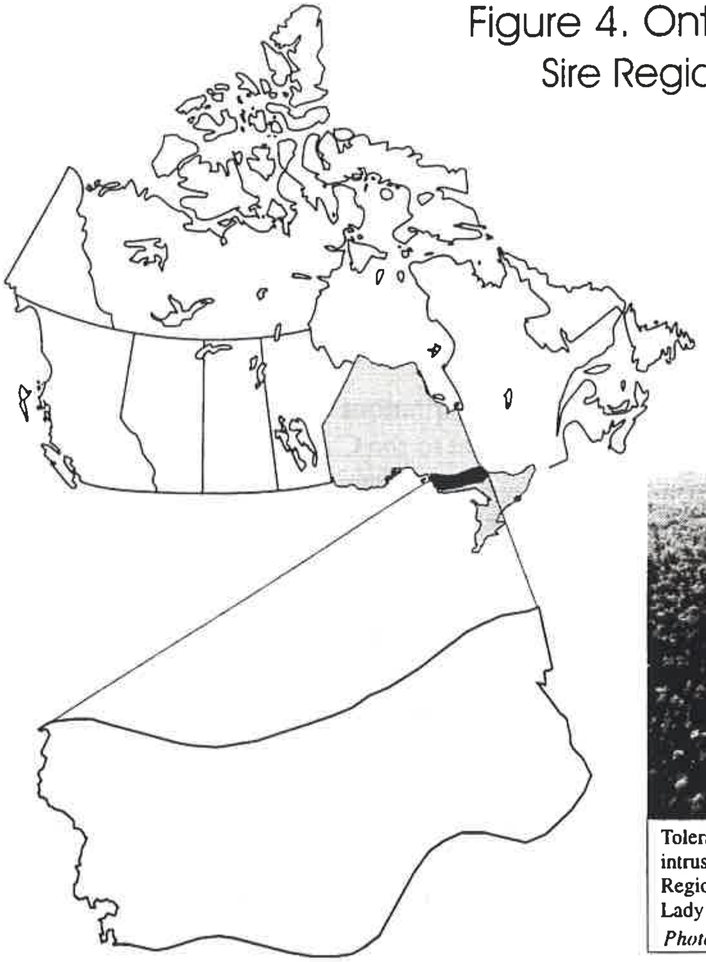
To undertake the gap analysis for Site Region 4E, a six step process was developed which addressed the following: i) physiographic characterization of the Ecoregion/Site Region; ii) identification of elements of representation; iii) determination of spatial requirements; iv) mapping of representative earth science/vegetation units; v) assessment of existing protected areas adequacy; and, vi) identification of remaining representative areas.

The determination of the amount of land area to be protected, in terms of maximizing ecological integrity within the protected area strategy, is based on the concept of protecting minimum viable populations (MVPs) of the largest carnivores and ungulates in each area. It is hypothesized that by protecting the larger representative landforms and the populations of the largest mammals inhabiting them, the smaller and rarer species will probably also be protected.

---

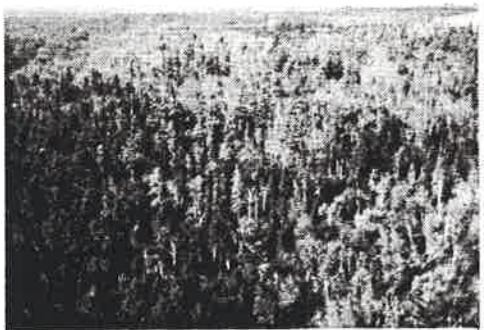
[8] Based on Geomatics International (1993), with commentary by T. Beechey.

Figure 4. Ontario Case Study Area.
Sire Region 4E - Lake Temagami



Tolerant hardwod forest landscape with boreal intrusions on rolling uplands in eastern Site Region 4E.
Lady Evelyn Smoothwater Wilderness Park.
Photo by T. Beechey.

Rugged Precambrian headlands punctuated with molded shores and dunes, on the east coast of Lake Superior, feature a boreal-tolerant hardwood forest transition (Lake Superior Provincial Park, Sand River Nature Reserve in the foreground).
Photo by T. Beechey.



Old-growth forest landscape dominated by White Pine (Pinus strobus) on till-mantled hills of the interior plateau of Site Region 4E. Tikamagenda Lake Old-Growth Forest.
Photo by P. Kor.

It is also noted that rare and endangered species must be protected under other programs as they often inhabit specialized or unique habitats that may not be captured using the methodology developed due to its coarse filter level of detail.

The case study for Site Region 4E corresponds with the conceptual approach and methodologies already employed by the Ministry of Natural Resources to assess terrestrial ecological representation for protected areas. Through its efforts on provincial parks, areas of natural and scientific interest and other natural heritage areas, the Ministry seeks to represent the different landscapes, biotic communities and distinctive species associations characteristic of the site regions and site districts of Ontario. This work takes its direction from a provincial framework which organizes ecological diversity for protected areas planning and management. This framework provides the basis to describe the ecological diversity within existing protected areas and to identify and select new areas required to address gaps in representation (McCleary *et al.* 1992).

Different ecological situations throughout Ontario have dictated three different but complementary applications of the framework. In the settled site regions of southern Ontario, work has focused on assessing remnant natural areas in the context of broad physiographic units, biotic communities and species occurrences. In the far north, a more generalized approach has been taken on the unforested wetlands in the Hudson Bay Lowland working from a combination of broad physiographic subdivisions and national and provincial wetland classification systems. The central, northern forested site regions (including Site Region 4E) have adopted a stronger physiographic approach utilizing existing terrain mapping, combined with an assessment of the vegetation types associated with the various landforms in the regions.

The Ministry's work in Site Region 4E and neighbouring forested site regions to the north and south has utilized the Ontario Land Inventory Landscape Unit map series. At a scale of 1:250 000, this series provides a finer sieve than that applied in the case study. The mapping discriminates landscape units on the basis of soil parent material, depth of soil to bedrock, and broad relief classes. Together, these parameters are in themselves, or control, the principle ecological determinants (soil type, nutrients, soil moisture and microclimate) which govern the development of vegetation. In simple terms, landscape units are productivity units, and their pattern in the landscape gives rise to the characteristic patterns that distinguish site districts from one another.

For purposes of assessing ecological representation at broader scales, the landscape units have been aggregated into larger physiographic complexes called biophysiographic units. This aggregation emphasizes pedogenic relationships of soil parent materials and mode of deposition as depicted on surficial terrain analysis mapping at 1:250 000. The broader biophysiographic units derived through this aggregation can be depicted and analyzed to determine representation at scales of 1:500 000 to 1:1 000 000. These biophysiographic units and scales correspond with the enduring features approach of CCEA, as generally demonstrated through the case study for Site Region 4E.

To apply the ecological framework, the Ministry has adopted a consistent methodological approach for gap analysis, which is conducted through standardized surveys and assessment of the site regions and site districts. This approach incorporates three major study phases addressing the analytical steps outlined in the case study, with the addition of reconnaissance field surveys to map, describe and evaluate candidate ecological areas. The process conforms closely with that prescribed by CCEA for the survey and evaluation of ecological areas (Beechey 1989). In some cases, these surveys are supplemented with more specific theme studies of particular types of ecosystems, such as old-growth forests, prairies and alvars.

Along with representation, ecological integrity is among the considerations applied by the Ministry in its efforts to select and design protected areas. Unlike the case study, which only utilized the idea of minimum viable populations, the Ministry's approach applies a wide range of considerations including size, shape, area objectives, compositional and functional integrity and surrounding land use in the selection and design of ecological areas. For some categories of protected areas, such as wilderness parks, minimum size and age distribution standards reflecting these considerations have been set to guide the development of the system. For example, the policy to establish one wilderness park at least 50,000 hectares in size, in each site region, has been satisfied in 9 of the 11 site regions in northern Ontario (including Site Region 4E) where it currently is feasible to achieve this target. Ecological representation and integrity considerations also guide the establishment and management of nature reserves, other provincial parks and areas of natural and scientific interest (McCleary *et al.* 1992).

2.4 Summary of Key Findings

Table 1 summarizes the five levels of mapping hierarchy established as part of the ELC approach. This table indicates the approximate scales of information pertaining to each level and identifies the type of biotic and abiotic information generally available across Canada. The most apparent data gap is the lack of information on vegetation, particularly across the middle three levels. Also, the mapped biotic information which is generally available tends to focus on forest canopy types and tree species to the exclusion of understory species. From this table, the need for reliance on regional landform and physiography for broad scale interpretations ("coarse filter") relating to ecological area selection and evaluation is particularly evident.

The coarse filter of analysis requires “top-down” structuring whereby ecoregions are identified as the geologically stable basis for representation followed by more detailed levels of study. This approach enables the determination of the broad physiographic composition of the ecoregion, followed by definition of the specific physiographic types occurring within each physiographic complex (using ecosection level of landform description). This latter level, is the key level for which representation should be established, existing protected areas evaluated, and new ecological areas selected.

Table 1: **Levels of ecological land classification indicating surrogate data bases and map scales generally available within Canadian jurisdictions determining representation of ecological areas.**

LEVEL	ECOLOGICAL LAND CLASSIFICATION[1]	ABIOTIC EQUIVALENTS/DATA SOURCES	SCALE OF MAP DATA	BIOTIC EQUIVALENTS/ DATA	SCALE OF MAP DATA
I	Ecoregion	Physiographic Regions[2]	1:5 000 000	Forest Regions[4]	>=1:1 000 000
		Ecoclimatic Regions[3]	1:7 500 000		
		NTS	1:1 000 000		
		Soil Landscapes of Canada	1:2 000 000		
II	Ecodistrict	Quaternary Geology Maps	1:1 000 000	Forest Sections[4]	>=1:1 000 000
		Surficial Geology Maps	1:506 880		
		NTS	1:500 000		
III	Ecosection	NTS	1:250 000	ND	1:250 000
IV	Ecosite	Provincial or GSC Quaternary Maps	1:50 000 to 1:100 000	ND	1:50 000
		NTS	1:50 000		
V	Ecoelement	ND	1:10 000 to 1:20 000	Provincial Forest Resource Mapping	1:10 000 to 1:20 000

NOTES:

ND	- No Data Available (or only partially available)
NTS	- National Topographic Series (Energy Mines and Resources Canada, Surveys and Mapping)

[1] The ecological land classification ecoregions and ecodistricts are ecosystem and biophysical units; see Wickware and Rubec (1989)
[2] Bostock (1970); [3] Ecoregions Working Group (1989); [4] Rowe (1972)

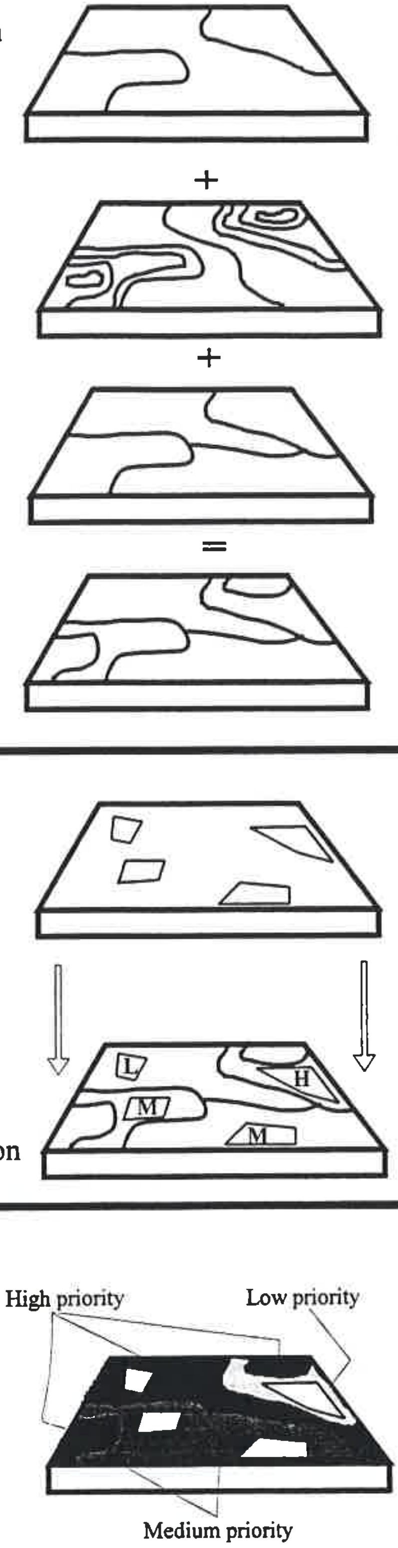
The specific types of abiotic data generally available include both physiography / topography (as expressed by direct physiographic mapping, *e.g.*, Bostock (1970), and by NTS mapping) and mode of deposition (quaternary/surficial geology). The soil landscape and soil mapping inventories conducted by the federal government are other important sources of information on the composition and surface form characteristics of landforms. These represent the minimum data set required to analyze representation. Additional data pertaining to features such as drainage, soil type, nutrient status and so on may be available for selected locations and should be utilized wherever possible. However, the results of the case studies suggest that, at least at the coarse filter level, one can determine the key elements of landform representation pertaining to actual or likely biotic diversity from a combination of mode of landform deposition, macro-relief and slope position. Macro-climate is included by definition at the ecoregion/ecoclimatic level of partitioning.

3.0 GENERIC METHODOLOGY FOR IDENTIFYING REPRESENTATIVE AREAS

Based on the results of the case studies it is apparent that the selection of only one area to represent any one ecoregion would not result in complete representation of an areas essential coarse level physiographic composition, unless that area were extremely large. Thus as a minimum, the number of sites required to ensure adequate representation of Canadian ecosystems is some multiple of the number of ecoregions. In some instances, representative protected areas could straddle a boundary between two or more ecoregions. However, it may not be possible to find an appropriate area located in close proximity to the boundaries of two or more ecoregions, as climatic factors as well as landform differences between ecoregions are more strongly expressed with increasing distance from the boundary.

The following method is proposed to determine coarse level representation, evaluate existing protected areas and determine size requirements required to maximize ecological integrity. In some cases, representation of a particular enduring feature may already be achieved within existing protected areas, in other cases new sites will be required. Part A of the methodology involves six distinct steps. Steps 1 to 3 focus on the determination of representation, step 4 assesses existing areas, and steps 5 and 6 allow for the selection of additional areas. Figure 5 illustrates the six steps and the required information layers and sources. Part B deals specifically with the determination of area requirements to maximize ecological integrity. Reference to ELC terminology and corresponding scales and levels are as defined in Table 1.

Figure 5. Schematic of methodology, themes, and data sources to access representation and ecological integrity



STEPS	INFORMATION LAYERS	INFORMATION SOURCES
	Ecoregions based on Climate and Broad Physiography	Protected Areas System Planning Frameworks used by Canadian Jurisdictions
Steps 1, 2, and 3 Characterization of ecoregion, physiography and landscape units	Topographic Relief	
	Surficial Geology	Soil Landscapes of Canada 1:1 000 000 scale *(Supplemental Information: National Topographic Series 1:1 000 000 scale and Quaternary Geology/ Surficial Deposit Maps 1:1 000 000 or 1:500 000 scale)*
	Enduring Features within Ecoregions	
		EXPLANATIONS
Step 4 Assessment of adequacy of protected areas based on coarse filter landscape criteria	Existing Protected Areas	Rank of the representativeness of existing protected areas relative to coarse filter level landscape criteria. Existing protected areas are judged to be adequate if they capture sufficient proportions of landscape features and are of sufficient size.
	Adequacy Assessment e.g., high (H), medium (M) and low (L) representation	
Step 5 Identification of candidate ecological areas	Gaps in protection relative to area requirements and a ranking of regions	Regions in which there are no protected areas or the existing protected areas are not adequate constitute the gaps in which new ecological areas should be situated.
Step 6 Evaluation and selection of new ecological areas	Area specific mapping and description of landscape units, vegetation, flora and fauna	Available documentation plus original field surveys to map, describe and evaluate biophysical systems and features

3.1 Part A - Determination of Representation

STEP 1. Characterization of Ecoregion
Purpose: To determine the physiographic composition of the ecoregion.

- Select ecoregion of interest according to the <u>Terrestrial Ecoregions of Canada</u>;
- Characterize climatic conditions according to the <u>Ecoclimatic Regions of Canada</u> database;
- Confirm the presence or absence of significant lake moderating effects or lee (rain shadow) effects using relief from NTS maps and other climate data; and,
- Determine dominant physiographic condition(s) at the regional landform level from ecoregion level database.

> If ecoregion or equivalent database is not available, consult level I surrogate data including <u>Physiographic Regions of Canada</u>, the <u>NTS</u> map sheets, or the <u>Soil Landscapes of Canada</u>.

STEP 2. Characterization of Physiography
Purpose: To characterize the broad physiographic complex(es) occurring within the Ecoregion according to major substrate and physiographic type(s).

- Refer to ecodistrict level database;
- Determine primary differences among ecodistricts which occur within the selected ecoregion; and,
- Define those areas most representative of the sub-regional level physiographic conditions determined in Step 1.

> If ecodistrict or equivalent database is not available, consult <u>level II surficial geology</u> information in combination with <u>NTS</u> map sheets.

STEP 3. Determination of Representative Landscape Units
Purpose: To characterize each broad physiographic type identified in Step 2 according to basic components affecting biotic diversity (mode of deposition, surficial texture, relief/topography, and slope position).

- Delineate landscape complexes by summarizing/generalizing the degree of brokenness, soil texture, and soil depth using mode of deposition from level II or level III surficial geology maps;
- Delineate aquatic complexes from level II data on lake/stream physical condition and soil/bedrock chemical conditions.

> The purpose of this step is to identify major landscape (land and aquatic) complexes using existing mapping. It is important to note that the purpose of this step is not to identify actual areas to be protected, but to identify the features that must be protected.

Level III surficial geology maps (*i.e.*, + 1:250 000 scale) or soils maps (+1:250 000) can be used to determine soil texture and mode of deposition. Degree of brokenness can be approximated using the equivalent scale NTS sheets.

If equivalent surficial geology mapping or soils maps are not available, then a significant data gap exists. This could be filled by attempting to generalize any available level IV surficial geology maps or undertake original interpretations from high altitude aerial photography (1:60 000) or satellite imagery.

STEP 4. Assessment of Adequacy of Existing Protected Areas
Purpose: To determine degree of representation captured within existing protected areas.

- Undertake a screening exercise to determine the extent to which landscape units identified in previous step are captured in existing protected areas and define protected areas using the IUCN criteria from Peterson and Peterson (1991). These areas must be mapped out and superimposed on the landform complexes and dominant biotic or plant associations derived in step 3.
- Evaluate existing areas with respect to their ecological integrity (Part B, see next page). Ideally, protected areas should be large enough to incorporate sufficient habitat to fulfill the minimum area requirements for representative top predator(s), large herbivore(s) and reclusive species populations, and maximize the range of seral stages and macro vegetation units.
- Decide whether large, regional scale disturbances can be accommodated within protected areas. If there are several, linked protected areas that together exceed the size of regional disturbance and could serve as faunal refugia, then each of the individual areas can be smaller than the area for a regional disturbance.

The product of this step is a list of enduring features which are not adequately represented in existing protected areas.

STEP 5. Identification of Candidate Ecological Areas
Purpose: To complete requirements for achieving complete representation by identifying additional areas necessary to fulfill representation determined from steps 1 through 3.

- Locate natural areas (*i.e.*, undeveloped, with as little human disturbance as possible) which include as many of the unrepresented landscape units as possible (as defined in step 3);
- To the extent possible, locate vegetation associations which maximize inclusion of seral stages (*e.g.*, old-growth forests) that are not adequately represented in existing protected areas.

  It is assumed that selecting areas that are large and undeveloped, the communities there will be most representative of the region with respect to ecological structure, species composition, diversity, functional organization, and process. Fulfillment of this requirement contributes to the ecological integrity of selected areas.

- Select areas based on the representative elements in steps 2 and 3 which are not already captured in protected areas. This is an iterative exercise which will involve identification of areas based on a combination of earth and life science features. Rowe (1972) and authoritative regional sources should also be consulted to determine the degree of variability in the vegetation;

- Determine size requirements based on the minimum area requirements for regional disturbance and wildlife MVPs (Part B). Wherever possible, size and representation requirements should be satisfied by expanding and/or linking existing natural areas; and,
- Consider fulfilling faunal requirements (primarily size) in part through management techniques on land adjacent to protected areas, where delineating large protected areas may no longer be possible.

STEP 6. Evaluation and Selection of New Ecological Areas
Purpose: To ground truth analysis with original field surveys, to enable mapping, description and documentation for evaluating and ranking areas.

- Conduct standardized assessments of candidate areas utilizing conventional air photo interpretation, enhanced remote sensing and standardized field surveys and reporting; and,
- Cooperatively assess candidate areas to determine those that provide the most diverse and least disturbed systems.

> To capture the maximum number of site types, as wide a range as possible of degree of brokenness (topography-relief) and soil texture should be selected for each landscape unit. Selection of a wide range of landscape units will maximize the diversity of vegetation associations and wildlife habitats included.

3.2 Part B - Determining Area Requirements

Purpose: To maximize ecological integrity of existing and additional ecological areas selected to achieve representation.

Once the representation requirements have been established, new areas and existing protected areas will need to be designed/assessed on the basis of maximizing ecological integrity. This goes well beyond the need to simply capture representative physiographic site - biotic complexes. The minimum size of areas to be protected must also be determined; however, it should be recognized that such estimates will vary depending on a wide array of factors in addition to the biophysical attributes of an ecoregion or ecodistrict, such as surrounding land use. Some principal factors to consider can include, where appropriate, the following:

- Determine natural patterns and relative significance of units in terms of their inherent biophysical diversity and spatial extent.

> In essence, this factor deals with "representational" integrity. This aspect of integrity is concerned with the need to incorporate characteristic landscape patterns and systems that maximize the representation of ecological features and functions at landscape scales. Design cues for applying this concept should

concentrate on broad landscape/physiographic patterns and diagnostic environmental gradients that characterize specific ecodistricts.

- Determine the area of the largest regional disturbances.

  In areas where fire is an important natural disturbance, investigate fire records to determine the largest historical fires (or other disturbances) in the area in which representative sites are being sought. The largest disturbance in the last 100 years should be used for determining spatial requirements (to be consistent with the assumptions for minimum viable populations), where such data are available.

- Identify the largest top carnivore, largest herbivore, and other reclusive species that require large areas and/or are intolerant of human presence which are indigenous to the area under consideration. Use guidelines provided by the literature (*e.g.*, Belovsky 1987) and species specific data, and estimate the area required to sustain minimum viable populations (MVPs) for a minimum of 100 years.

  It is important to remember that the prime focus of this exercise is not the preservation of the indicator species themselves, but the use of them to define areas large enough to capture the needs of all representative flora and fauna.

  The species ranges and areas of disturbance will be used for determining the size of areas, but are initial estimates only and can be refined when information regarding the habitat quality of candidate areas is known. Areas with excellent habitat for indicator species will not need to be as large as areas with marginal habitat.

- Determine area specific needs and network size and design requirements in relation to the foregoing ecological requirements, existing policies for protected areas, requirements to complete the system, existing land use and development constraints, and opportunities for long term restoration.

It is important to note that the foregoing approach is meant only as a guide. It is seldom possible to capture the large sizes required by the largest fires or the most demanding species. In ecoregions which are mostly forested, consideration should be given to management prescriptions for areas between and adjacent to protected ecological areas (such as via the use of wide buffer zones, selective cutting, rotational cutting, *etc.*) as well as the use of functional corridors. In settled portions of Canada, the use of natural corridors is essential (several such "natural heritage systems" are currently being incorporated into municipal Official Plans in southern Ontario). In general, the larger the area, the greater its ability to withstand disturbance, incorporate natural ecological processes, and be self-regulating. More detailed discussions pertaining to ecological integrity can be found in Noss (1992, 1995).

4.0 SUMMARY AND CONCLUSION

Along with CCEA's **Strategic Framework** (Gauthier 1992), this report provides a methodology for undertaking Ecoregion Gap Analyses and for assessing and selecting representative Protected Areas. The landscape matrices (Appendix 1: Tables 2 and 3) provide a standardized approach for determining the "coarse filter level" of landform representation utilized in steps 1 through 3 of the methodology. Their value lies principally in helping to organize the broad scales of information to describe hierarchically nested ecological systems as illustrated in Table 1. These matrices could easily be supported with more detailed biotic and abiotic characterizations (ecosection level of hierarchy, Table 1), which may form the basis of existing or planned programs in various jurisdictions.

In undertaking evaluations of existing protected areas and gap analysis on a national basis, it is essential that comparable information and scales be utilized. The appropriate scales and data are outlined in the methodology. It is understood that some further refinement of these matrices, particularly the Landscape Matrix (Appendix 1: Table 3) may be required. It is further understood that some or all jurisdictions may wish to undertake (and are encouraged to do so) a more detailed landform matrix synthesis allowing for data representing the ecosection and ecosite levels of detail.

5.0 REFERENCES

Beechey, T.J. 1989. Guidelines for the selection of ecological areas. Occasional Paper Number 5, Canadian Council on Ecological Areas.

Belovsky, G.E. 1987. Extinction models and mammalian persistence. in M.E. Soule (Ed.). Viable Populations for Conservation. Cambridge University Press, Cambridge.

Biodiversity Working Group. *in prep*. Canadian biodiversity strategy. Biodiversity Convention Office. Ottawa, Ontario.

Bostock, H.S. 1970. Physiographic subdivisions of Canada. in geology and economic minerals of Canada. R.J.W. Douglas (ed.), Geological Survey of Canada, Dept. Energy, Mines and Resources, Queen's Printer, Ottawa: 10-30; accompanying map -Physiographic Regions of Canada- scale 1:5 000 000.

CCEA. 1994. Canadian Council on Ecological Areas business plan 1994-1997. CCEA Secretariat. Ottawa, Ontario.

Enns, K.A. 1993. Achieving representation in protected area strategies in BC: a problem analysis. Unpublished Report prepared for CCEA.

Environmental Conservation Task Force. 1987. Ecological land survey guidelines for environment impact analysis. Ecol. Land Class Serv., No. 13. Lands Directorate, Environment Canada, Ottawa, Ontario.

Gauthier, D.A. (editor) 1992. Framework for developing a nation-wide system of ecological areas. Part 1 - a strategy. CCEA Occasional Paper Number 12. Ottawa, Ontario.

Gauthier, D. 1993. Representation of four landscape variables in protected areas, Grasslands Landscape Region, Saskatchewan. Unpublished Report prepared for CCEA.

Geomatics International Inc. 1993. CCEA case studies on representation ecoregion gap analysis: site region 4E, Ontario. Unpublished Report prepared for CCEA.

Geomatics International Inc. 1994. Ecoregion gap analysis: part 2, framework for developing a nation-wide system of protected ecological areas. Unpublished Report prepared for CCEA.

Gray, P.A. and C.D.A. Rubec. 1989. National registry of ecological areas. Canadian Council on Ecological Areas. Ottawa, Ontario. 2 volumes with updates.

Hills, G.A. 1961. The ecological basis of land use planning. Res. Rept. 46, Ont. Dept. Lands and Forests, Toronto, Ontario.

Ingram, G.B. 1992. Landscape indicators for conservation of biological diversity: an example from the Haida Gwaii, British Columbia. in: G.B. Ingram and M. Moss (Eds.). Landscape Approaches to Wildlife and Ecosystem Management, Proceedings of the Second Symposium of the Canadian Society for Landscape Ecology and Management, University of British Columbia, May 1990. Polyscience Publications Inc.

McCleary, K.G., Davidson, R.J. and T.J. Beechey. 1992. Protecting Ontario's natural diversity through provincial parks and areas of natural and scientific interest. in: J.H.M. Willison, S. Bondrup-Nielson, C. Drysdale, T.B. Herman, N.W.P. Munro and T.L. Pollock (Eds.). Science and the Management of Protected Areas, Proceedings of an International Conference held at Acadia University, Nova Scotia, Canada, 14-19 May 1991, organized by the Science and Protected Areas Association. Elsevier Science Publishers. B.V. Amsterdam, Netherlands.

Noss, R.F. 1992. The wildlands project: land conservation strategy. Wild Earth (Special Issue): 10-25.

Noss, R.F. 1995. Maintaining integrity in representative reserve networks. World Wildlife Fund (Canada-United States) Discussion Paper. Toronto, Ontario.

Peterson, E.B. and N.M. Peterson. 1991. A first approximation of principles and criteria to make Canada's protected area systems representative of the nation's ecological diversity. Report to the Canadian Council on Ecological Areas.

Province of British Columbia. 1993. Gap analysis workbook for regional protected areas teams: a protected areas strategy for British Columbia. Working Draft. Victoria, BC.

Rowe, J.S. 1972. Forest regions of Canada. Canadian Forestry Service. Ottawa, Ontario.

Rowe, J.S. 1992. Prologue: site classification research priorities forest and culture. Forestry Chronicle 68(1).

Shields, J.A., C. Tarnocai, K.W.E. Valentine and K.B. MacDonald. 1991. Soil landscapes of Canada. Agric. Can. Pub. 1868/E, Agriculture Canada. Ottawa, Ontario.

Wiken, E.B. (Compiler). 1986. Terrestrial ecozones of Canada. Ecological Land Classification Series No. 19. Environment Canada. Hull, Quebec.

Wiken, E.B., C.D.A. Rubec and G. Ironside. 1993. Terrestrial ecoregions of Canada (Map MCR 4164F). National Atlas of Canada-5th Edition. Energy, Mines and Resources Canada/Environment Canada. Ottawa, Ontario.

Wickware, G.M. and C.D.A. Rubec. 1989. Ecoregions of Ontario. Sustainable Development Branch, Environment Canada, Ecol. Land Class. Ser. No. 26, Ottawa, Ontario. (1:2 000 000 scale map of Ecoregions and Ecodistrict and accompanying biotic/abiotic data base for each level of ELC).

APPENDIX 1. GENERIC MATRICES FOR ANALYZING REPRESENTATION

Introduction

Two generic matrices have been developed to assist with determining ecoregion representation. These are referred to as the "Ecoregion" and the "Ecodistrict" matrices and are intended to deal with the ecoregion and ecodistrict levels of detail, respectively. These matrices are presented as a guide and are not necessarily intended to replace existing methods of summarizing representative abiotic characteristics of ecoregions and ecodistricts. They have been prepared to illustrate the level of information required to address steps 1 through 3 in the methodology (Section 3). The terminology employed in these matrices is sufficiently generic as to allow inclusion of all landform/physiography variation in Canada. More intricate matrices can be used, and will in fact be necessary, as more detailed (larger scale) data sets are employed.

The Ecoregion Matrix is used to determine the physiographic unit(s) which might occur in a region and the associated dominant surface material type(s) (steps 1 and 2). The Ecodistrict Matrix summarizes characteristics determined from the next level of detail (step 3) to identify landscape units based on surface, relief and slope position. For any ecoregion, one Ecodistrict Matrix assessment should be undertaken for each category defined. It is very important that the matrices be filled-out based on the appropriate scale of information.

A third matrix has also been developed to allow specific biotic information to be related to each of the units identified according to the Ecodistrict matrix.

Ecoregion Matrix

The Ecoregion Matrix (Table 2) facilitates the determination of broad physiographic complexes. This matrix should be filled out based on the step 2 information requirements.

In step 1, the general complexity of the ecoregion is considered in terms of its regional physiographic composition. In step 2, ecodistrict (or equivalent) information is reviewed to determine the character of the physiographic complex(es). Hence, the information sources which are used to fill-out the Ecoregion Matrix involve scales of 1:500 000 and smaller (1:1 m to 1:5 m); the "visualization" required is approximately 1:1 000 000.

It should be relatively simple to identify the combinations of physiographic units and surface materials that occur within any ecoregion based on widely available national databases. It is probable that several units will be identified.

Based on the results of the three case studies, the following matrix positions would be indicated for each area:

Southern Interior BC	mountain - bedrock/shallow drift, sand/gravel, water/ice highland - bedrock/shallow drift, sand/gravel, clay/silt, water/ice plateau - sand/gravel, clay/silt, water/ice

Table 2: Application of Eco-Region matrix to Define Representative Physiographic Types in B.C. (Scale 1:500 000 to 1:1 000 000)

PHYSIOGRAPHIC UNITS Surface Material	Delta	Coastal Lowland	Coastal Plain	Lowland	Basin	Plain	Plateau Interior (A)	Hill, Foothill	Upland	Highland Columbia (B)	Trench	Mountain Columbia Mtns. (C) Coast Mtns. (D) Cascade Mt[illegible]E)
Bedrock/shallow drift												
Cobble/Boulder												
Sand/Gravel												
Clay/Silt												
Organics												
Water/Ice												

(Source: adapted from Geomatics International 1994)
Note: Physiographic Units after Bostock 1970.

Saskatchewan Grasslands	plains - sand/gravel, clay/silt, water/ice
Ontario Southern Boreal	uplands - bedrock/shallow drift, sand/gravel, organics, water/ice plains - bedrock/shallow drift, sand/gravel, clay/silt, water/ice

Clearly, each of the physiographic units identified for the three regional examples include a variety of other surface material textures and may also have inclusions of other physiographic types; however, those identified above are most representative of the corresponding region at the required level of visualization. Once the region has been defined by these coarse level descriptors, an analysis of the landscape units within the region can be undertaken.

Ecodistrict Matrix

Once the Ecoregion Matrix (Table 2) is completed, an Ecodistrict Matrix (Table 3) can be completed (one for each grid location filled-out on the Ecoregion Matrix). The scale of information required to complete this matrix is approximately 1:250 000 to 1:500 000 (see step 3).

Each grid square on the Ecodistrict Matrix represents one enduring feature and each of these should be included within protected areas to ensure adequate representation. Across the top of the matrix is the topography (degree of brokenness) which is subdivided according to very general slope position assignments.

Surficial landform units form the vertical axis of the matrix. These are subdivided on the basis of texture, depth, or wetland type.

The assignment of slope position is, in part, meant to reflect macro-drainage conditions as typically associated with mid- and, especially, lower slope positions due to seepage, slower internal and surface drainage. These drainage differences are assumed to result in differences in vegetation. This reflects the concept of "toposequence" as defined in the Ontario Forest Ecosystem Classification Program and of subzone and "variant" as defined in the Bioclimatic Ecosystem Classification System of British Columbia. If vegetation communities are known not to be differentiated on the basis of slope position for the area of interest, then only one landscape unit would be identified reflecting the degree of brokenness.

The vertical axis of this matrix specifies dominant texture affecting soil moisture regime and rooting conditions (*i.e.*, surface texture, upper 50 cm to 1 m). As in the case of slope position/drainage, these textural differences are assumed to result in differences in vegetation. Bedrock, whether or not it is calcareous, becomes important as a surficial unit where it either occurs at the surface or at shallow rooting depth. Depth is important for

Table 3: **Ecodistrict matrix: an example of how to define representative enduring features (scale 1:500 000 to 1:1 000 000).** ***(adapted from Geomatics International 1994)***

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
fluvioglacial	*very coarse*												1
	coarse												2
	medium												3
	fine												4
morainal	*very coarse*												5
	coarse												6
	medium												7
	fine												8
lacustrine/marine and glaciolacustrine/ glaciomarine	*coarse*												9
	medium												10
	fine												11
alluvial	*coarse*												12
	medium												13
	fine												14
colluvial	*very coarse*												15
	coarse												16
	medium												17
	fine												18
eolian	*medium*												19
	fine												20

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
undifferentiated	*very coarse*												21
	coarse												22
	medium												23
	fine												24
volcanic ash/pumice	*coarse*												25
	medium												26
	fine												27
bedrock	*exposed calcareous rock*												28
	intermittent exposed calcareous rock with thin (<1 m) surficial deposits												29
	exposed non-calcareous rock												30
	intermittent exposed non-calcareous rock with thin (<1 m) surficial deposits)												31
wetlands	*fen*												32
	bog												33
	swamp												34
	freshwater marsh												35
	saltwater marsh												36
water/ice	*shallow water (<=2m)*												37
	deep water (>= 2 m)												38
	glacier/icefield												39

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
shoreline	*bedrock*												40
	very coarse												41
	coarse												42
	medium												43
	fine												44

NA	- not applicable

**** DOMINANT TEXTURE DEFINITIONS**

very coarse	-stone/boulder (>256 mm)
coarse	- gravel/cobbles (2 mm - 256 mm)
medium	- sand (63 microm - 22 mm)
fine	- silt/clay (< 63 microm)

*** TOPOGRAPHY DEFINITIONS**

very weakly broken	- the land is flat or almost flat
weakly broken	- gently undulating plain
moderately broken	- rolling hills
strongly broken	- high hills with frequent elevation changes
very strongly broken	- mountainous

* Note: If sufficient information exists, grid squares should be identified according to dominant vegetation communities.

open water; in the case of wetlands, the highest order of classification is used (bog, fen, marsh, swamp, saltmarsh). Each of these types have diagnostic flora and soils. The presence of continuous or discontinuous permafrost is extremely important with respect to vegetation response. This designation should be used in combination with the other surficial units to specify textures/wetland types.

The matrix grid squares (landscape units) can be filled-out in two ways. The simplest is to block off the grid square denoting that the type is present in the ecodistrict. As previously noted, in doing so, one has also implicitly captured representative vegetation communities. If the data are available, one should attempt to actually identify macro-vegetation types which are either extant or have the potential to be restored in each type. This is filled in the third matrix, the Biological Feature Summary Sheet.

Once the Ecodistrict Matrix has been completed, the specific attributes required for representation of the ecoregion have been determined.

Biological Feature Summary Sheet

Once the enduring features have been identified in each ecoregion, each area can be characterized by its distinctive biological features (Table 4). The general biological features such as vegetation types and wildlife types can be described. The dynamics of the system are important and should be further indicated through biological characteristics. Some vegetation types may be seral stages and a heterogeneous matrix of sites may be linked through time. Also, there is an important time component which has to be incorporated at this stage; for instance, some birds may use an area as an important staging or breeding area but not be present year round. There is an attempt in the descriptive sheet to list distinctive features of each of the landscape subunits within the matrix.

Once Biological Feature Sheets have been completed for each characteristic community within the Landscape Matrix, they can be compared and checked for similarities. It should be possible to see at a glance whether there is duplication of representation for the ecoregion, or whether any representative areas have been omitted.

Table 4: **Biological feature summary sheet.**

Biological Feature Description			
Vegetation Cover	General	Important	Dynamics

Ungulates	Breeding	Staging	Wintering	Population Dynamics
Carnivores				
Other animals/ insects				
Passerines				
Raptors				
Waterfowl/ Other species				
Fisheries				

	General	Important
Threats		
Protection Considerations		

APPENDIX 2. EXAMPLES OF MATRICES ILLUSTRATIVE OF NATURAL AREA AND LANDSCAPE ANALYSIS[9]

---

[9] From Enns (1993), Gauthier (1993) and Geomatics International (1993).

Table 1. Application of Eco-Region Matrix to Define Representative Physiographic Types in B.C.
(Scale 1:500 000 to 1:1 000 000)

PHYSIOGRAPHIC UNITS Surface Material	Delta	Coastal Lowland	Coastal Plain	Lowland	Basin	Plain	Plateau Interior (A)	Hill, Foothill	Upland	Highland Columbia (B)	Trench	Mountain Columbia Mtns. (C) Coast Mtns. (D) Cascade Mtns. (E)
Bedrock/shallow drift										X(B)		X(D)
Cobble/Boulder												
Sand/Gravel							X(A)			X(B)		X(C,D,E)
Clay/Silt							X(A)			X(B)		
Organics												
Water/Ice							X(A)			X(B)		X(C,D)

Note: Physiographic units after Bostock 1970.

Table 2. **Example of Ecodistrict Matrix to Define Representative Enduring Features for Selected Regions in BC.**
(Scale 1:500 000 to 1 000 000).
Interior Plateau = A; Columbia Highland = B; Columbia Mountains = C; Coast Mountains = D; Cascade Mountains = E

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
fluvioglacial	*very coarse*												1
	coarse		A/B/C	←	A/E	→	←	D	→				2
	medium												3
	fine												4
morainal	*very coarse*												5
	coarse			←	A/B/C/D	→	←	B	→				6
	medium			←	A	→							7
	fine			←	A	→							8
lacustrine/marine and glaciolacustrine/ glaciomarine	*coarse*												9
	medium												10
	fine		A/B				←	A	→				11
alluvial	*coarse*	A	A/B/C/E	←	D	→							12
	medium		A/B										13
	fine		A/B										14
colluvial	*very coarse*			←	A/E	→	←	A/B/ C/D	→	←	D	→	15
	coarse												16
	medium												17
	fine												18
eolian	*medium*												19
	fine												20

Table 2 continued

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
undifferentiated	*very coarse*												21
	coarse												22
	medium												23
	fine												24
volcanic ash/pumice	*coarse*			←	D	→							25
	medium												26
	fine												27
bedrock	*exposed calcareous rock*												28
	intermittent exposed calcareous rock with thin (<1 m) surficial deposits												29
	exposed non-calcareous rock						←	D	→	←	B/D	→	30
	intermittent exposed non-calcareous rock with thin (<1 m) surficial deposits)												31
wetlands	*fen*												32
	bog												33
	swamp												34
	freshwater marsh												35
	saltwater marsh												36
water/ice	*shallow water (<=2m)*	A	A/B			A			A/B/ C/D			D	37
	deep water (>= 2 m)	A	A/B			A			A/B/ C/D			D	38
	glacier/icefield												39

Table 2 continued

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
shoreline	*bedrock*												40
	very coarse												41
	coarse	A	A			A			A/B/ C/D			D	42
	medium		A			A							43
	fine		B			A							44

NA - not applicable

**** DOMINANT TEXTURE DEFINITIONS**

very coarse -stone/boulder (>256 mm)
coarse - gravel/cobbles (2 mm - 256 mm)
medium - sand (63 microm - 22 mm)
fine - silt/clay (< 63 microm)

*** TOPOGRAPHY DEFINITIONS**

very weakly broken - the land is flat or almost flat
weakly broken - gently undulating plain
moderately broken - rolling hills
strongly broken - high hills with frequent elevation changes
very strongly broken - mountainous

* Note: If sufficient information exists, grid squares should be identified according to dominant vegetation communities.

Table 3. Application of Region Matrix to Define Representative Physiographic Types in the Grasslands Ecoregion of Saskatchewan (Scale 1:500 000)

PHYSIOGRAPHIC UNITS Surface Material	Delta	Coastal Lowland	Coastal Plain	Lowland	Basin	Plain	Plateau	Hill, Foothill	Upland	Highland	Trench	Mountain
Bedrock/shallow drift												
Cobble/Boulder						26						
Sand/Gravel						2300						
Clay/Silt						6187						
Organics												
Water/Ice						87						

* In the Saskatchewan case study, actual area size (km^2) was able to be assigned to categories.

Table 4. **Example of Ecodistrict Matrix to Define Representative Enduring Features in the Grasslands Ecoregion of Saskatchewan** (Scale 1:500 000 to 1 000 000. Numeric values represent km^2)

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
fluvioglacial	*very coarse*												1
	coarse		26										2
	medium		401	←	24	→							3
	fine												4
morainal	*very coarse*												5
	coarse												6
	medium		425	←	600	→							7
	fine		2618	←	1084	→							8
lacustrine/marine and glaciolacustrine/ glaciomarine	*coarse*												9
	medium		125	←	5	→							10
	fine	4	1679	←	52	→							11
alluvial	*coarse*												12
	medium		6										13
	fine	101											14
colluvial	*very coarse*												15
	coarse												16
	medium												17
	fine												18
eolian	*medium*		140	←	168	→							19
	fine		292										20

Table 4 continued

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
undifferentiated	*very coarse*												21
	coarse												22
	medium			←	405	→							23
	fine	17		←	340	→							24
volcanic ash/pumice	*coarse*												25
	medium												26
	fine												27
bedrock	*exposed calcareous rock*												28
	intermittent exposed calcareous rock with thin (<1 m) surficial deposits												29
	exposed non-calcareous rock												30
	intermittent exposed non-calcareous rock with thin (<1 m) surficial deposits)												31
wetlands	*fen*												32
	bog												33
	swamp												34
	freshwater marsh												35
	saltwater marsh												36
water/ice	*shallow water (<=2m)*	present											37
	deep water (>= 2 m)	present											38
	glacier/icefield												39

Table 4 continued

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
shoreline	*bedrock*												40
	very coarse												41
	coarse												42
	medium	present											43
	fine	present											44

NA - not applicable

**** DOMINANT TEXTURE DEFINITIONS**

very coarse	-stone/boulder (>256 mm)
coarse	- gravel/cobbles (2 mm - 256 mm)
medium	- sand (63 microm - 22 mm)
fine	- silt/clay (< 63 microm)

*** TOPOGRAPHY DEFINITIONS**

very weakly broken	- the land is flat or almost flat
weakly broken	- gently undulating plain
moderately broken	- rolling hills
strongly broken	- high hills with frequent elevation changes
very strongly broken	- mountainous

* Note: If sufficient information exists, grid squares should be identified according to dominant vegetation communities.

Table 5. Application of Region Matrix to Define Representative Types in Ontario Site Region 4E (Scale 1:500 000 - 1:1 000 000)
Physiographic Units: Cobalt = A; Abitibi = B

PHYSIOGRAPHIC UNITS Surface Material	Delta	Coastal Lowland	Coastal Plain	Lowland	Basin	Plain Cobalt	Plateau	Hill, Foothill	Upland Abitibi	Highland	Trench	Mountain
Bedrock/shallow drift						X(A)			X(B)	X		
Cobble/Boulder												
Sand/Gravel						X(A)			X(B)			
Clay/Silt						X(A)						
Organics									X(B)			
Water/Ice						X(A)			X(B)			

Table 6. **Example of Ecodistrict Matrix to Define Representative Enduring Features in Ontario Site region 4E**
(Scale 1:500 000 to 1 000 000).
Physiographic Units: Cobalt = A; Abitibi - B; Abitibi (Upland) = C

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
fluvioglacial	*very coarse*												1
	coarse			←	B	→							2
	medium	A	A/B										3
	fine												4
morainal	*very coarse*												5
	coarse		A	←	A/B	→							6
	medium												7
	fine												8
lacustrine/marine and glaciolacustrine/ glaciomarine	*coarse*		B										9
	medium	A	A										10
	fine	A	A/B										11
alluvial	*coarse*												12
	medium												13
	fine												14
colluvial	*very coarse*												15
	coarse												16
	medium												17
	fine												18
eolian	*medium*												19
	fine												20

Table 6 continued

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
undifferentiated	*very coarse*												21
	coarse												22
	medium												23
	fine												24
volcanic ash/pumice	*coarse*												25
	medium												26
	fine												27
bedrock	*exposed calcareous rock*												28
	intermittent exposed calcareous rock with thin (<1 m) surficial deposits												29
	exposed non-calcareous rock			←	A/B	→	C	C					30
	intermittent exposed non-calcareous rock with thin (<1 m) surficial deposits)		A/B	←	B	→	←	C	→				31
wetlands	*fen*												32
	bog	B											33
	swamp												34
	freshwater marsh												35
	saltwater marsh												36
water/ice	*shallow water (<=2m)*	A	A/B			A/B							37
	deep water (>= 2 m)	A	A/B			A/B							38
	glacier/icefield												39

Table 6 continued

SURFICIAL UNIT	TOPOGRAPHY*	very weakly broken	weakly broken	moderately broken			strongly broken			very strongly broken			
	SLOPE POSITION DOMINANT TEXTURE OR SURFICIAL DESCRIPTION**	NA	NA	upper	mid	toe	upper	mid	toe	upper	mid	toe	
		A	B	C	D	E	F	G	H	I	J	K	
shoreline	*bedrock*		A/B			A/B							40
	very coarse												41
	coarse		B										42
	medium		B										43
	fine	A											44

NA - not applicable

**** DOMINANT TEXTURE DEFINITIONS**

very coarse	-stone/boulder (>256 mm)
coarse	- gravel/cobbles (2 mm - 256 mm)
medium	- sand (63 microm - 22 mm)
fine	- silt/clay (< 63 microm)

*** TOPOGRAPHY DEFINITIONS**

very weakly broken	- the land is flat or almost flat
weakly broken	- gently undulating plain
moderately broken	- rolling hills
strongly broken	- high hills with frequent elevation changes
very strongly broken	- mountainous

* Note: If sufficient information exists, grid squares should be identified according to dominant vegetation communities.