METHODS FOR BIOGEOCLIMATIC ECOSYSTEM MAPPING

by
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RR 89002-KL

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REPORT

Internal Reports of the Ministry of Forests
Research Program

BC
Ministry of Forests
and Lands

Methods for Biogeoclimatic Ecosystem Mapping

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November, 1989

Ministry of Forests

This publication is RR89002-KL

Copies of this report may be obtained, depending upon supply, from:

Research Branch
B.C. Ministry of Forests
31 Bastion Square
Victoria, B.C.
V8W 3E7

Citation:

Mitchell, W.R., R.N. Green, G.D. Hope, and K. Klinka. 1989. Methods for biogeoclimatic ecosystem mapping. B.C. Min. For. Research Report 89002-KL.

ACKNOWLEDGEMENTS

Special acknowledgement is given to R.D. Eremko for her contribution to initial drafts of this report.

Special thanks are also due to those people who have reviewed and commented on the initial drafts. K. Valentine, D. Moon, and H. Luttmerding have provided invaluable ideas, advice, and comments. Other valuable comments were provided by M. Fenger, E. Lea, S. Lindeburgh, D. Lloyd, D. Meidinger, F. Nuzdorfer, H. Quesnel, R. Trowbridge, G. Still, T. Braumandl, T. Vold, and D. Walkem. Other personnel of the Ministries of Forests and Environment have also made useful comments at various stages.

Both the Kamloops and Vancouver Forest Regions provided support during report preparation. The personnel of the Ministry of Forests, Research Branch, in particular Dr. T. Baker, Dr. D. Lousier, and Dr. R. Annas, have also provided support throughout the development and presentation of the report. Special acknowledgement is given to: S. Fergusson, for preparation of the figures; and to P. Frehlick, L. Jones, J. Quinlan, and L. Holowatiuk for typing the manuscript.

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1 INTRODUCTION

As demands on the forest land base increase, so does the need for intensive integrated resource management. An essential tool in this is a land inventory that will provide information for the planning of intensively managed environmentally sensitive areas. Various land inventories (e.g., of soil, terrain, biophysical features, and surficial geology) have been used with varying degrees of success in forest land planning. The classification and subsequent mapping of ecosystems using the Biogeoclimatic Ecosystem Classification system (Pojar *et al.* 1987) provides another, more effective approach. It offers a biological or ecological basis for managing forest land. Rather than considering different components of ecosystems in separate inventories, it integrates the biotic (vegetation) and abiotic (climate, physiography, and soils) ecosystem components into one classification and map.

An ecosystem map assists in area-specific land management by providing information on the location and distribution of ecosystems, from which a number of management interpretations can be developed to facilitate silvicultural, timber management, range, wildlife, and watershed planning. Ecosystem mapping has been used for a number of demonstration and operational applications (Klinka 1976; Klinka *et al.* 1980; Inselberg *et al.* 1982; Utzig *et al.* 1983; Lindeburgh and Trowbridge 1984; Banner *et al.* 1985; Mitchell and Eremko 1987; Green and Klinka 1981[1]; Lewis 1981[2]), usually at a scale of 1:20 000 or larger.

To ensure that ecosystem maps are consistent in quality and utility and are completed efficiently, a standardized set of methods and procedures is necessary. The purpose of this report is to propose such a set of methods, which have been developed on the basis of several ecosystem mapping pilot studies. These methods are intended to serve as a reference for ecosystem mapping projects carried out or funded by the B.C. Ministry of Forests.

The audience addressed in this report is assumed to have an understanding of forest ecology, biogeoclimatic ecosystem classification, and basic mapping procedures and techniques (e.g., photo interpretation). This includes pedologists, ecologists, biologists, agrologists, and foresters involved in ecosystem mapping for intensive resource planning and management. From this report, the reader should gain an understanding of: the relationship between ecosystem classification and mapping; the criteria required for mapping, including how to determine survey intensity, establish map units, select appropriate nomenclature, and set up legends; the procedures for undertaking a mapping project; and the design of maps and reports. The report will also help potential users understand the limitations of ecosystem maps. Although an outline of the taxonomic classification of ecosystems is provided, the actual methods for classifying them are contained in another report (Pojar *et al.* 1987). Similarly, a summary of how to map biogeoclimatic units is provided, although the methods of classifying of these units are not.

2 APPROACH TO ECOSYSTEM MAPPING

Forest ecosystems are relatively uniform segments of the landscape which are characterized by a particular plant community and its associated soil. An ecosystem map essentially shows the pattern or mosaic of ecosystems in a given area. A taxonomic approach is followed in ecosystem mapping, where the initial step is to classify ecosystems, or adopt an existing classification, for the area that is to be mapped. Using the vegetation and environmental characteristics of the taxonomic units, mapping begins by delineating segments of landscape where changes in these differentiating properties are recognized. This is generally done with a combination of ground survey and air photo interpretation. Map delineations are tentatively labelled as to their component taxonomic units, and are then field-checked to verify boundaries and labels. The resulting map shows the distribution of ecosystems, which are shown either individually or in complexes, named and defined in terms of taxonomic units.

[1] Green, R.N. and K. Klinka. 1981. Ecosystems of the Sayward Forest: their description and interpretation. Unpublished report.
[2] Lewis T. 1981. Ecosystem mapping of TFL 24, Queen Charlotte Islands, Rayonier Canada. Unpublished report to Rayonier Canada Ltd.

Before the ecosystem classification of an area can be carried out, detailed ecological information must first be collected. In most cases this will already have happened. For some projects, however, such information may not be available. In such cases, the classification should be developed concurrently with field mapping. The classification may be adjusted during the mapping process as additional information is collected. The mapping process actually serves as a test of the classification and allows the mapper to identify gaps and accommodate any variations. Once the classification is in place, the mapping procedure requires less detailed data aimed primarily at defining and describing map delineations.

So that the map is useful to forestry managers, the units on it should reflect ecosystem information that is relevant to forest management practices. These relationships or interpretations are established during or shortly after the classification, before mapping, although they may be fine-tuned to local conditions observed during mapping. With this information, interpretive maps relating to specific management practices can be derived from the basic ecosystem map. However, such interpretive maps should be considered ephemeral, as the criteria for deriving interpretations may change. It is important that an accurate ecosystem base map be completed first. Derivative maps can then be easily modified from that base information. To initially develop a single purpose interpretive map with narrow objectives, bypassing the basic ecosystem map, results in a product with limited value and lifespan.

3 BIOGEOCLIMATIC ECOSYSTEM CLASSIFICATION

Taxonomic classification of ecosystems is a process of grouping ecosystems (real entities) into abstract classes (taxa) according to their properties and natural relationships (Pojar *et al.* 1987). Such a classification organizes knowledge about ecosystems and, since the ecosystem is the fundamental unit of forest management, provides a basic framework for forest management. Taxa generated from a classification of ecosystems are used in the mapping of those ecosystems, that is, delineating areas where those classes occur (Mapping Systems Working Group 1981).

The approach to ecosystem mapping is based on the biogeoclimatic ecosystem classification (BEC) system originally developed by V.J. Krajina and his students (Krajina 1960, 1969, 1977), and subsequently modified by the B.C. Ministry of Forests (Pojar *et al.* 1987). The BEC system is a hierarchial classification scheme that organizes ecosystems at three levels of integration: local, regional, and chronological (Pojar *et al.* 1987). The classification deals principally with three ecosystem elements: climate, vegetation, and soil (including topography and parent materials).

A simplified discussion of the BEC system is presented here; a more detailed outline can be found in Pojar *et al.* (1987).

3.1 Ecosystem

An ecosystem can be defined as a segment of the landscape which is relatively uniform in the composition, structure, and properties of its vegetation, animals, and physical environment, and in their interactions.

Thus, an ecosystem is a natural entity that has unique properties resulting from the interaction of climate, soil, relief, organisms, and time (Major 1951). An ecosystem can be characterized by a ‘‘plant community’’ (volume of relatively uniform vegetation) and a ‘‘soil polypedon’’ (volume of relatively uniform soil) (Soil Survey Staff 1975). The geographic extent of an ecosystem is variable; its lateral boundaries are commonly gradual but may be abrupt.

3.2 Classification Structure

The BEC system organizes ecosystems at local, regional, and chronological levels to show the relationships among ecosystems in form, space, and time, respectively. The local level organizes ecosystems according to similarities in their vegetation and sites (or environments). This is done by vegetation and site classifications, producing vegetation and site units (Figure 1). At the regional level, the stable climax vegetation on zonal sites is used to infer the regional climate. Biogeoclimatic units are a result of this zonal (or climatic) classification. The chronological level is used to organize ecosystems according to their successional relationships in time within a given site unit. This is done by arranging the vegetation units recognized for a particular site unit into site-specific chronosequences, according to disturbance, treatment, and successional status (Klinka *et al.* 1985; Hamilton 1987).

Although vegetation units are important in developing both biogeoclimatic and site units, it is the latter two types of units that are commonly used in operational applications of the BEC system. Biogeoclimatic units represent groups of geographically related ecosystems, each affected by a relatively uniform regional climate (*sensu* Major 1963). These are the units mapped during biogeoclimatic mapping (Section 10).

Site units are groups of ecosystems, regardless of present vegetation, that have similar environmental properties and vegetation and productivity potentials. From a management perspective, they represent similar sites with similar responses to treatment. Site units, commonly used in ecosystem mapping, are described in the following sections.

3.2.1 Site association

The site association is the basic category in site classification. A site association consists of all sites that have similar or equivalent physical properties and are capable of producing vegetation belonging to the same plant association at climax (Pojar *et al.* 1987). Site associations are characterized and identified by a range of climatic, soil moisture, and soil nutrient regimes, and, if appropriate, by an additional environmental factor or property strongly influencing the development of vegetation.

The name of a site association consists of the Forest Service code of a major climax tree species and one or two vernacular names of indicator plants that are expected to be nearly always present on the site: for example, Cw - Oak fern site association.

3.2.2 Site series

Site series result from the subdivision of a site association according to changes in the regional climate. That portion of a site association occurring within a specific biogeoclimatic subzone or variant forms a site series. The site series is equivalent to the ecosystem association previously used in the BEC system (Pojar 1983). To name a site series, the name of the site association is prefixed by the symbol for a biogeoclimatic subzone: for example, ICHwk: Cw - Oak fern. Each site series has a unique code, such as ICHwk/01.

3.2.3 Site type

Site types are divisions of site series according to one or more topographic and soil properties thought to affect ecosystem response to management. That portion of a site series that occurs on edaphically uniform sites forms a site type. To name a site type, the site series name is modified with one or more diagnostic edaphic adjectives: for example, ICHwk: Cw - Oak fern/Sandy site type (or ICHwk/01/01). Site types approximate ecosystem types (Pojar 1983) previously used in the BEC system.

3.2.4 Phase

To form a phase, a modifier may be added to the name of any of the recognized vegetation, biogeoclimatic, or site units (Pojar *et al.* 1987). Phases, however, are not formal taxonomic units. They are commonly used to recognize differences in soil or topographic features that are significant for operational use, without being as formal and detailed as the site type category.

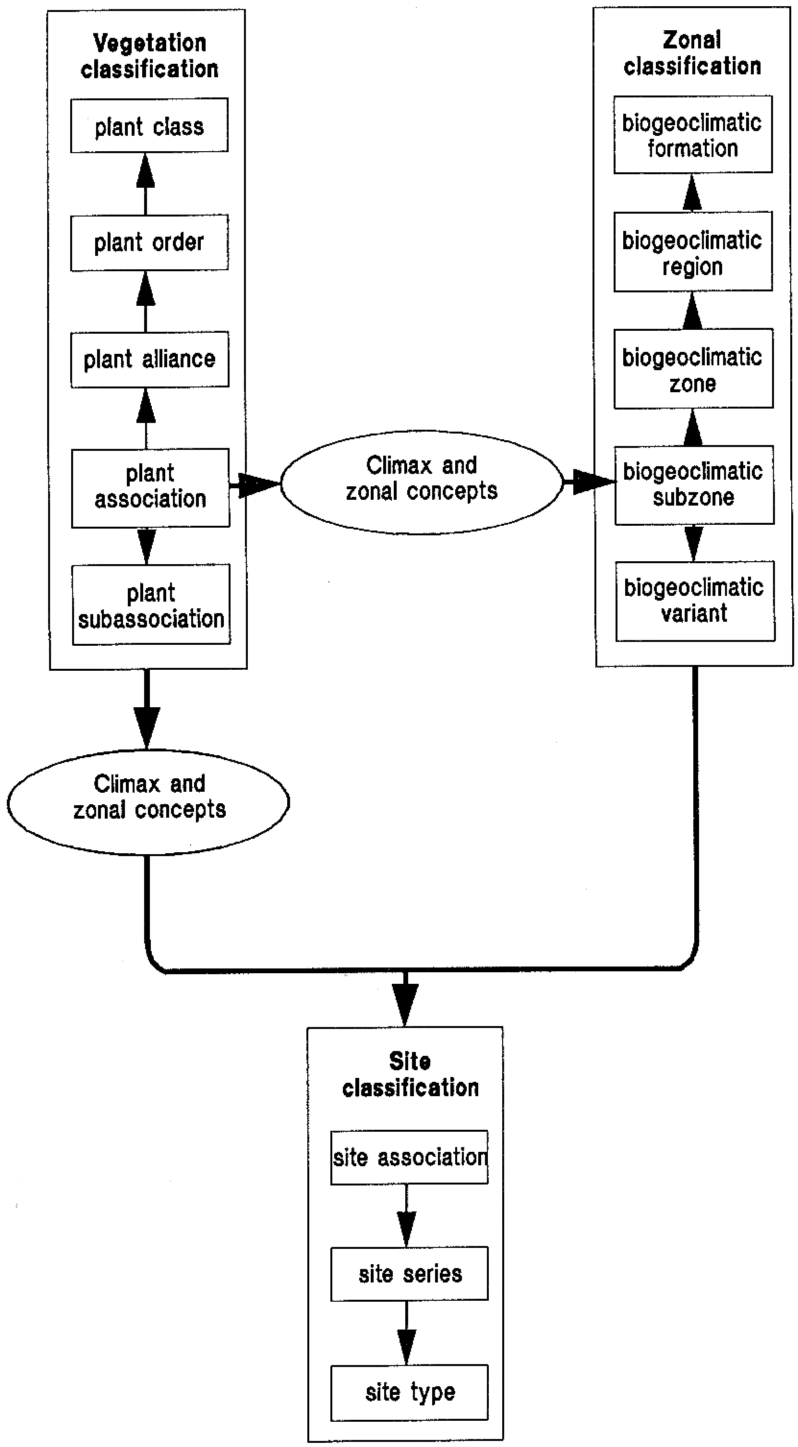


FIGURE 1. Levels and categories of the biogeoclimatic ecosystem classification system (from Pojar *et al.* 1987).

3.3 Seral Ecosystem Units

The BEC system has been developed largely through the sampling of stands considered to represent the climax state. In areas where seral ecosystems are present, any mapping project may also require a classification system for those ecosystems.

Hamilton (1987) has proposed that seral ecosystems be differentiated on the basis of both floristic (seral plant associations) and structural/developmental attributes (see also Klinka *et al.* 1985). The seral ecosystem units would then be integrated into the BEC system at the site classification level by the grouping of site units and seral units with similar environmental properties. This results in prediction of the seral units occurring on a site over time. The classification approach used for seral ecosystems may vary, depending on the level of detail or the interpretations required.

3.4 Interpretive Units

The BEC system groups ecosystems according to their ''natural'' relationships. These natural classes can then be grouped, divided, or regrouped into interpretive units, according to their value for a specific purpose. Such a system relies on a technical or interpretive classification (Cline 1949; Lavkulich 1972). When management interpretations for two or more taxonomic units are found to be similar, the units may be grouped according to their value for some specific management activity.

Interpretive units have commonly been called management or treatment units in British Columbia (Klinka *et al.* 1980; Mitchell and Eremko 1987). Klinka and Krajina (1986) grouped site units recognized in the University of British Columbia Research Forest into interpretive units, with the criteria being suitability for use and sensitivity to disturbance in relation to regeneration and productivity. The matrix showing the relationship between site and interpretive units for the study is shown in Figure 2. Mitchell and Eremko (1987) grouped site units into treatment units for timber, watershed, and wildlife interpretations in the Truax Creek Basin. Treatment units for other management purposes could also be developed, depending on the requirement or objectives of the mapping project.

4 MAPPING CONCEPTS

4.1 Mapping Individuals and Site Units

Mapping individuals are a conceptual group of ecosystems that are similar enough to group together for the purpose of the survey (Valentine 1986). They are the components of the polygons that are displayed on a map. Mapping individuals on an ecosystem map are site units that have been formed through the process of classification (Section 3). They may also include unclassified ecosystems such as rock outcrops. The term ''site units'' will be used for mapping individuals in the remainder of the report.

4.2 Map Delineation

A map delineation (or polygon) is a single area on a map bounded by a continuous line (Valentine 1986). It represents a real segment of the landscape. Boundaries between map delineations are placed where differences in composition or characteristics of site units are the greatest. In many cases, changes in topography (e.g., slope, slope position, and aspect) are associated with significant changes in site units, and therefore form convenient breaks between map delineations. In some instances, boundaries are not apparent by any means other than site-specific investigation. Consequently, the field mapper must be given considerable latitude in establishing map delineations (Soil Survey Staff 1975).

4.3 Map Unit

A map unit represents a grouping of recurring map delineations with similar kinds and proportions of site units. Map units are differentiated, classified, described, and named on the basis of their component site units. The relationship between ecosystems, site units, map delineations, and map units is shown in Figure 3.

Montane *CWHb2*		*Submontane* *CWHb1*		*CWHa2*		
Acer-Ribes		Acer-Ribes			*Fragmental*	Impoverished sites
Gaultheria-Polypodium		Gaultheria-Polypodium		Gaultheria-Polypodium	*Slope-rocky*	
Vaccinium-Gaultheria		Vaccinium-Gaultheria	A1	Gaultheria-Kindbergia	*Rocky & shallow*	
Vaccinium-Rhytidiadelphus		Vaccinium-Rhytidiadelphus			*Shallow*	
Vaccinium-Gaultheria		Vaccinium-Gaultheria	A2		*Slope & slope-stony*	
		Gaultheria-Kindbergia		Gaultheria-Kindbergia		
				Gaultheria-Kindbergia	*Moderately deep to deep*	
		Rhytidiadelphus-Plagiothecium		Rhytidiadelphus-Plagiothecium	*Slope & slope-stony*	Zonal sites
Vaccinium-Rhytidiadelphus		Vaccinium-Rhytidiadelphus	B1			
Vaccinium-Rhytidiadelphus	B2	Vaccinium-Rhytidiadelphus		Rhytidiadelphus-Plagiothecium	*Moderately deep to deep*	
Vaccinium-Rhytidiadelphus		Vaccinium-Rhytidiadelphus		Rhytidiadelphus-Plagiothecium	*Ortstein*	
Polystichum-Dryopteris		Polystichum-Dryopteris		Polystichum-Dryopteris	*Slope & slope-stony*	Enriched sites
		Polystichum-Tiarella	C1	Polystichum-Tiarella		
Blechnum-Streptopus	C2	Oplopanax-Rubus		Oplopanax-Rubus		
Blechnum-Rubus		Blechnum-Rubus				
				Polystichum-Dryopteris	*Moderately deep to deep, sandy & sandy—skeletal (loamy & loamy-skeletal)*	
Blechnum-Streptopus		Polystichum-Tiarella	C3	Polystichum-Tiarella		
Blechnum-Rubus		Blechnum-Rubus				
Blechnum-Streptopus	C5	Polystichum-Tiarella		Polystichum-Tiarella	*Gleyed, gleysolic & organic*	
Blechnum-Rubus		Blechnum-Rubus	C4	Blechnum-Rubus		
Blechnum-Sphagnum						
		Polystichum-Tiarella	C6	Polystichum-Tiarella	*Alluvial*	
		Oplopanax-Rubus		Oplopanax-Rubus	*Inundated*	
Oplopanax-Rubus		Oplopanax-Rubus	C7	Oplopanax-Rubus	*Stream-edge & ravine*	
Lysichitum-Rhizomnium		Lysichitum-Rhizomnium	C8	Lysichitum-Rhizomnium	*Gleysolic & organic*	

FIGURE 2. The relationship between site units and interpretive units distinguished in the UBC Research Forest (from Klinka and Krajina 1986). Each heavily outlined box represents an interpretive unit (with symbols A_1, A_2, B_1, etc.) formed by the grouping of the site units within each box. Lightly outlined boxes on the right hand side of the table are site descriptors.

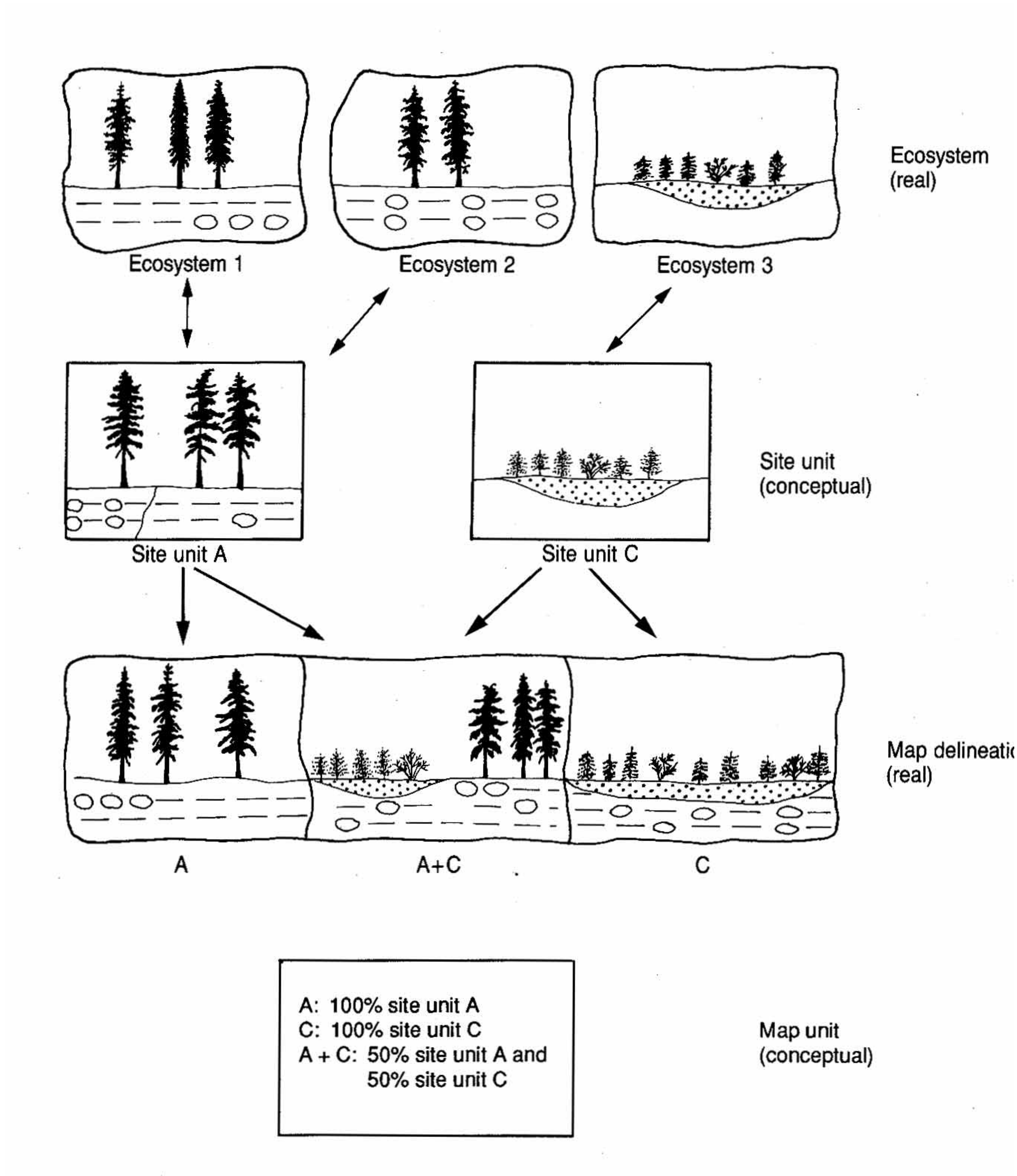


FIGURE 3. The relationship between some concepts used in ecosystem mapping.

An alternative approach that does not involve grouping map delineations may be used to recognize map units. In this case, the delineations are labelled with names and symbols representing their component site units and relevant environmental properties. Map labels are flexible, depending on the composition of each delineation. In effect, this creates a wide variety of map units that are not formally synthesized. The map that is produced has an open legend; this is discussed more fully in Section 4.4.

4.3.1 Map unit composition

A given map unit is composed of one or more major site units plus a minor proportion of other site units that are unmappable at the scale of the survey. When the map unit is composed of one major site unit, it is referred to as a simple map unit; if it is composed of two or more site units, it is a compound map unit (Figures 3 and 4). The unmappable site units are referred to as inclusions (Figure 5). The maximum proportion of inclusions considered acceptable depends on the survey intensity (see Section 5.3).

The components of map units are of two main types (modified from Mapping Systems Working Group 1981). Some are similar, having many characteristics in common. These components are usually within two functional class limits[3] (e.g., one with a 3 [submesic] and the other with a 4 [mesic] soil moisture regime). They are sufficiently alike that management interpretations are essentially the same. The other types of components are dissimilar, having contrasting characteristics. They generally differ by more than two functional class limits (e.g., one with a 4 [mesic] and the other with a 6 [hygric] moisture regime). The differences between components are sufficient to require different management interpretations.

4.3.2 Map unit establishment

Map units are established as a result of the investigation of ecosystems and map delineations in the study area. Map delineations with similar kinds and proportions of ecosystems are grouped into unique map units (see Figures 4 and 5). However, the establishment of map units is not a simple procedure. Complexity of ecosystem patterns, the scale of mapping, and the purpose of the survey determine the kind of map units that are needed (Gilkeson 1979). The following general principles in establishing map units can be stated:

1. Map units should have the smallest number of dissimilar inclusions practical.
2. The map unit should represent a significant area of land and, if possible, should represent more than one map delineation.
3. If possible, a map unit should have a limited range of characteristics that allow it to be interpreted and treated uniformly. The purpose of the survey will often determine which characteristics are important.

4.3.3 Map unit nomenclature

Map unit names should convey some, if not all, of the following elements:

- site series or type (and phase, if used)
- seral stage of the site series or type
- other landscape features (e.g., rock outcrop).

The site series and type have standardized nomenclature (see Section 3). Names for phases and seral stages have not been standardized at this time. Where compound map units are mapped, the proportion of each component site unit should be denoted. Examples of names and symbols are given in Section 7.2.

[3] Refers to the functional relationship between ecosystems and two major soil properties: soil moisture regime and soil nutrient regime.

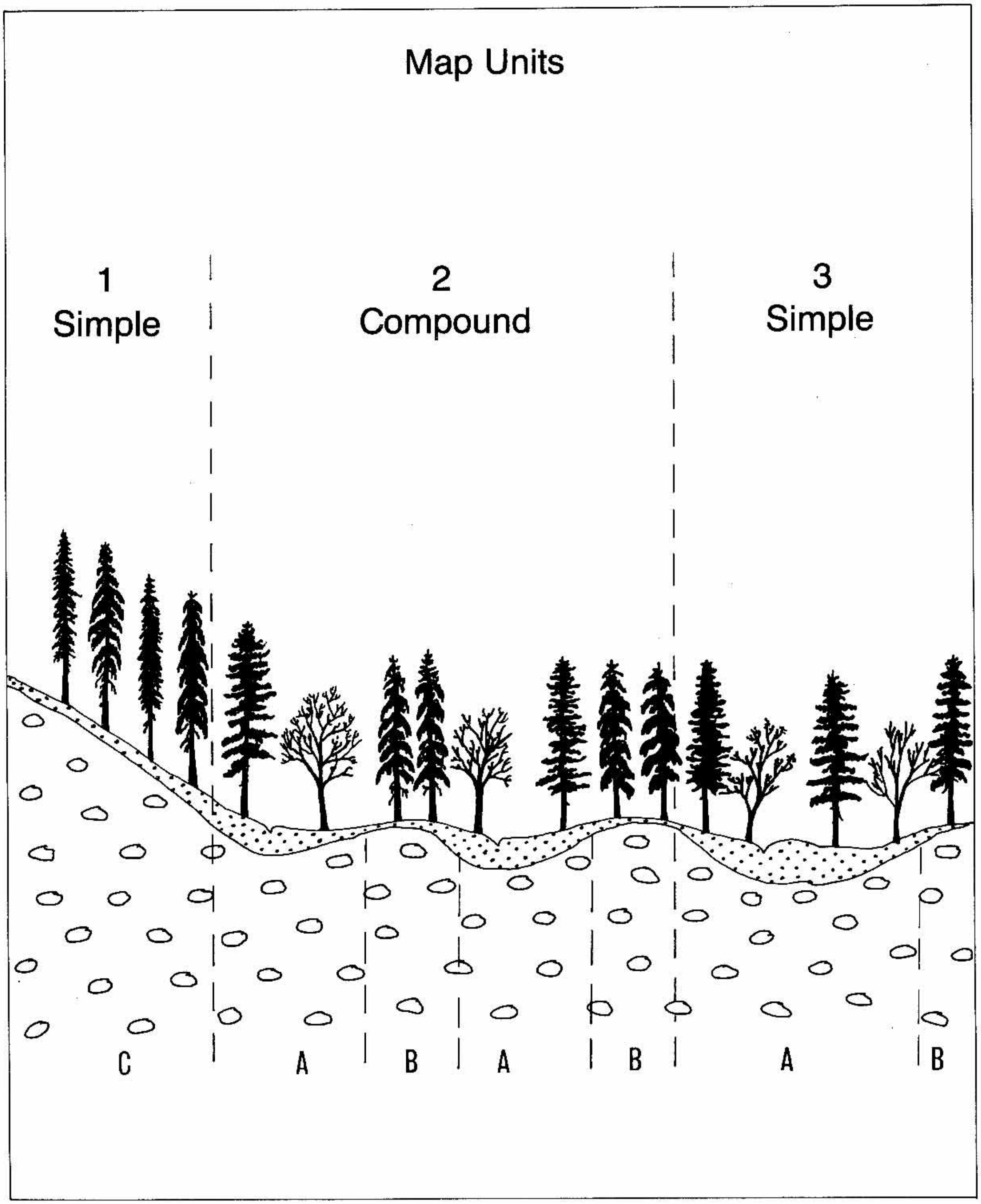
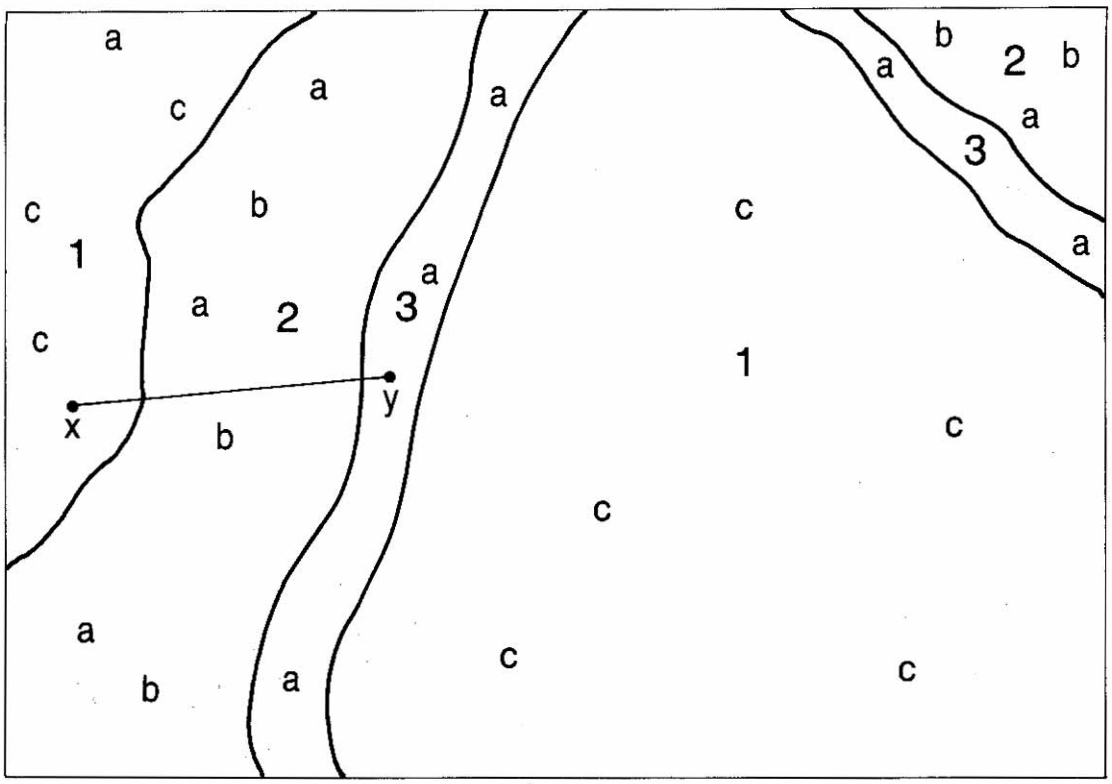


FIGURE 4. Simple and compound map units. 1, 2, and 3 are map units; A, B, and C are site units.



field observations of site units A, B, and C, respectively

Units: 1, 2, and 3

Delineations: two of 3, two of 2, and two of 1

Inclusions: map unit 1 contains inclusions of site unit a

FIGURE 5: A generalized ecosystem map (Fig. 4 shows the section x...y through Fig. 5).

4.4 Legends

The list of map units, site units, or map delineation symbols that accompanies the ecosystem map is its "legend". Detailed discussions of soil map legends may be found in Mapping Systems Working Group (1981), Forbes *et al.* (1982), and Valentine (1986). The concepts for ecosystem map legends are similar.

A map where every single or combined symbol in a delineation corresponds to an entry in the legend is said to have a "closed" legend. The map delineations are grouped into a finite number of map units, each with a unique symbol, and these are listed in the legend. A closed legend is shown in Figure 6.

When the map delineations are not classified into map units, the legend serves to summarize the list of symbols that may be used singly or in combination on a map delineation. The map then has an "open" legend and map labels are flexible, depending on the component site units. An example of an open legend is given in Figure 7.

The two types of legends have both advantages and disadvantages. Individual delineations can be described more accurately with an open legend, which is probably more suitable for high intensity surveys (see Section 5.3). However, comparisons between different areas are easier to make with closed legends. For these reasons, closed legends are generally preferred by less experienced users, whereas experienced users may prefer the more detailed information in open legends. Because open legends, in effect, result in map units that are not formally synthesized, it is more time-consuming to correlate, test for reliability, and interpret the units. More accurate interpretations, however, can be made for individual delineations with an open legend.

There are two stages of legend development during production of an ecosystem map: the "working legend" and the "publication legend". The working legend is used by the surveyor to identify sites, delineations, and map units as the survey progresses (this is discussed further in Section 6.4). The publication legend accompanies the final published map. Its purpose is to convey information about the site units and map units to the user, and it is generally developed through synthesis and generalization of the working legend, although the latter may serve as the published legend (see Section 7.5 for more discussion).

Map unit	Component ecosystem units and landscape features	Compos. (%)	Aspect	Slope gradient (%)	Moisture regime	Nutrient regime	Parent material (terrain)	Soil particle size
M1c	1c-F, Se, (Pl)/ *Arctostaphylos uva-ursi* *Paxistima myrsinites*	80-100	All	5-40	Subxeric	Very poor to poor	Vv/Mv(b)	Ashy/sandy-skeletal
M1d//R	1d-F, Se, (Pl)/ *Arctostaphylos uva-ursi* *Paxistima myrsinites*	60-80	S, W	35-70	Subxeric	Very poor to poor	Vv/Cv(Mv)	Ashy/sandy-skeletal
	R - Rock outcrop	20-40						
M2d	2d-Se, Bl, (Pl)/ *Paxistima myrsinites*	40-60	S, W	35-65	Submesic	Poor	Vv/Cv(b) (Mb)	Ashy/sandy-skeletal
M2d/R	2d-Se, Bl, (Pl)/ *Paxistima myrsinites*	40-60	S, W	35-65	Submesic	Poor	Vv/Cv(b) (Mb)	Ashy/sandy-skeletal
	R - Rock outcrop	40-60						
M3d	3d-Se, Bl, (Pl)/ *Paxistima myrsinites* *Vaccinium membranaceum*	80-100	All	5-35	Submesic & mesic	Poor to medium	Vv/Mb	Ashy/loamy to sandy, skeletal
M3e	3e-Se, Bl, (Pl)/ *Paxistima myrsinites* *Vaccinium membranaceum*	80-100	N, E	35-70	Submesic & mesic	Poor to medium	Vv/Cb(Mb)	Ashy/loamy to sandy, skeletal
M3e//g	3e-Se, Bl, (Pa)/ *Paxistima myrsinites* *Vaccinium membranaceum*	60-80	N, E	45-80	Submesic & mesic	Poor to medium	Vv/Cb(Mb)	Ashy/loamy to sandy, skeletal
	g - Gullied	20-40						

FIGURE 6. A published map legend of closed form (from Mitchell and Eremko 1987).

Ecosystem Association	
11	Rhacomitrium – Lichen *
12	Fd – Pl – Gaultheria – Pleurozium
13	Fd – Hw – Gaultheria – Stokesiella
14	Fd – (Cw) – Gaultheria – Polystichum
21	Hw – Mahonia – Moss
22	Cw – Hw – Achlys – Polystichum
31	Cw – Tiarella – Polystichum
32	Cw – Rubus – Polystichum
33	Cw – Oplopanax – Rubus
34	Cw – Hw – Blechnum – Hylocomium
35	Cw – Lysichiton – Athyrium
36	Cw – Carex – Sphagnum
41	Non-forested wetland ecosystems **

** on this sheet only occurs as subdominant mapping unit*

Phases

Soil Parent Material

0	rock	5	lacustrine
1	morainal blanket	6	marine
2	morainal veneer	7	colluvial blanket
3	glaciofluvial	8	colluvial veneer
4	fluvial	9	organic

Particle Size

.1	sandy	.5	loamy skeletal
.2	loamy	.6	clayey skeletal
.3	clayey	.7	fragmental
.4	sandy skeletal	.8	not applicable

Slope Class

.1	0 – 35 %	.3	61 % +
.2	36 – 60 %	.4	variable

*** tentative (not sampled or studied)*

Key to Map Symbols

Simple

21 / 1.2.1 — Ecosystem association (21); Phase (1.2.1)

Phase: Parent material . Particle size . Slope class

Compound

13 / 2.1.1 / 21 / 1.1.1 — different phases

22/31 / 6.2.1 — common phase

The proportion of each component occupying the unit is indicated by the dividing system

50–70% / 30–50%

70–85% // 15–30%

FIGURE 7. An open legend[a] for an ecosystem map (terminology not updated as per Pojar *et al.* 1987).

[a] Green and Klinka, 1981.

5 PLANNING THE MAPPING PROJECT

5.1 The Planning Sequence

Any mapping project should be well planned, and should follow a logical sequence of steps. During the planning stage it is important to involve forest managers and other users (Gilkeson 1979; Valentine 1986), because the end product they desire will influence the decisions made in the planning process. Experience in forest soil survey (and applicable to ecosystem mapping) has shown that decisions about the following need to be made in the planning stage:

1. definition of survey objectives;
2. determination of information presently available;
3. mapping specifications (survey intensity level, scale, map units, and legend);
4. sampling design and field procedures;
5. staff required;
6. type (and availability) of remote sensing;
7. laboratory support required;
8. use of computers;
9. types of interpretations;
10. logistics of field work;
11. quality control procedures;
12. estimation of time and costs; and
13. presentation of results (maps, report, and technology transfer).

5.2 Objectives

Following the request for a project, the first requirement in planning a project is to define the objectives clearly. This determines first whether ecosystem mapping will be able to meet these requirements; and second, what criteria should be followed in the mapping process. The most important factors to consider are: 1) who the primary users will be; 2) what the map will be used for; and 3) what specific interpretations are to be provided.

By defining the objectives, the appropriate survey intensity can be determined, the essential information required to make the interpretations can be decided, and the most appropriate presentation format determined. The objectives of most ecosystem mapping projects are directed towards providing information for local resource use and resource development planning (B.C. Ministry of Forests 1983), with emphasis on local needs such as silviculture, harvesting and engineering, range, wildlife, and recreation interpretations. Such projects may also be used for allocating resource use and resolving multiple resource use conflicts (local plans), or for planning development strategies for a particular area and directing specific operational practices (development plans). Actual users range from government forest or wildlife managers to company foresters. With this range of applications, it is important that the mapping procedure and product match the intended use.

While ecosystem mapping provides a holistic data base that may be applied to a number of interpretations, a specific intended use may require emphasis on certain features of ecosystems. For example, if the objectives focus on wildlife management, it is important that information on successional habitats from pioneer to climax be provided. If forest engineering is the primary use, emphasis is placed on physiography, slope stability, soil, and surficial deposits. For silvicultural interpretations (e.g., tree species selection, sensitivity to site preparation, productivity potential, and brush hazard), emphasis is placed on ecosystem information (soil, vegetation, physiographic) relating to the anticipated silvicultural decisions. Establishing the required information while setting objectives ensures that the survey will be planned accordingly. The objectives should be established through joint discussions between the user, the individuals doing the mapping, and Ministry of Forests research staff.

5.3 Survey Intensity

The amount of effort to be expended on the survey must be determined. An index of this effort is the survey intensity level. It is based mainly on intensity of field procedures and, in essence, it identifies the level of detail produced by the survey. Appropriate field procedures are derived according to the selected survey intensity level. Two intensity levels appropriate for ecosystem mapping are shown in Table 1. The major factor to consider in determining survey intensity is the level of planning for which the map is designed. Based on the general objectives of the Ministry of Forests planning levels (B.C. Ministry of Forests 1983), it is recommended that survey intensity level 1 be used for development planning, and survey intensity level 2 for local planning.

TABLE 1. Survey intensity levels appropriate for ecosystem mapping[a]

Level	Procedure intensity	Field method	Publication scale		Hectares represented by 0.5 cm^2	Suitable site classification unit
			Range	Typical		
1	1 inspection/2 ha; at least 1 inspection in 95% of delineations; up to 30% of boundary length checked	Traverses 0.5 km apart; descriptions and samples from all mapping individuals	1:5000 to 1:15840	1:5000 1:10000	0.125 0.5	Site series and phases Site types
2	1 inspection/2-20 ha; at least 1 inspection in 75% of delineations; up to 10% of boundary length checked	Traverses 0.5-1.0 km apart; descriptions for all mapping individuals, over 75% sampled	1:7500 to 1:40000	1:20000 1:25000	2.0 3.13	Site series and phases Site associations

[a] Modified from Valentine 1986.

5.3.1 Map delineation size

For the map scale to be adequate for the intended use, the minimum area of land to be represented by a map delineation must be determined. This depends on the objectives of the survey. For example, areas as small as 2 ha may be required for site-specific concerns, but areas larger than 50 ha may be required for local resource use planning.

The minimum size of map delineation to be shown on the final map must also be considered. A minimum legible size of 0.4-0.5 cm^2 (0.63-0.71 cm square) has been recommended (Forbes *et al.* 1982; Valentine 1986). With coloured final maps, minimum delineation sizes down to 0.25 cm^2 (and as low as 0.15 cm^2 if necessary) can be used.[4] These are not the average size, but should only be used for strongly contrasting units.

The land area represented by delineations of 0.5 cm^2 at various scales of mapping is shown in Table 1. This information can be used to determine the appropriate scale of the final map. For example, if a minimum land area of 1 ha must be differentiated, a scale of at least 1:10000 or larger is required (assuming a minimum size delineation of 0.5 cm^2).

5.4 Sampling Design

An appropriate sampling design must be selected before field work is initiated and must also be specified in the working plan. It is not within the scope of this report to provide a complete description of sampling procedures. Discussions of sampling methods for soil mapping (also applicable to ecosystem mapping) may be found in Webster (1977), Forbes *et al.* (1982), and Valentine (1986). However, it is important that this issue be addressed at the onset of any project.

[4] Skoda L., Canadian Cartographics Ltd., personal communication.

In general, the choice of an appropriate sampling strategy depends on the specific project. If the area is large and complex, if time and money are limited, or if the mapper is experienced, authoritative sampling is probably the best choice. If it is important to have accurate, quantified statistics for map unit properties, then probability sampling is recommended.

5.4.1 Authoritative sampling

Authoritative sampling (or purposive sampling) entails the surveyor consciously selecting inspection locations based on his or her knowledge and past experience of the relationships between ecosystem units and landscape features. The sampling procedure often involves sampling along transects and traverses (often across pre-determined map delineations).

The area or transects selected are not random, but usually consist of samples of representative landscapes, in particular areas where difficulties in mapping may be expected (e.g., complex terrain). This information is then extrapolated to other similar areas (Valentine 1986). Authoritative sampling is the most common sampling method for mapping because when time or access is limited, not all areas need to be inspected. It is often the approach used once the realities of field work are encountered. Its limitation is that as the sampling is selective, objective conclusions cannot be made about the precision of the survey. The accuracy of the map also depends on the surveyor's judgement and knowledge. An experienced surveyor, however, can produce a precise, accurate map using this sampling method.

5.4.2 Probability sampling

Probability sampling requires that every individual (in this case an ecosystem) has as much chance of being inspected and described as any other (Webster 1977). This allows quantitative description of the individuals in a map unit (means, variances, confidence limits, etc.).

Simple random sampling involves selection of sample points from anywhere in the survey area. This method of sampling in forested land is slow, inefficient, and expensive. An example of this method, where sampling sites are selected from a reference co-ordinate system, is outlined in Forbes *et al.* (1982). If the survey area is partitioned into strata (landscape delineations or map delineations), and then samples are randomly allocated within these strata, that is stratified random sampling. If the sample points are scattered throughout the strata, then sampling will still be slow and laborious.

If sampling is conducted at specific distances along a randomly oriented transect (termed "stratified systematic sampling with a random start"), it produces similar results to those from stratified random sampling (Steers and Hajek 1979) — provided the systematic location of sampling points does not coincide with natural patterns in the landscape. This approach is substantially more time-efficient than stratified random sampling. Valentine (1986) states that this is perhaps the most practical probability sampling strategy in forests. It can be applied during the field inspection stage to characterize map units and their delineations, or it can be used to test map reliability (see Section 6.9).

5.5 Working Plan Preparation

A working plan is required for all proposed ecosystem mapping projects, with standards and procedures as specified by the Ministry of Forests, Research Branch. The working plan should follow the following format:

1. an introduction to the problem;
2. the objectives of the project;
3. proposed interpretations;
4. definitions of terms, including classification system modifications, if any;

5. survey and mapping procedures
    - ecosystem classification procedures, if no biogeoclimatic ecosystem classification exists for the area
    - the survey/sampling methods to be used
    - plot size and shape
    - minimum size delineation
    - survey intensity level and mapping scale (working and publication)
    - inspection density (% field checks)
    - total area to be classified or mapped
    - a map delineating the area proposed for classification and mapping with areas designated as to mapping detail;
6. map presentation
    - a short description of what information will be presented
    - a statement of relative map reliability
    - legend format and tentative contents
    - type of interpretive maps;
7. report presentation
    - a short description of what information will be included;
8. responsibilities of:
    - implementing agencies (e.g., the Ministry of Forests might be responsible for quality control, classification, and map correlation)
    - co-operating agencies (e.g., the Ministry of Environment might be responsible for soil analysis and soils correlation)
    - contractor(s) (e.g., a consulting company might be responsible for mapping and reports);
9. a work timetable, including dates for interim and final reports; and
10. an itemized breakdown of all expenses and costs.

6 SURVEY PROCEDURES

The procedures for collecting data, preparing a working legend and map, and correlating, reviewing, and testing the map for reliability should follow the sequence outlined in this section.

6.1 Biogeoclimatic Ecosystem Classification

Biogeoclimatic maps, classification reports, and field guides are presently available for 80-90% of British Columbia. Extra steps may be required if the ecosystem mapping project occurs in an area for which maps and reports are not available, or where further classification of seral ecosystems is necessary even though a classification report exists. In general, preparation for ecosystem classification can occur simultaneously with preparation for ecosystem mapping (ecosystem classification is carried out according to methods described in Pojar *et al*. 1987).

During the preliminary reconnaissance stage (Section 6.3), data should also be collected for biogeoclimatic classification. This data can be used to develop preliminary units. During the initial review (Section 6.8), these units can be compared with those of adjacent mapped areas. If the biogeoclimatic units are the same, then the biogeoclimatic map unit boundaries can be extended into the project area. Previously unrecognized site units (including seral vegetation units, and units of previously unrecognized biogeoclimatic units) can then be included in the tentative working legend (Section 6.4). Further data for the classification should be collected during field mapping (Section 6.6). Final data synthesis should proceed before the final review is finished.

6.2 Preparation for Field Work

After an area has been selected for ecosystem mapping, all available data on climate, forest cover, vegetation, bedrock and surficial geology, soils, hydrology, wildlife, and range should be compiled. Aerial photographs, the kind and scale specified in the work plan, should be obtained. The scale of the aerial photographs should be equal to or larger than the scale at which the final map will be published. If special air photography is required, it should be ordered well in advance of any scheduled field work. In large scale mapping (e.g., 1:10 000), smaller scale photographs (e.g. 1:50 000) are useful to study broad vegetation and landscape (terrain, drainage, etc.) relationships. Satellite imagery may also give useful information on small scale landscape patterns.

Initially, all aerial photographs must be prepared for mapping. This involves locating control or match lines based on the identification of principal and wing points on adjacent photographs (British Columbia Ministry of Forests 1987). Control lines and subsequent map delineations are commonly placed on alternating photographs encompassing the most central portion of the photographs. In steep, mountainous terrain, however, all photographs should be used to minimize distortion. Final map compilation should be on a topographic or planimetric map. An air photo mosaic is also useful throughout the mapping process and for displaying final results for training.

6.3 Field Reconnaissance

After all available information has been collated and photographs obtained, a preliminary reconnaissance of the survey area helps to establish tentative relationships between air photo and ecosystem characteristics. In many instances, tentative correlations can be made between air photo characteristics and ecosystem attributes (slope position, slope gradient, aspect, parent material [genetic material and surface expression], overstory vegetation [forest cover expressed by height, density, etc.]). The reconnaissance is also useful for obtaining information on the type and distribution of ecosystems, ecological classification requirements, and sampling requirements, particularly on the tentative location of sampling transects. Consequently, this initial reconnaissance is very important to the other mapping procedures, and omissions in reconnaissance are the primary cause of operational inefficiencies in mapping (Gilkeson 1979). The objectives and the working plan may have to be adjusted, for example, depending on the complexity initially observed.

6.4 Development of a Working Legend

Once the reconnaissance has been completed, a tentative working legend should be established. This legend should contain a listing of all site units and land features that are expected to occur in the survey area, based on information from available data, plus the reconnaissance. It will not be a final legend until the field mapping is complete, at which time it can then be modified to include all site units in the area. As working legends are generally developmental, they are often of the “open” form. A legend of map units (including symbol and name) may also be given some consideration. In most situations, however, this listing of map units (consisting of single or compound site unit components and landscape features as represented by the map delineations) will be developed during the field investigation stage.

6.5 Preliminary Map Delineations

Once a preliminary reconnaissance has been completed and a working legend established, tentative delineations should be mapped on the aerial photographs. Patterns in tone, texture, shadows, and relief on the photos can be used to distinguish physiographic features (slope, aspect, slope position), overstory vegetation, and parent materials. Site units can, in turn, be recognized on air photos if the field mapper has knowledge of their environmental and vegetation characteristics. Map delineation boundaries should be established where changes occurring in air photo features correspond to changes in relevant site units. The importance of specific features depends on the study area.

Further information on interpreting aerial photographs for landform or parent materials (genetic and surface expression) is given in Keser (1976) and Howes and Kenk (1988); and for forest cover, by B.C. Ministry of Forests (1987).

6.6 Field Inspections

Field inspections are required to verify or modify the preliminary map delineations, and to describe the range of characteristics within map units and their delineations. An inspection may take the form of a detailed plot with a complete description of vegetation, soil, and site characteristics; a more general "reconnaissance" level plot description; or simply field notes describing a brief ground or air examination.

The manner in which the inspections are distributed over the map area is determined by the sampling design. The number of inspections relative to the area mapped is referred to as the inspection density (Mapping Systems Working Group 1981). The appropriate inspection density depends on the survey intensity (see Table 1), complexity of the survey area, the experience of the mapper, and the sampling design used.

6.6.1 Inspection numbers and methods

Several sample plots are needed to characterize the components of a map unit adequately. If a probability method of sampling is used, then the number of inspections to achieve required levels of confidence and precision should be determined from sample size calculations. If an authoritative method of sampling is used, the following guidelines are proposed. Within a given survey area, a minimum of three reconnaissance plots (an example of a reconnaissance plot form is shown in Appendix 1) are required to identify a previously classified site unit and to note any variation between its characteristics in the study area and those recognized in the original classification. A minimum of five detailed sample plots are required for newly encountered, unclassified site units. The methods for ecosystem description should follow Vold *et al.* (1989).

When authoritative sampling methods and a closed legend are used, data should also be collected to help define the range in characteristics of the map delineations, the variability in composition of the included site unit(s), and variability in landscape features. An example of a form used by Mitchell and Eremko (1987) is shown in Figure 8. Each map unit included in the legend and described in the report should be based on data from a minimum of three map delineation descriptions.

6.7 Correlation

The survey leader is responsible for ensuring that the field crew is mapping consistently and meeting quality standards. Correlation is an important job of the leader. Correlating site units identified in the survey area with previously recognized site units, and correlating map units, both within the survey area and between adjacent surveys, should occur as the mapping proceeds.

Any correlation problems that cannot be solved by the survey leader should be brought to the attention of regional or provincial Ministry of Forests research staff. These staff are also responsible for correlating units in the study area with those found elsewhere. Other specialists (in soils and terrain classification, for example) can also be helpful in handling correlation problems.

6.8 Reviews

Informal reviews are required to evaluate the field work. Generally, initial and final reviews are made, although interim progress reviews can be conducted as needed.

Project Name:________ Date:________ Surveyor:________

Map Delineation:________ Map Unit:________

Biogeoclimatic Unit:________ Air Photo No.:________

Location:________ Terrain Classification:________

Elevation Range:________ Slope Range (%):________ Aspect Range:________

Macroslope Position:________ Drainage Frequency:________

Present Erosion (Surface):________ Mantle Failures:________

Site History:________

Composition of the Map Delineation

Components	Percent of Map Delineation Area	Mesoslope Position	Comments

Management Considerations:

Other Comments:

FIGURE 8. A map delineation form used to collect information on map unit variability (from Mitchell and Eremko 1987).

6.8.1 Initial review

During the reconnaissance and preliminary map delineation stages, the survey leader should begin to develop a working legend. An initial review, at the start of the field inspection stage, assists in developing this working legend. During the initial review, an assessment of the legend and the need to establish new site units should be made. Any adjustment in the sampling design and inspection density (depending on the complexity of the survey area) should also be made at this stage.

The initial review team usually consists of the survey leader and the Regional Research Ecologist and Research Pedologist. In some instances, the Provincial Correlator, Regional or District management staff, forest company representatives, and other soil, hydrology, and terrain classification staff may also be a part of the review team.

6.8.2 Progress review

Progress reviews are held at the request of the survey leader or review team only if special problems arise during the survey (such as changes in survey leaders).

6.8.3 Final review

When the field mapping is complete, a final review is made. As a minimum, the following items and information should be assessed:

- the complete working legend of map and site units,
- sample plot data,
- selected sites representative of the important map and site,
- units (all newly recognized site units should be represented),
- draft map or typed air photos, and
- any measure of map reliability.

6.9 Map Reliability

Once the field map is completed, a measure of the map reliability may be obtained. Reliability in this sense refers to the degree to which the map and legend accurately represent the landscape. The aim of the measure is to discover the amount of a map's area that is acceptably surveyed. Tests for reliability can concentrate on map delineation boundary accuracy, or on the reliability of information provided for any point on the map (Forbes *et al*. 1982). Tests generally concentrate on the latter as (1) it generally incorporates boundary accuracy, and (2) checking and quantifying boundary accuracy is difficult.

The basic steps in carrying out a map reliability test are (modified from Forbes *et al*. 1982):

1. Identify ground truth criteria — those attributes from the legend that will be used to assess each ground truth sample location (e.g., site unit, parent material, slope class).
2. Select sample sites. These sites are drawn from the total map area as one unit, or drawn from strata identified within the map area. Transect, grid, or random methods may be used for selecting sample points. Enough points must be sampled to ensure adequate coverage of the map area and to provide sufficient statistical precision for the reliability test. The number of samples should be considerably smaller than the total sample size required to make the map.
3. Assess each sample site in the field according to the ground truth criteria. Determine a ''reliability'' score according to how closely the map information reflects the actual ground conditions. The score should consider the nature of the ground truth discrepancy. A strongly contrasting discrepancy (e.g., dissimilar map unit components) receives more weight than less contrasting discrepancies (e.g., similar map unit components).
4. Combine results of all sample points for the overall level of reliability of the map (or map strata). Usually this indicates the proportion of sample points according to reliability score.

The most common methods used to test map reliability involve a random selection of transects. These methods test if the actual proportions of the components of heterogeneous map units agree with those stated in the legend. Although developed for soil surveying, the methods for testing map reliability may also be used for ecosystem mapping. Moon and Selby (1985) used a stratified random procedure to map the soil and vegetation units on the west coast of Vancouver Island and were able to express the reliability of their map units in quantitative terms.

The steps in testing for map reliability using a random selection of transects are (modified from Forbes *et al*. 1982 and Valentine 1986):

1. Randomly select a number of delineations of the map unit to be tested. The number of delineations selected depends on the inherent variability of the map unit, and also on the required precision. It is most efficient to start out with a moderate number (e.g., 5-10).
2. Plot a transect in each selected delineation. The transects (straight lines) must cross all significant landscape features within a map unit and have 10-20 sample sites along them at fixed intervals.
3. Sample along the transects. Assess each sample site in the field according to selected ground truth criteria (i.e., ‘‘score’’ the site).
4. Analyze the information using statistical techniques. This allows the estimation of the mean proportion of each component of the map unit, with a stated confidence level and precision. It is suggested that an 80% confidence level be used, and that the estimated mean be within 30% of the true mean proportion. Further transects may be required to reach these levels.

More details of the method, including transect layout, sampling interval, and statistical computations, are given in Steers and Hajek (1979), Wang (1982), Forbes *et al.* (1982) and Valentine (1986).

Map reliability may be assessed by spot checks or re-surveys of selected areas by senior surveyors or correlators. The areas selected are usually not random, but consist of samples of representative landscapes. This process allows the mapper to learn what mistakes were made, and provides a check on map quality. It is also usually cheaper, faster, and more informative than statistical methods (Forbes *et al.* 1982), but it does not allow any objective assessment or prediction of the precision of the map.

7 MAP DESIGN AND FINAL LEGEND

The final published map is intended to portray information to the user in accordance with the survey objectives. In many cases, it will represent a modification of the manuscript (working) map. A number of factors must be considered in designing the map.

7.1 Minimum Delineation Density

Legibility of a map is decreased if too many of the delineations are near the minimum size, or if many symbols have to be printed outside the delineation. If map delineation density is defined as (modified from Mapping Systems Working Group 1981):

$$\frac{\text{minimum size delineation}}{\text{average size delineation}^{5}} \times 100$$

then map delineation densities are recommended to range between 5 and 25% (Mapping Systems Working Group 1981; Forbes *et al.* 1982). Densities greater than this make the map look cluttered; values smaller imply that a larger survey scale or a smaller map scale might have been appropriate. Consultation with the user may be required before a decision is made.

7.2 Map Symbols

Unique map symbols are used to denote each map unit. The selection of an appropriate set of symbols should remain flexible, depending on the individual project. Therefore, rather than specifying a system of map symbols here, the following guidelines are offered:

- Whenever possible, the symbol useage should follow Meidinger *et al.* (1989).
- The symbol should be kept as short as possible to help reduce map clutter.
- Characters in the symbol should convey some, if not all, of the following information:
    - site series or type (including biogeoclimatic unit)

[5] Average size delineation = total land area of map ÷ total number of delineations.

- phase
- seral stage
- landscape features (e.g., rock outcrop).

- The relative dominance of components making up a compound unit should be indicated. If only one class of dominance is used, the two components should be separated with a hyphen (-), with the component in front being the dominant one. If two classes of dominance are considered, the two components should be separated with either a single (/) or double (//) slash. A single slash indicates the two components occupy roughly equal portions of the unit, while a double slash signifies the first component occupies a significantly greater portion (60-80%) of the unit than the second component. If three classes of dominance are considered, it is recommended that the system used for terrain mapping in British Columbia (Howes and Kenk 1989) be followed, with the symbols =, /, and // used for the three classes of dominance. Other mappers may prefer to denote the actual proportion of each map unit component (essential for computer mapping). Examples of symbols that have been used in ecological mapping are given in Table 2.

- On-site symbols should be used to identify very small, dissimilar components of a map unit which will significantly affect management. These may have limited areal extent or simply be point observations. Figure 9 gives some recommended on-site symbols, based on those of Mapping Systems Working Group (1981). Other symbols may be required on a map-specific basis.

TABLE 2. Some examples of map symbols used in ecosystem mapping

Survey	Simple map unit	Compound map unit
Mitchell and Eremko (1987)	biogeoclimatic unit E4b phase site series	E4b//E4c
Banner *et al.* (1985)	site series successional stage variation 06B8 F1 landform/soil unit	80[a]20[a] 06B8 06F F1
Lindeburgh and Trowbridge (1984)	soil type LM-9 vegetation type (site series)	5[a]:LM-9 5[a]:LM-7
Green and Klinka 1981, unpublished report	21 — site series 1.2.1 — phase	13/2.1.1 / 21/1.1.1

[a] Numbers indicate %, or relative %, of delineation occupied by each site unit.

7.3 Colour Scheme

If the map is to be coloured, the colour scheme should convey information to the user rather than simply identifying different map units. A colour scheme has been developed by Klinka and Skoda (1977) for ecosystem mapping. This scheme defines each ecosystem unit within a two-dimensional colour space. Hue is assigned to represent soil moisture regime, while chroma represents soil nutrient regime (using the Munsell

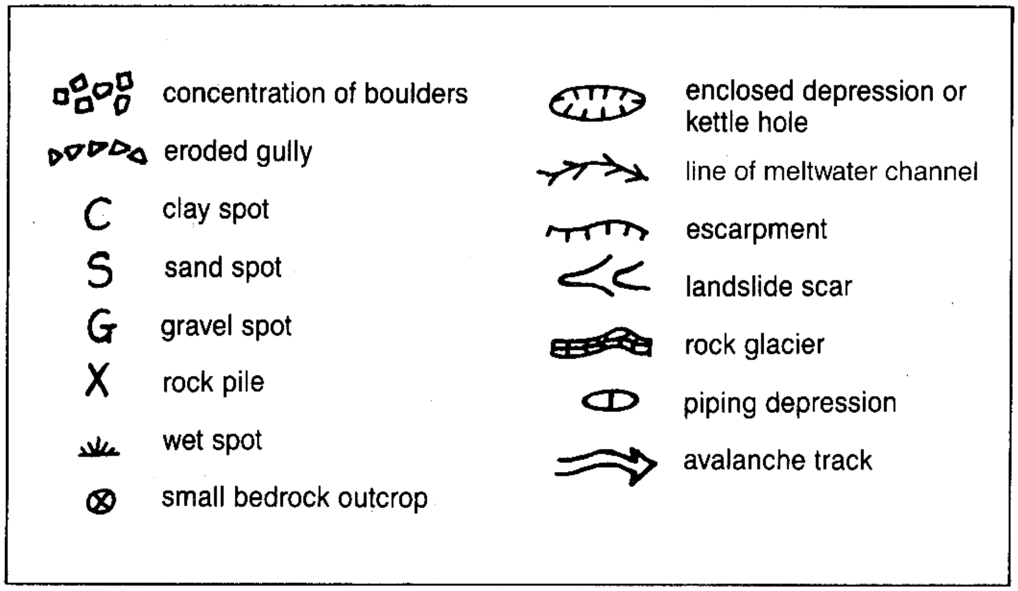


FIGURE 9. Recommended on-site symbols for ecosystem maps.

colour terminology). This scheme should be considered as a starting point for the design of published Other colour schemes may be devised for special-purpose interpretive maps developed from ecosystem

7.4 Inspection Locations

The location of sample points and sampling transects may be identified on the published map, they do not add undue clutter and reduce the map legibility.

7.5 Publication Legend

The publication legend accompanies the final map. It may be of an open or a closed form, the objectives of the survey (see Section 4.4).

In addition to listing all the map units, their components, and their symbols, the published include some of the map unit characteristics, such as moisture and nutrient regime, parent material, and depth, and additional relevant site features (see Figure 6). The detail of information presented the purpose of the survey, the ease of incorporating such information into the legend, and the information presented in the accompanying report.

The format of the published legend should remain flexible. However, it must contain a complete map units (closed legends) and the map symbols for the map units or map delineations (open should also include an explanation of the map symbols used (see Table 2), definitions of any terms description of the map units, some discussion of map reliability, and references for the base map.

8 INTERPRETIVE MAPS

Site units may be grouped into interpretive (treatment) units according to their value for a specific purpose (see Section 3.4). The map displaying the distribution of these interpretive units is referred to as an interpretive (or treatment) map. Such a map will have map units, map delineations, and a legend as described for ecosystem maps. The interpretive map, however, is based on the ecosystem map; map delineation boundaries on the original map may be deleted but new boundaries are not drawn.

8.1 Interpretive Map Units, Map Delineations, and Legends

Interpretive map units are developed in two stages. First, site units are grouped into interpretive units. These interpretive units are the mapping individuals of the interpretive map. Second, those map units of the ecosystem map whose component site units belong to a common interpretive unit are grouped into single interpretive map units. Figure 10 illustrates how the units are related. The interpretive map units are then delineated on a map.

Interpretive map units, like any other map unit, may contain inclusions belonging to dissimilar interpretive units. Similarly, interpretive map units may be simple or compound (composed of more than one interpretive unit).

Several interpretive maps for different resource uses can be developed from a single ecosystem map. The original ecosystem map is usually redrawn, with interpretive map unit symbols replacing ecosystem map unit symbols. Common boundaries between contiguous delineations belonging to different site units, but the same interpretive unit, can be deleted.

A legend should accompany the interpretive map, and should include all information that is necessary to explain the interpretive units and map units. It may be of an open or closed form.

8.2 Interpretive Map Design

Because interpretive maps can be presented for a range of uses (e.g., timber, watershed, and wildlife management), the nomenclature and design of the maps can vary considerably.

Ecosystem map units do not have to be formally synthesized into treatment map units. For example, Lindeburgh and Trowbridge (1984) developed several interpretations for each component of their map units, and presented maps showing the overall interpretation for each specific purpose on each map delineation. Klinka *et al*. (1980) grouped site types into treatment (interpretive) units for the purpose of resource planning at the subunit level. Land use evaluations and a variety of forest management recommendations were then given for each treatment unit. These treatment units were mapped as simple or compound map units. Mitchell and Eremko (1987) formally synthesized treatment (interpretive) map units for timber, watershed, and wildlife management; each map unit was given a symbol and specific interpretations. The legend for their interpretive map for timber management is shown in Figure 11.

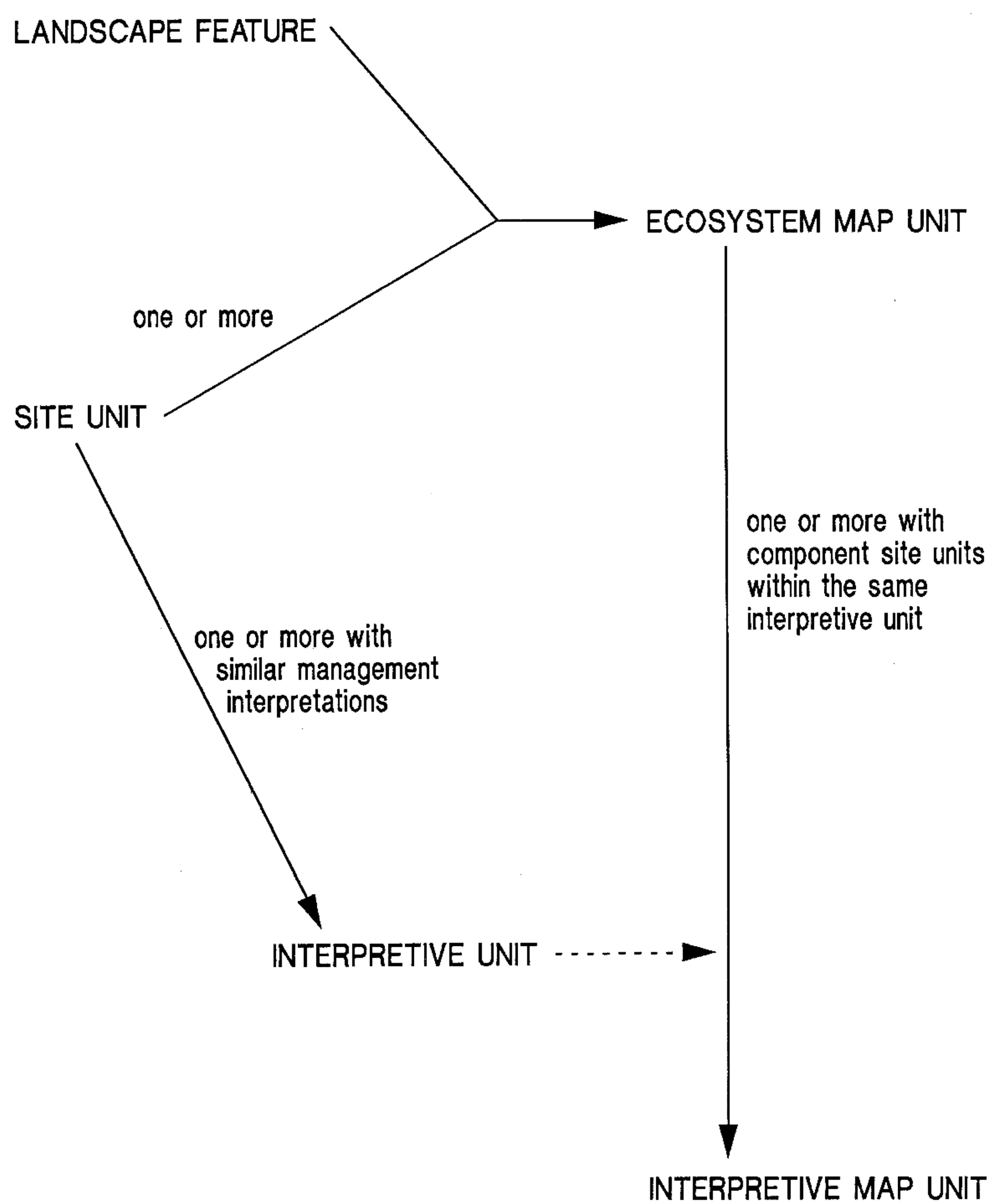


FIGURE 10. A flowchart illustrating how interpretive map units are derived.

Map units	Included ecosystem and miscellaneous map units	Surface erosion hazard	Cutslope failure hazard	Forest product.	Logging & road sensit.	Regen. diff. status	E.P.A.
ESSFe - Dry Southern Forested Engelmann Spruce-Subalpine Fir Subzone							
E-A1	2i, 2i//R, (2h//R, R)	H-E	M-H	P-M	H-VH	M-Se	Esp, Es
E-A1a	2i//Av, Av, 2i	E	H	L-P	VH	Se	Esp, Es
E-A2	2h//R, R//2h	E	M-H	L-P	H-VH	M-S	(Es)
E-A2a	2h, 2h//R, 2h//Av, Av, 4b//Av, (R//2h, R)	E	H	L-P	VH	Se	Esp, Es
E-Bo	4a, 5c, (7c)	L-M	L-M	M-(G)	L-M	Sl-M	-
E-Boa	5c//Av, 5c, Av, (W)	M	M-H	M	M-H	Sl	-
E-B1	4c, 4c//R	H	M-H	M	H-VH	Sl-M	(Esp)
E-B1a	4c//Av, 4c//R, 4c, Av, (5c)	H-E	H	P-M	VH	M-Se	Es,Ep,Esp
E-B2	4b, 4b//R, 4c, 4b/4c, (Av)	H	M-H	M-(G)	H-VH	Sl-M	(Esp)
E-B2a	4b, 4b/4c, 4b/Av, 4b//Av, 4b//R, 5b, 5b//Av, Av	H-E	H	M	VH	M-Se	Es,Ep,Esp
E-Do	8, W	M	Fill-no cuts	-		Sl	-
MSb1 - Thompson Plateau Dry Montane Spruce Variant							
M-Ao	1c	M	L-M	M	M	Sl-M	-
M-A1	1d//R	E	M	P-M	VH	M-Se	(Esp)
M-Bo	3d	M	L-M	M-G	L-M	Sl-M	-
M-B1	2d, 3f, (2d/R)	H	M-H	M	H-VH	M-Se	-
M-B1g	3f/4d	H	H	M-G	H-VH	Sl-M	-
M-B2	3e	H	M-H	M-G	H-VH	Sl	-
M-B2g	3e//g	H-E	H	M-G	VH	Sl	Es
M-Do	6	L-M	M	G	M	Sl	-
IDFd - Dry Western Montane Interior Douglas-Fir Subzone							
D-A1	2f/R	E	M-H	L-P	VH	Se	Esp
D-Co	3g//5c, 4d	M	M	M-G	M	Sl-M	-
D-C1	3f//5d	H	M-H	G	H-VH	Sl-M	-
D-C2	5d 4e	H	M-H	M-G	H-VH	Sl	Es
D-C2g	4e//g	H-E	H	M-G	VH	Sl	Es
( ) Occasionally occurs - Not applicable		E-Ext. H-High M-Mod.	H-High M-Mod. L-Low L-Low	G-Good M-Med. P-Poor	VH-V High H-High M-Mod. L-Low	Se-Sev. M-Mod. Sl-Slight L-Low	Es-Soil Ep-Regener. Esp-Soil Regener.

FIGURE 11. The legend of an interpretive map for timber management (from Mitchell and Eremko 1987).

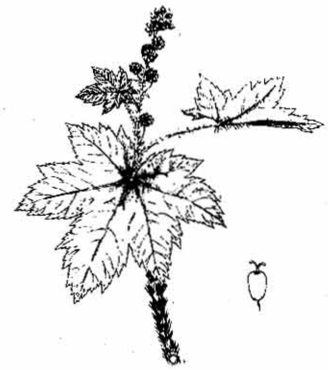
9 REPORT PREPARATION

The content of the report will vary depending on the purpose of the mapping project. The least it should have includes:

- use of the report and maps;
- introduction
  - the introduction should include the objectives and purpose of the mapping survey as well as the intended use of the results;
- location and extent of the area to be mapped including a location map;
- physiography and relief of the area;
- geology and parent material
  - briefly describe the bedrock geology, parent material and landscape patterns of the area;
- climate
  - briefly describe the overall climate of the survey area;
- biogeoclimatic units
  - briefly describe the biogeoclimatic map units (subzones and variants) in the survey area. Include climate and general ecosystem patterns and development (e.g., characteristic species and soil forming processes);
- methods and procedures
  - describe the methods used in classifying, sampling, mapping and data synthesis;
- description of map units and/or site units
  - map units: All map units in the survey area should be described from the data collected during the field investigation. The occurrence and variability of all recognized components plus inclusions of the map unit should be described. Reports often only describe simple map units, and the reader is left to combine the separate descriptions of the units in a compound map unit;
  - site units: All site units should be described in terms of their differentiating characteristics, particularly those features relevant to the interpretations provided. Figure 12 shows an example of a site unit description. Depending on the objectives of the survey, site unit descriptions may be more or less detailed than the example, and may be included in the map unit description;
- map unit or site unit interpretations
  - not all mapping projects will include interpretations, and those that are made will depend on the objectives of the survey. The report should include (modified from Valentine 1986):
    - an explanation of what is interpreted: site units or map units (or map delineations);
    - the methods and criteria used to develop the interpretations, including synthesis of site units into interpretive units and interpretive map units (if undertaken);
    - an expression of the limitations and reliability of the interpretations (and interpretive maps);
  - interpretive maps, if presented, should be explained as in the steps above;
- summary and conclusions; and
- references.

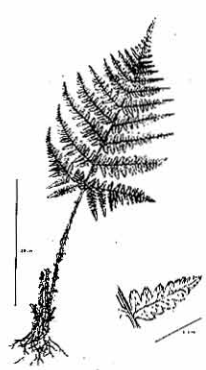
ICHwk3 | 05(b)

CW - DEVIL'S CLUB, FINE - TEXTURED



Oplopanax horridus

Gymnocarpium dryopteris



Dryopteris assimilis

VEGETATION

Tree Layer: 65% cover
Western redcedar, western hemlock, hybrid white spruce, (subalpine fir)

Shrub Layer: 75% cover

Oplopanax horridus	(devil's club)
Ribes lacustre	(black gooseberry)
Acer glabrum	(Douglas maple)
western redcedar	
western hemlock	

Herb Layer: 75% cover

Gymnocarpium dryopteris	(oak fern)
Dryopteris assimilis	(spiny wood fern)
Tiarella unifoliata	(one-leaved foamflower)
Tiarella trifoliata	(three-leaved foamflower)
Rubus pedatus	(five-leaved bramble)
Cornus canadensis	(bunchberry)
Goodyera oblongifolia	(rattlesnake-plantain)
Streptopus roseus	(rosy twistedstalk)
Galium triflorum	(sweet-scented bedstraw)
Circaea alpina	(enchanter's nightshade)
Athyrium filix-femina	(lady fern)

Moss Layer: 75% cover

Hylocomium splendens	(step moss)
Mnium spp.	(leafy mosses)
Ptilium crista-castrensis	(knight's plume)
Rhytidiadelphus triquetrus	(electrified cat's-tail moss)
Pleurozium schreberi	(red-stemmed feathermoss)

SOIL AND SITE

Moisture Regime:	subhygric
Nutrient Regime:	medium - rich
Slope Gradient (%):	usually 0
* Slope Position:	lower - level
* Parent Material:	lacustrine
Soil Texture:	medium - fine
Coarse Fragments (%):	usually 0

COMMENTS
Limited data for fine-textured phase.

DISTRIBUTION: common

FIGURE 12. A site unit description (from Meidinger *et al.* 1988). The sketches are of important indicator species for the site unit.

10 BIOGEOCLIMATIC MAPPING

The classification of vegetation and site units into biogeoclimatic units was briefly described in Section 3. Biogeoclimatic mapping is the process of delineating the extent and distribution of the biogeoclimatic units within a given area. Classification of the units is not the same as mapping them. Mapping of biogeoclimatic units is based on the same mapping concepts and follows, with minor deviations, the same planning and survey procedures as described for ecosystem mapping. The deviations are imposed by the nature of biogeoclimatic units and mapping scale.

Mapping individuals are biogeoclimatic zones, subzones, or variants (and their phases) as distinguished by zonal classification. These mapping individuals are best represented by simple map units. Exceptions are appropriate in poorly accessible areas where there are complexes of non-forested and marginally forested ecosystems, such as alpine and adjacent subalpine parkland ecosystems. Map unit nomenclature should follow the provincial standard: uppercase alphabetical symbol for zones, two- or three-letter lower case alphabetical symbol for subzones, and an Arabic numerical symbol for variants. These symbols should be fully explained in a closed legend.

Biogeoclimatic mapping should be preceded by:

1. the plotting on a working map of the location of zonal ecosystems used to define subzones or variants, and climatic stations used to characterize the units;
2. the study of aerial photographs in conjunction with forest cover maps;
3. the study of satellite imagery (if available). Steps 2 and 3 will identify areas where potentially significant vegetation (e.g., tree cover) or environmental (e.g., snow cover) changes occur. These can be subsequently checked during field inspections; and
4. the preparation of an identification key. This key should be based on diagnostic combinations of species and accessory characteristics such as morphological soil properties, or the pattern or toposequence of azonal (non-zonal) climax ecosystems.

Mapping proceeds by a combination of ground and aerial survey. Boundaries are drawn primarily according to the occurrence of differing zonal climax ecosystems (the map sample points). These are identified most reliably by ground survey. Aerial survey is more suited for identifying changes in the physiognomy and composition of the tree strata. Biogeoclimatic boundaries not verified at selected locations along ground and aerial transects are extrapolated on the basis of elevation, forest cover, physiography, and climatic data analysis and modelling.

Because of the large area involved, the survey intensity appropriate for biogeoclimatic mapping will likely be below level 2 (defined in Table1), except for specific ecosystem mapping projects. As well, boundaries between biogeoclimatic map units are diffuse, reflecting a gradual change from one climate regime to another over a large horizontal distance. This is especially true where the changes occur along a latitudinal or longitudinal gradient; changes along a steep altitudinal gradient are commonly less diffuse, occurring over a relatively short horizontal distance. Consequently, map scales are generally 1:100 000 or smaller, with the final scale representing a compromise between the requirements of the operational users and the actual survey intensity. The difficulty of using such small scale maps in an operational setting may be compensated for by the presentation of identification keys either on the map or in the accompanying report.

Biogeoclimatic subzones, variants, or their interpretive groupings offer a suitable framework for delineating seed collection and transfer (seed zones), forest protection (fire weather zones), forest inventory (inventory zones), and silvicultural management (local yield table, productivity zones, regional working groups).

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APPENDIX 1. Ecosystem Description Form Recommended for Reconnaissance Level Plot Description (FS 882)

PROVINCE OF BRITISH COLUMBIA
Ministry of Forests

ECOLOGICAL CLASSIFICATION RECONNAISSANCE FORM

DATE ____
SURVEYOR ____
SITE NO. ____
PLOT NO. ____

SITE DESCRIPTION

SITE TYPE ____

BIOGEOCLIMATIC UNIT ____ MAP UNIT ____

ECOSYSTEM ASSOC. ____

LOCATION

TRANSECT ____
LOCATION ____
AIR PHOTO NO. ____ X CO-ORD. ____ Y CO-ORD ____
MAP SHEET (NTS) ____ LONG. ____ LAT. ____
ELEVATION ____ ( ) SLOPE ____ % ASPECT ____ °
MESO SLOPE POS ____ SURFACE SHAPE ____
MOISTURE REGIME ____ NUTRIENT REGIME ____
SUCCESSIONAL STATUS ____ EXPOSURE ____

SITE HISTORY ____

SITE DIAGRAM

GEOLOGY

BEDROCK GEOLOGY ____ COARSE FRAG. LITH ____

NOTES: ____

SURFACE SUBSTRATE	
HUMUS	
DEAD WOOD	
BEDROCK	
ROCKS	
MINERAL SOIL	
WATER	

FS 882 RES 88/08

SOIL DESCRIPTION

SOIL CLASSIF. ____ TERRAIN CLASSIF. ____
HUMUS FORM ____ DRAINAGE CLASS ____
ROOTING DEPTH ____ cm ROOT RESTRICTING LAYER TYPE ____ DEPTH ____ cm
SEEPAGE WATER DEPTH ____ cm

PROFILE DIAGRAM

HUMUS

HORIZON	DEPTH	FABRIC STRUCTURE / CONSIST / CHAR. / TEXTURE	ROOTS AB.	ROOTS SIZE	MISCELLANEOUS COMMENTS

MINERAL SOIL

HORIZON	DEPTH	COLOUR	A Sp	TEXTURE	% COARSE FRAGS G	C	S	TOT.	ROOTS AB.	ROOTS SIZE	MISC	COMMENTS

NOTES: ____

APPENDIX 1. (Continued)

VEGETATION

STRATA COVERAGE TREE [ ] SHRUB [ ] HERB [ ] MOSS + LICHEN [ ] SITE NO. ______

FLORISTIC LIST PLOT NO. ______

	A	B	D	TOTAL %		%		%

MENSURATION - WILDLIFE - NOTES

MENSURATION

TREE SPECIES	D.B.H.	C/C	HEIGHT CALCULATIONS								AGE CALCULATION					SITE INDEX
			TOP	BOT.	TOTAL	% S	S.D.	H.D.	COR.	HEIGHT	COUNT	B/H	P. COR.	HT. COR.	AGE	

WILDLIFE REMARKS (TRACKS, SCATS, % UTILIZATION) : ______________________

RANGE REMARKS (CONDITION, UTILIZATION, PRODUCTIVITY) ______________________

NOTES: ______________________

FS 882 RES 88/08