THE NUMERICAL CLASSIFICATION AND MAPPING OF VEGETATION IN TWO
MOUNTAINOUS WATERSHEDS OF SOUTHEASTERN BRITISH COLUMBIA

by

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ABSTRACT

Concomitant with an increasing trend towards the ecological classification of forest land in British Columbia is the need for more detailed vegetation inventories and larger mapping scales. Although existing classification schemes (biogeoclimatic, provincial biophysical and habitat type classification) usually present a useful initial stratification of broad zonal vegetation patterns, they seldom provide, or were intended to provide a classification suitable for detailed vegetation inventory and mapping in a particular study area. In most instances, primary vegetation data must be collected and classified at a level of detail compatible with the scale of mapping and the variability of the vegetation landscape. Limited access and steep mountainous terrain are additional problems contributing to the acquisition, classification, interpretation and mapping of vegetation at large scales.

Dissimilarity Analysis is a numerical classification analysis programmed and studied by the provincial government as a means to stratify large volumes of vegetation data in a relatively objective and efficient manner. As a divisive-polythetic classification strategy it demonstrates several advantages over other numerical analyses. Although it is now used as a routine analysis by the provincial biophysical survey, it has not yet been thoroughly evaluated or formally presented with regard to its suitability for vegetation classification and mapping on an operational basis.

This study investigated four related questions: a. What methods can be employed for detailed vegetation mapping (scale 1:15,840) in mountainous terrain with limited access? b. What is the value of Dissimilarity Analysis for the classification of vegetation in primary survey? c. What is the predictive capability of the pretyping (prestratification) approach developed for vegetation mapping? d. What is the reliability of the vegetation maps. The
study was divided into two separate but related investigations: the operational classification and mapping of vegetation in two small mountainous watersheds and a detailed systematic sampling study of two representative areas within one of the watersheds to assess the vegetation mapping procedure and map reliability.

A detailed vegetation mapping procedure was developed which utilized permanent physiographic landscape features directly observable or inferred from black and white stereo aerial photographs (scale 1:15,840), macro and meso physiognomic vegetation features, a simple concept relating the above features to the available moisture for vegetation, and information about existing vegetation (e.g. forest cover maps; concepts and maps of vegetation zonation).

Dissimilarity Analysis was found to be an objective and efficient method of vegetation stratification by reducing personal bias and ensuring an optimum and consistent utilization of the available information in the data set. It was felt to be an appropriate technique for stratifying primary vegetation data since it maximizes differences between groups, defines limits to classes and facilitates the formation of a hierarchical identification procedure.

It was concluded that the vegetation pretyping approach developed for operational mapping provided a methodical, preliminary stratification of the landscape upon which improved mapping criteria could be added to better predict present vegetation condition.

A quantitative assessment of map reliability in two representative areas of one of the watersheds resulted in a value of 79% relative to an independent chance of agreement of 6.2% and an optimum chance of agreement of 29%. It was felt that these values were representative of the map reliability in the remainder of the watershed.
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Engelmann spruce - subalpine fir parkland subzone

Vegetation Type A
Vegetation Type B
Vegetation Type C

Avalanche Zone

Vegetation Type C-1
Vegetation Type D-1

Engelmann spruce - subalpine fir forest subzone
(Douglas fir not usually a seral species)

Vegetation Type D
Vegetation Type E
Vegetation Type F

Avalanche Zone

Vegetation Type G
Vegetation Type I-1

Engelmann spruce - subalpine fir forest subzone
(Douglas fir often a seral species and persist-
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* Maps are in Special Collections Division, Main Library, University of British Columbia.
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CHAPTER 1. INTRODUCTION
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1.1 The need for an ecological classification of forests

The ecological classification of forest land in British Columbia has recently been considered as a means to improve existing forest management practices. There are several reasons to consider the merits of ecological classification in forestry. First, it is now widely recognized that not all forest "sites" are identical; that a forest landscape consists of a mosaic of forest sites of which some are similar to one another while others are very dissimilar. Consequently, broad management policies, applied ubiquitously over forest districts, have proved ineffective in terms of both ecological considerations and long range economic goals. The day for intensive forest management is forthcoming when decision-making processes will occur on a site-specific basis.

Second, it is also now recognized that forest management is no longer timber management. Traditional forest management is, out of necessity, becoming forest landscape management in the holistic sense. Forest management must now consider the forest-associated resource values of water, wildlife, fish, recreation and, in some instances, agriculture (grazing). This approach to forest management is often referred to as the "multiple use concept" of management or "integrated resource management".

Third, public concern for forest management practices is no longer an avoidable issue. Forest harvesting and reforestation activities are under closer public scrutiny as a result of increased forest recreational activity and a more educated general public. Public response to forest
operations is becoming increasingly more effective as a method of instigating change in forest management policies. As a consequence of these three factors, forest management is becoming a challenging and difficult task which must be cognizant of ecological, economical and social needs.

1.2 The ecosystem concept in forest management

A forest landscape consists of a spatially arranged mosaic of forest ecosystems. An ecosystem is "the total assemblage of living organisms together with their total physical environment in any time-space unit" (Tansley, 1935). It is a concept useful in defining a functional level of biological and physical organization and integration (Rowe, 1961). The essence of an ecosystem is the circulation, transformation and accumulation of energy and matter from the physical environment through the medium of a structured assemblage of living things and their activities (Kimmins, 1973). The ecosystem is therefore a complex multiply-determined entity.

The complexity of the forest ecosystem poses a serious problem to forest management. Successful forest management implies the ability to correctly assign and predict the response of management practices on particular segments of forest land. In order to properly manage a forest ecosystem, the manager must understand the complexity and interactive, interdependent nature of the system. The greater the understanding of the system, the greater the prediction success.

Inasmuch as a forest ecosystem is a conceptual unit with no defined boundaries, it is often of practical value to artificially
delineate its bounds. This spacially defined entity may be defined by assigning an arbitrary level of homogeneity to its component parts. Jenny (1941), when discussing factors of soil formation and Major (1951), when discussing factors of vegetation formation, essentially presented a simplistic model of an ecosystem and its component parts:

\[ v, s = f (c_1, p, r, o, t). \]

In this model, the regional climate \((c_1)\), parent material from which the soil originated \((p)\), topography \((r)\), biotic factor \((o)\) and the fourth dimension, time \((t)\) are the independent state factors while both vegetation \((v)\) and soil \((s)\) are the dependent factors. Crocker (1952) suggested that the five independent variables approximate the ecosystem concept of Tansley and that vegetation and soil together integrate the independent ecosystem factors. Hence, vegetation and soil, which occur as repeatable patterns on a landscape, can be used to identify and describe the boundaries of an ecosystem, an ecosystem type (Klinka, 1976), or biogeocoenose (Sukachev, 1960).

Since forest ecosystems can be given practical spacial limits, they may be identified and delineated on a forest landscape. With a knowledge of the distribution and extent of the various forest ecosystem types, the forest manager may prescribe and predict the effects of his management practices with greater confidence.
1.3 Forest land classification in British Columbia

Several approaches for classifying forest land have been devised for British Columbia. They include a national stratification of Canadian forests into "Forest Regions" (Halliday, 1937; Rowe, 1959, 1972); a "biotic zone" classification for B.C.'s fauna and flora (Munroe and McT. Cowan, 1947); a detailed forest cover classification (B.C. Forest Service); a biogeoclimatic classification for B.C. (Krajina, 1965, 1969); a more recent, biophysical classification (Lacate, 1969; Kowall and Runka, 1968; Young et al., 1973) and a relevant "habitat type" classification developed for the neighbouring United States (Daubenmire, 1952, 1968).

The forest regions approach and forest cover approach will not be considered at this time, as they are both phyto-geographical in nature and are not strictly ecological classifications. In the first case, the intent is to describe the geographic extent of the major forest types (an association of existing trees) in Canada. In the second case, the intent is to prepare detailed maps of the geographical extent of the "goods on hand" at the present time - a static inventory of B.C.'s timber resource. It should be noted, however, that both these mapping and descriptive procedures often provide useful information for ecological studies in particular areas. The classification developed by Munroe and McT. Cowan will also not be discussed in detail below, since the biogeoclimatic classification is essentially a more recent and more sophisticated development of the earlier "biotic zone" concept.
1.3.1 Biogeoclimatic classification

Biogeoclimatic classification in British Columbia (Krajina, 1965, 1969) stemmed from classical European schools of phytosociology (Braun-Blanquet, 1928) and the biogeocoenotic studies of the Russian ecologist, Sukachev (196). This rather traditional method of classification is an ecosystematic approach, employing the integrative role of vegetation and soil to recognize and describe ecosystems (biogeocoenoses). At the higher level of the classification, biogeoclimatic zones and subzones (when identified) are geographic areas which have a characteristic pattern of vegetation and soil within a uniform macroclimate. Each zone and subzone is named by one or two shade tolerant tree species capable of self-regeneration on most of the habitats. Within each zone or subzone a series of biogeocoenoses have been described. Each biogeocoenose characterizes the vegetation and soil of the various habitats which occur as a result of local changes in topography and climate. A biogeocoenose is named by its differentiating species and associated soil. This classification is particularly valuable for making interpretations concerning silviculture, reforestation and provenance (i.e. those of a biological nature). Some of the more common criticisms of the biogeoclimatic approach and its presentation may be summarized as follows:

a. it is too abstract and sophisticated for the practicing resource manager to comprehend (concepts, terminology and nomenclature);

b. the sampling methods used in the detailed biogeocoenotic studies are highly subjective;

c. techniques used for data synthesis and analysis are not
always consistent or repeatable and tend to require a certain "artistry";

(d) the higher synsystematic units of order, alliance and class are floristically hierarchical but have little practical classification value for resource management;

e. it does not always illustrate zonal, subzonal and biogeocoenotic patterns within a clear geomorphological framework;

f. the system is not completely geographically hierarchical;
   (i.e. zones and subzones are quite broad, biogeocoenoses are very detailed);

g. since the classification units are based on modal concepts rather than class limits, they (zones, subzones, biogeocoenoses) are difficult to map on an operational basis;

h. biogeoclimatic units can have limited geographic extrapolation capability from their original area of study; and

i. the classification is strongly biased for making interpretations concerning forest productivity and does not always provide the necessary base information for other forest (land) resource concerns (e.g. terrain characteristics for engineering and recreation interpretations).

1.3.2  Biophysical classification

The biophysical classification evolved from studies in Ontario (Hills, 1953) and Australian land classification studies (Christian et al., 1960). Referred to as the "landscape approach", it stresses the
value of the rather permanent-site features as these exert the fundamental control over all other associated phenomena (local climate, surface, subsurface hydrologic regime, soil, fauna and flora) (Rowe, 1971). Rowe (1971) suggests the classification has a strong geomorphic bias where:

Landforms constitute the essential framework of environment, and the factors or parameters such as soil moisture, temperature, nutrients etc. are attached to this framework which in reality creates, supports and positions them in space. A full description of the land requires attention both to the genetic structural features and to the parameters that adhere to them.

Due to its physiographic nature, the biophysical approach is able to place a heavy reliance on the interpretation of aerial photographs. The biophysical approach may be applied at almost any mapping scale, depending on the purpose of the survey (e.g. national, provincial, regional, watershed) and the time, manpower and money available. At all scales there is an attempt to integrate and map patterns of physiography, soil, vegetation and water (Lacate, 1966, 1969; Jurdant, 1968, 1969; Kowall and Runka, 1968). For all intents and purposes, the "land type", the most detailed biophysical unit, is approximately the same as the biogeocoenose of the biogeoclimatic classification. Vegetation information is employed at all levels of the classification but is set within a clearly defined framework of physiography, geomorphology and soils - a landscape approach. The classification is intended to be holistic in the sense that it is capable of serving the needs of all resource concerns (forestry, agriculture, water, wildlife, fish and recreation).

The biophysical approach applied in B.C. is somewhat different from the national classification (Lacate, 1966, 1969). The provincial biophysical survey uses a "sector" approach whereby component inventories
are conducted in particular map areas. These component maps are then interpreted for specific concerns or integrated using standard overlay techniques. The vegetation component of the biophysical classification employs similar concepts to the biogeoclimatic zone classification and that used by Daubenmire in the United States. However, the vegetation is sampled according to a prestratification of landforms and soils. The vegetation data is then coded and analysed by a computer assisted, numerical classified approach called "Dissimilarity Analysis".

Some of the criticisms of the B.C. biophysical classification are:

a. to date, the methods used in this approach are still not clearly defined and published;

b. it attempts to characterize units of landscape with parameter information at a level of taxonomy too detailed for the scale of mapping and the amount of ground verification;

c. the integrative potential of this approach is frequently neglected; component inventories are seldom integrated into "biophysical units"; and

d. the information is usually of a reconnaissance nature and not always appropriate or presented in a manner suitable for site-specific management decisions.

1.3.3 Habitat Type classification

The habitat type classification was developed by Daubenmire for the forest vegetation of northeastern Washington and northern Idaho. His classification technique has been applied in parts of B.C.'s southern
interior. This synusial vegetation classification characterizes a series of habitat types which may be considered climax phytocoenoses (the climax plant community of the biogeocoenose). Daubenmire uses a bionomial system of nomenclature, listing the dominant species in both the tree and understory "union" for each habitat type (Daubenmire, 1952). A "key" to the habitat types is also provided for the field investigation of both seral and climax communities. His classification is strictly a vegetation classification although soil information is discussed for each habitat type but is not used as definitive criteria for his classification. Zones define a higher level of classification and are clearly related to patterns of macroclimate (Daubenmire, 1968).

Daubenmire's approach has been employed in the southern interior of B.C. (McLean, 1969; Tisdale and McLean, 1957; McLean and Holland, 1957), in the Rocky Mountain region of Alberta (Ogilvie, 1962, 1963, 1966, 1969), in Montana (Pfister et al., 1974) and to some extent in western Washington and Oregon (Franklin and Dyrness, 1973). Operational trials have been conducted to test the feasibility of mapping habitat types in a U.S. national forest (Deitschman, 1973).

For the most part, Daubenmire's classification approach is similar to both the biogeoclimatic and B.C. biophysical approach but applies the "sociation" concept in forming the classification. The habitat type classification is criticized for:

a. placing a reduced importance on edaphic factors and too heavy an emphasis on elevation and aspect;

b. placing too much importance on dominance; and
c. describing types that are too geographically extensive from an ecological point of view.

From the above discussion, it is evident that there are several approaches in existence for classifying forest land in British Columbia. This diversity of classifications and classification approaches has led to considerable confusion among the various resource agencies regarding which approach is most suited to their needs.

1.4 Problem definition

1.4.1 Detailed vegetation inventory

Although it is well recognized that vegetation is an integral component of the forest landscape, it is seldom given adequate consideration in natural resource inventories. Vegetation is the most evident feature of the forest landscape which can serve as a useful integration tool for the identification and mapping of forest ecosystems. In addition, it is important to consider vegetation as a resource in itself which requires a suitable inventory and interpretation for a variety of resource concerns.

The growing trend towards intensive forest land management suggests the need for more detailed vegetation inventories and larger mapping scales. Detailed resource information and interpretation is increasing in demand: data needs for resource folios and environmental protection areas (B.C. Forest Service), wildlife and fish habitat mapping, environmental impact assessments, urban suitability mapping, recreation capability mapping, grazing capability mapping and domestic watershed
inventories. However, access and steep mountainous terrain are common problems in the acquisition of such detailed vegetation information in B.C. Very few detailed vegetation surveys have been conducted in the province.

Unfortunately, the classification approaches discussed in section 1.3 have limited application in detailed vegetation surveys. They usually provide a working concept of broad zonation patterns (sometimes sub-zonation) and may, depending on the geographic location of the survey, describe some of the plant associations for the area. Daubenmire's classification key is a useful guide for vegetation inventory and mapping but unfortunately has limited application in B.C. The two remaining classifications, biogeoclimatic and biophysical, were not specifically designed for the more pragmatic concerns of vegetation inventory and mapping at a detailed scale. Many of the deficiencies of the existing classification and their methods of classification are simply a result of a lack of information on the vegetation of British Columbia and a lack of concern for the geographic process of vegetation mapping.

1.4.2 Dissimilarity Analyses - a numerical classification technique

The classification of vegetation has followed a rather disjointed evolution and even today different views are expressed by classical and numerical phytosociologists. The lack of standardized methods for the classification and description of vegetation has done little to assist the inclusion of vegetation in forest land inventory programs (Kowall and Runka, 1968). Today, plant ecologists are often faced with voluminous masses of data, making classical analytical techniques less favourable.
In B.C., no standardized approach has yet been accepted for classifying primary vegetation data, as both classical and numerical techniques are employed by practicing plant ecologists. The classical approach usually follows the method developed by the Zurich-Montpellier school of phytosociology (Braun-Blanquet, 1928). On the other hand, there is a multitude of numerical techniques available, nearly all of them requiring the assistance of an electronic computer.

Dissimilarity Analysis, as originally conceived by Macnaughton-Smith (1964, 1965), is a numerical classification analysis which has been programmed and studied by the provincial government as a means to stratify large volumes of data in a relatively fast and objective manner. It is a divisive, polythetic classification technique which demonstrates some advantages over other numerical approaches. The classification is now employed as a routine method to stratify and characterize vegetation information in the B.C. biophysical classification approach. Dissimilarity Analysis has not yet been thoroughly evaluated or formally presented with regard to its suitability for vegetation classification and mapping on an operational basis.

1.5 Thesis objectives and study outline

The above review of the existing approaches to stratify forest land in British Columbia indicates that none of the methods are well suited for detailed vegetation inventory and mapping. There is an obvious need for a practical and meaningful method to classify and map forest vegetation at a scale suited to an integrated approach to forest
management. The method should accommodate the complexity of B.C.'s terrain and the difficulty that this imposes on detailed vegetation inventories. The approach should be as simple as possible; should have clearly defined methods and be therefore repeatable; should be feasible in terms of time, manpower and costs; should be relatively flexible with scale; and should be presented in a manner that is understood by a forest land manager.

Computer assisted, numerical classification techniques are now available to analyse large volumes of vegetation data in a relatively objective manner. Dissimilarity Analysis is the numerical classification analysis presently used by the provincial biophysical inventory program. A formal presentation and evaluation of this approach as an aid to the classification and mapping of vegetation is required.

Consequently, this study was undertaken to attempt to answer the following questions:

a. What methods can be employed for detailed vegetation mapping (scale 1:15,840) in mountainous terrain with limited access?

b. What is the value of Dissimilarity Analysis for the classification of vegetation in primary survey?

c. What is the predictive capability of the vegetation pretyping (prestratification) approach developed for vegetation mapping?

d. What is the reliability of the vegetation maps?

The following general outline will be used to describe the study. Chapter 2 will discuss the various aspects of traditional and numerical approaches to vegetation classification, methods of landscape mapping and the status of vegetation maps in B.C. Chapter 3 will describe the development of the Dissimilarity Analysis classification analysis, the
general function of the analysis and the present format of the program. Chapter 4 will outline the study strategy, the methods used to collect the field data, and the analysis, interpretation, mapping and presentation of the vegetation data collected for the two operational watershed studies (Grassy Creek and Templeton River). Chapters 5 and 6 have a parallel structure describing the Grassy Creek and Templeton River watersheds respectively. Each chapter describes the study area, presents and discusses the results of the classification analysis and the subsequent mapping of the vegetation. Chapter 7 is an inclusive discussion of the systematic sampling study used to determine the predictive capability of the pretyping approach and the reliability of the vegetation maps. Chapter 8 is a summary discussion of vegetation classification and mapping procedures and findings in this investigation. Chapter 9 gives the conclusions to this study.

Footnotes:

1. The terms "detailed" and "large scale" will be used to indicate a scale of approximately 1:15,840.
2. These will be discussed in more detail in Chapter 3.
CHAPTER 2. THE CLASSIFICATION AND MAPPING OF VEGETATION
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2.1 Principles of classification as they apply to vegetation

Classification is a natural, inherent and intuitive process of man which imposes a state of relative order on an otherwise disorderly array of entities. Classification assists our memory, allows for communication and comparison and is an abstraction of our knowledge. It provides a model for testing and generating hypotheses and predicting events. All classifications are purposive (Rowe, 1971). They may be devised for purely pragmatic reasons or for less tangible, abstract reasons, but in all cases the purpose will dictate the criteria chosen for classification and the results obtained.

In the biological and earth sciences, the process of classification attempts to identify discrete entities within naturally continuous systems. These systems consist of a number of individuals which collectively form a population. The individuals possess certain properties or attributes which can be used to partition a population into a series of classes. Thus, "a class is a group of individuals, or of other classes, similar in selected properties and distinguished from all other classes of the same population by differences in these properties." (Cline, 1949). Each class contains individuals with the "differentiating characteristics" chosen to define the class; with "accessory characteristics" which covary with the differentiating characteristics; and with "accidental characteristics", independent of the differentiating characteristic(s). Each class is
therefore defined by both the differentiating and accessory characteristics, the range of the class being the standard deviation. The central concept of the class is expressed by the properties of a modal individual, whether real or statistically estimated (Cline, 1949).

"Vegetation" is a collective term used to describe the assemblage of plant species on the surface of the earth. It is a three dimensional feature which varies in structure, composition and spatial distribution. Consequently, vegetation is naturally heterogeneous, the degree of heterogeneity being a measure of its continuity as well as its discontinuity. The classification of vegetation highlights its discontinuous nature, while the process of ordination accentuates its continuous nature. The interest of this study is in the classification of vegetation.

When classifying vegetation, the phytosociologist views the landscape as a mosaic of rather distinct and repeatable three dimensional units. Each tesserae1 of the mosaic is called a plant community and possesses a number of attributes (growth form, life form, strata, species composition). When communities (or samples representing these) are grouped according to their similar and dissimilar attributes, a classification is formed. In each class the central concept represents a "community-type" (Whittaker, 1973).2 The community-type is an abstract entity which has been synthesized from a number of real individuals observed in the field.

2.2 History of and traditional approaches to vegetation classification

The classification of vegetation has had a remarkably complex and disparate history. Classification was, and still is of central concern
to those studying natural communities (Whittaker, 1962). Shimwell (1971) suggests that historically much of the confusion over vegetation classification was due to problems with language barriers; the constant attempt to form an analogous classification to that of species taxonomy and systematics; and classical problems with scientific jargon and its misinterpretation. Several exhaustive reviews of the history and evolution of phytosociology have been written (Whittaker, 1962, 1973; Alexandrova, 1969; Shimwell, 1971). This section will highlight some of the more important aspects discussed in these reviews.

The study of natural communities had its origin in the field of botany, where the term "association" (von Humbolt, 1807), used to define a group of co-existing plants, had its first use in a scientific classification (Clifford and Stephenson, 1975). Grisebach (1838) later defined the term "formation" as a fundamental physiognomic expression of natural communities. It was not until the latter half of the 1800's that the community concept was considered for animal populations (von Post, 1868 and Mobius, 1877).

Various "schools" or traditions" of phytosociology have developed since the early part of the twentieth century. The tradition generally evolved in different geographical regions, and accordingly reflected the character of the local vegetation as well as the philosophical bias of the particular school. Whittaker (1973) suggests that unlike species taxonomy, there is no "natural" unit in vegetation. He suggests that if species are distributed individualistically and communities tend to
integrate, a variety of features may be selected to classify vegetation, all of them resulting in arbitrary units. Most of these features are closely related to one another but have their own distribution within a vegetation structure. Depending on the features chosen to classify, the vegetation units may be quite different in their membership and areal extent. The five major approaches (traditions) will be discussed below to illustrate the variety of features and concepts used in vegetation classification: physiognomic, dominance-type, stratal, site-type and floristic. However, some of the approaches are similar to one another since they use related features and properties of vegetation.

The physiognomic tradition marked the earliest approach used to classify vegetation. This approach came into early favour with those undertaking studies in plant geography (von Humbolt, 1807; Grisebach, 1839). Physiognomic attributes of vegetation are particularly useful during preliminary investigations and studies conducted at small scales, since the units can be quickly established, easily recognized and readily mapped. The resulting units ("formation-types") are usually highly correlated with macroclimatic patterns. According to Beard (1973), the physiognomic classification relates well to "the salient structural characteristics of communities" and their functional relationship to the environmental factors of the landscape. Physiognomic methods of vegetation classification have been employed throughout the world and are still used today as a useful measure of community structure.
The "dominance-type" approach defines its units on the basis of one or more dominant species within the community. It is often used to complement a physiognomic treatment of vegetation, since it is the next most obvious character of the plant community. The American tradition, developed by Clements (1928, 1936), emphasized successional relationships and dominant species growth forms (Whittaker, 1962). The British tradition also favored the use of dominance-types and the successional approaches used by Clements (Tansley, 1939). Classifications based on dominance are easily accessible and relatively simple to convey to field practitioners less familiar with the complexity of vegetation. On the other hand, many ecologists believe that dominance is only one feature that characterizes a community and is seldom the most significant (Whittaker, 1973; Shimwell, 1971).

The "Northern" tradition (sometimes called "Scandinavian" and "Baltic" traditions) was originally influenced by physiognomic concepts of classification. Although the flora in these northern regions lacked species diversity, it displayed well-defined strata, or layers. The stratal concept in classification was pursued in three major directions. A synusial approach fathered by Gams (1918, 1927), recognized distinct species strata and lifeforms and called them "unions". The famous Uppsala School developed an approach which used a combination of unions and called them "sociations". The sociation concept has been used extensively throughout Scandinavia (Whittaker, 1962). Daubenmire (1952) has used this concept for characterizing the vegetation of northeastern Washington and northern Idaho.
The fourth tradition was the "forest site-type" originally developed in Finland by Cajander (1909). The forest site-type approach groups forest stands on the basis of a similar understory composition. The composition of the forest canopy was felt to have little indicative value for site quality (Frey, 1973). Forest site-types have been a useful method to assess site quality and have accordingly, been a preferred unit for forest management. This concept has had considerable use in classifying Canadian forests (Ilvessalo, 1929; Heimburger, 1934; Sisam, 1938; Ray, 1941; Spilsbury and Smith, 1947).

Floristic methods in vegetation classification are best represented by the Braun-Blanquet school of phytosociology. This floristic method classifies communities on the basis of their entire complement of species. Selected stands are grouped by floristic criteria to form abstract units called "associations". An association is characterized by a group of diagnostic species which are later used to establish a more generalized hierarchy above the level of the association (syntaxa: orders, alliance and class). Sometimes called the "Southern" tradition, the Braun-Blanquet school still has the largest following: "it is the most widely applied and most effectively standardized of all approaches to classification" (Whittaker, 1973). Variations of this school have been used in eastern Canada (Grandtner, 1960; Lafond et al., 1964; Jurdant and Roberge, 1965) and in British Columbia (Krajina, 1965).

Many of the approaches discussed above are used today as they were originally conceived, with modifications to the original approach or by
combining the various concepts. When discussing the merits of the various techniques in phytosociology, Poore (1955) aptly points out: "It is important not to be dogmatic about these concepts. None of them has complete validity; all are useful."

2.3 Numerical approaches to vegetation classification

As a framework for a later discussion on Dissimilarity Analysis (Chapter 3), this section will review some of the basic principles employed in the numerical classification of vegetation. Although some of the advantages and disadvantages of various approaches will be highlighted, this section is not intended to be an exhaustive critique of the multitude of numerical classification analyses that are now available.

2.3.1 Introduction to and objectives of numerical classification

Over the last 25 years, biological and ecological sciences have shown increasing favour towards numerical methods of classification, where classification has been the desired end result. Some of the reasons for this trend in phytosociology are:

a. a decreasing confidence in subjective sampling and analytical methods and an increasing need to make investigations more objective and repeatable;

b. the vast quantities of data presently being collected for analysis and the need to correlate fresh data and analyses with those of earlier studies;
c. the development and availability of fast, sophisticated, digital computers; and
d. concomittant with the above reasons, a reciprocal interest by statisticians, mathematicians and computer programmers to devise appropriate analytical techniques and programs.

Initially, the use of numerical methods in the biological sciences was restricted to standard statistical and mathematical procedures. For approximately the last 15 years, however, there has been a surge of numerical techniques for taxonomy and synecology (biocoenology). Several adjectives have been used to describe these techniques, not all of them synonymous: statistical, mathematical, computer, objective, quantitative and numerical. The term "statistical" is used in the more general sense to include both probabilistic and non-probabilistic studies (as defined by Lambert and Dale, 1964). The word "mathematical" simply suggests that the analyses used have a mathematical basis even though in many cases not all the mathematical properties are fully understood (Clifford and Stephenson, 1975). The term "computer" has often been used to acknowledge the dependency of these techniques on the speed and efficiency with which computer systems can perform complex and repetitive calculations. That all of these approaches are "objective" is somewhat misleading. No approach to classification can be completely objective since subjective decisions will always enter a scientific investigation in the nature of the data collected and the form of analysis. However, many of these approaches are more objective than the more classical, intuitive methods
of classification. In some instances, the term "quantitative" has been introduced. The use of this word should be restricted to techniques that employ quantitative data and quantitative analyses. The term "numerical" seems most appropriate for this study, since both mathematics and statistics employ numbers as fundamental characters of examination.

For the most part, numerical and traditional approaches to vegetation classification use similar principles but employ different symbols and terminology. The prime objective in classification is to reveal some structure in a continuous set of data. This process should be distinguished from "identification" which involves the allocation of an individual to an already established set of classes. Orloci (1975) states three main objectives of classification:

a. problem solving (prediction, hypothesis testing etc);
b. problem recognition (hypothesis generation); and
c. data reduction, inventory etc.

In the first case, there has been some concern that "while classifications can be used to perform a predictive function reasonably well, they are generally not suited to serve as a basis for testing hypotheses about the existence of natural types" (Orloci, 1975). Presently, there is considerable disagreement between and among statisticians and "taxonomists" over the relative merits of predictive analyses. The concern arises over whether probability concepts apply to many of the numerical classification approaches (particularly the non-probabilistic techniques). Statistical parameters may be used as relative indices, although such parameters cannot serve to test
hypotheses involving frequency distribution, since such distributions are usually not known. The inference aspects of numerical classifications have been discussed in considerable detail with no apparent agreement on the issue (Macnaughton-Smith, 1965; Williams and Lance, 1968; Goodall, 1975; Orloci, 1975). Any classification will technically be arbitrary rather than "natural". Depending on the number of accessory characteristics associated with a class, some classifications are more "successful" than others at predicting the value of unobserved variables.

In the second case, Orloci suggests that classification acts as a preliminary analysis, by revealing causal factors and permitting the generation of hypotheses. Contrary to this viewpoint, Cormack (1971) warns that where data are continuous in nature, classification has an imposing influence thereby restricting the potential number of hypotheses that can be generated (e.g. it rejects the possibility of the continuum hypotheses). Goodall (1973) emphasizes that if numerical analyses are used to generate hypotheses then the hypotheses should be stated clearly in a tangible form and subsequently tested for their performance, preferably using a separate data set.

The third, and probably most essential function of classification is that of data reduction, sometimes referred to as descriptive analysis (the analysis applies only to the individuals being classified). This operation is of particular value when the number of individuals and their attributes exceed our capacity to identify them as individuals. This common utilitarian practice serves as a basis for inventory, mapping and the general organization of information. Its purpose is to reveal structure
and pattern among the groups formed (Yamada, 1976). For each class we can make a number of statements, assign an appropriate name and disclose other qualities of the class that are otherwise not apparent.

2.3.2 Vegetation data

Studies using numerical classification generally recognize vegetation as a three component system: the plants (usually species), the sites (geographic position - latitude and longitude) and the habitat (climate, relief, parent material and fauna) (Lambert and Dale, 1964). Phytosociology is the study of plant/plant relationships on a site and plant/plant relationships over a number of sites. Plant ecology or vegetation ecology (Mueller-Dombois, 1974) is the study of plant/site/habitat relationships.

Numerical approaches to vegetation classification predominantly investigate plants in relation to one another and in relation to their geographic position (sites). The correlation of habitat factors with classification units generally occurs as a separate operation. The most frequently used vegetation attribute is species composition (floristic variables). The reason for this is the "general acceptance of the species concept as an economical method of characterizing plant material by a number of properties simultaneously at a generally convenient level of abstraction." (Lambert and Dale, 1964). Classification proceeds in two directions: "normal analysis" where sites are grouped according to their
species or "inverse analysis" where species are grouped according to sites of their occurrence. Ideally, an optimal grouping should occur with a single, composite analysis (nodal analysis) whereby normal and inverse analyses are performed simultaneously.

Qualitative and quantitative floristic variables are used in numerical classification analysis, the most common being simple binary data or the presence or absence of a species. There is some difference of opinion concerning the relative merits of presence/absence data and qualitative data. Presence/absence data is quicker to obtain in the field, requires shorter computing time and permits the use of more powerful analytical techniques. Some authors contend that the information gain using quantitative data (informing classification) is minimal (Lambert and Dale, 1964 and Macnaughton-Smith, 1965). Arguments against the sole use of binary data are: rare species occurrences have high information value, emphasis is placed on the extremes of a specific distribution (Clifford and Stephenson, 1975), and a species presence is not necessarily the same as a species absence (Lambert and Dale, 1964). A general consensus of opinion would suggest that presence/absence data and analyses are appropriate when samples are quite heterogeneous but should yield to more sensitive quantitative procedures when the samples are relatively less heterogeneous. Most numerical classifications give equal weight to all attributes in the primary analysis. Less obvious weighting may occur however as a result of certain analytical calculations (e.g. indices), plot-species ratios, highly associated attributes and structure in the community.
2.3.3 Numerical classification strategies

Similar to traditional approaches to classification, each numerical approach has a particular classification strategy. Williams, who is a renowned authority on numerical classification, has rather appropriately (amusingly) "classified" the various classification strategies according to a dichotomous key (see Figure 2.1). The categorical levels of the resultant dendrogram are in order of increasing difficulty of "choice". It is important for the user of numerical classifications to be cognizant of these choices. The resulting classification will be a function of the data collected and analysis strategy selected.

The first dichotomy (choice 1) is between non-exclusive and exclusive classifications. In the latter situation, an individual (entity) belongs exclusively to one class, once classified. This form of grouping is common to systematics and land survey where "boundaries" must be delineated. The non-exclusive grouping allows each individual a membership in more than one class. This non-exclusive strategy is extremely purposive (e.g. a geographic index of vegetation samples).

The second dichotomy (choice 2) occurs between extrinsic and intrinsic classification. Intrinsic classification employs all attributes of the individual equally in forming groups. In land survey, the resulting clusters can reveal discontinuities in the "external" attributes which were unknown in advance (e.g. common plant communities revealing discontinuities in the depth of the water table). Extrinsic clustering,
Figure 2.1 A dichotomous key showing the choices of classification strategy (based on Williams, 1971) and the relative position of Dissimilarity Analysis in this key.
on the other hand, results in groups which enhance discontinuities in the external attributes, which were defined in advance. These first two choices are strongly governed by the use to which a classification is intended.

Choice 3 is between a hierarchical and non-hierarchical strategy. Hierarchical classification expresses the relationship between the grouping(s) and the entire population at any given level (Lambert and Dale, 1964). The hierarchy is presented in a two-dimensional dendrogram which outlines a "route between the entire population and the set of individuals of which it is composed" (Williams, 1971). The hierarchical dendrogram may plot the route from the entire population to the individual or due to some arbitrary stopping rule, may only plot to some convenient "final" grouping of individuals. The advantage of a hierarchical scheme is that a grouping may be extracted at any chosen level of generalization. Most hierarchies are dichotomous, the few trichotomous approaches having proved less useful (Williams, 1971). Unlike hierarchical systems which optimize the route of fusion or fission (which can result in sub-optimal groupings), non-hierarchical systems optimize the final group structure (homogeneity), with no route defined between the individuals, groups and parent population. Although the non-hierarchical approaches are in some instances theoretically favourable, the analyses are at an early stage of development and do not have the flexibility, sophistication and speed of hierarchical methods.

Choice 4 is between a divisive or agglomerative procedure. In the former, the initial data set is successively divided into smaller groupings,
the groupings at each level of division being examined independent of
the original population prior to splitting. An agglomerative procedure
begins with the individuals and progressively groups individuals, in-
dividuals and established groups (or individuals) with one another.
Divisive strategies tend to emphasize differences between groups while
agglomerative strategies tend to highlight similarities within groups.
Divisive techniques have several advantages over agglomerative approaches
(Lambert and Dale, 1964; Orloci, 1967; Goodall, 1973; Poole, 1974;
Williams, 1971; Clifford and Stephenson, 1975).

The final choice in classification strategy (choice 5) is between
a monothetic or polythetic treatment of attribute information. Monothetic
classification divides a set on the basis of a single attribute whereas a
polythetic method divides or aggregates a set on the basis of all attributes.
Monothetic approaches can only be divisive while polythetic techniques apply
to all agglomerative and some divisive analyses (Lambert and Dale, 1964 and
Williams, 1971). Monothetic techniques are simple and well suited to the
formation of discriminant keys. Polythetic procedures take advantage of all
attribute information in the construction of the hierarchy and often the
final groups formed. The most commonly used hierarchical strategies are
polythetic and agglomerative.

2.3.4 Measures of similarity or dissimilarity and algorithms

Measures of similarity or dissimilarity in numerical classification
analysis are used to define the "likeness" or "unlikeness" of: two
individuals, an individual and a grouping, and two groups of individuals. Similarity and dissimilarity are mutually dependent concepts, the former term usually being applied to both concepts (Clifford and Stephenson, 1975). A plethora of similarity measures have been developed: coefficients of similarity and association, Euclidean distance, information content and similarity measures dependent on probability estimates, and many others. Not all measures can be performed on all data types and classification strategies. Comprehensive reviews of similarity measures can be found in Sokal and Sneath (1963) and Cormack (1971).

An algorithm is a mathematical procedure used to implement a classification strategy. It is the mechanism by which the measures of similarity are synthesized and evaluated to form groupings. As an example, "Association Analysis", as developed by Williams and Lambert (1959 and 1960), employs a popular algorithm. This monothetic divisive approach successively divides an initial set by the presence or absence of one species. The species chosen is based on the $\chi^2$ test using the $2 \times 2$ contingency table. After division of the initial set, the process is iterated on the resulting groups by selecting another species criterion. The process continues until the groups formed in the previous division have an association matrix which may have occurred by chance (as measured by an arbitrary stopping rule based on a selected $\chi^2$ level of significance). Many other algorithms have been developed to implement the various classification strategies and measures of similarity. These have been reviewed by Pielou (1969), Cormack (1971), Goodall (1973), Orloci (1975) and Clifford and Stephenson (1975).
2.4 Vegetation mapping

2.4.1 Maps, inventories and classification

A map is typically a two-dimensional flat surface representing a segment of the earth's sphere. Maps portray an arrangement of features geographically and in spacial arrangement to one another. Maps, together with their legends, serve a number of practical functions:

a. they provide a visual characterization of earth features and locations at a reduced scale, comprehensible to the human mind;

b. they provide a visual synthesis, simplification and emphasis of earth features and locations that are of particular interest;

c. they provide for the dissemination of information (data) in a geographic form; and

d. they provide for a geographic comparison of earth features and locations.

Maps are a tool used extensively for the study and management of natural resources. Natural resource inventories are usually presented in the form of a map and legend. Such mapping involves the identification or recognition of "units" of landscape which are similar or dissimilar according to some classification. Hence, classification should not be considered the same as an inventory but rather a tool used to compare one unit with another - a yardstick. The usefulness of a particular classification to "landscape mapping"\(^9\) depends on the similarity of the units being classified to those being mapped, the similarity of the attributes chosen to classify to those chosen as mapping criterion and the distribution of these units on the landscape.
2.4.2 Approaches to landscape mapping

The approaches used in landscape mapping will vary with the nature of the information being mapped, the scale of mapping and the availability of existing information or relevant associated information. From an holistic point of view, it would be ideal to map all natural landscapes using an almost infinite number of observations to facilitate an almost infinite number of interpretations. For obvious reasons, this is very impractical. Generally, two major approaches are used for mapping: one in which samples are collected to represent different units of landscape and one in which samples are collected to reveal the existence of particular units or landscape.

The first approach favours the use of extrinsic attributes of the landscape (e.g. slope, aspect, slope configuration) for mapping the resource but usually defines the mapped units on the basis of its intrinsic attributes (e.g. soil development, plant community). The assumption behind such a procedure is that repeatable discontinuities observed for external features imply a relative homogeneity of the internal features within the unit. Samples within the extrinsically defined repeatable "pretyped" (prestratified) units characterize the intrinsic nature of the unit thereby testing the internal-external correlation. The reliability of this mapping approach depends on the correlation success. This technique can be applied at nearly all scales, is well suited to remote sensing aids and is quick and economical in terms of the time and effort required per unit area mapped. Many exploratory and reconnaissance surveys therefore employ this approach to mapping.
The second approach to landscape mapping imposes no prior stratification of the landscape into pretyped units. Using this procedure, samples are taken either at random or systematically; systematic sampling being obviously more practical for mapping objectives. The systematic sample is usually conducted using a pre-selected, intersample distance grid. The samples are then classified, similar grid points forming a map unit. Since there is no sample criteria for the exact placement of boundaries between two adjacent grid points, extrinsic features may be used to approximate a boundary position. This approach lends itself well to statistical analytical techniques. However, for practical reasons it is often not feasible since many samples are required per unit area, making it slow and uneconomical. This approach is a necessary technique when there is no prior knowledge about the distribution of the resource being considered or its relation to extrinsic features.

2.4.3 Vegetation maps

Kuchler (1967), in describing the history of vegetation maps, states that vegetation features first occurred on maps during the fifteenth and sixteenth centuries. Forests were the common feature shown since they were "of significance in military matters, hunting reserves, timber resources or obstacles of communication" (Kuchler, 1967). Most of the early maps however, employed vegetation symbols as purely decorational features or to indicate the vast unexplored regions of a map. Seventeenth and
eighteenth century maps began to distinguish between a number of vegetation features: meadows, fields, swamps, deciduous and coniferous forests and vineyards. During the nineteenth century, vegetation mapping was conducted in various parts of the world at a variety of scales and with an increasing sophistication. The early twentieth century saw a greater development of phytosociological methods and their gradual influence on vegetation mapping. European approaches at this time were usually of a large scale and very precise. By the early twentieth century, vegetation mapping had become a science and its value affirmed by the establishment of two famous institutions: "Service de la carte de la végétation de la France an 1:200,000" at Toulouse, founded by Gaussen; and the "Service de la carte des groupements végétaux de la France an 1:20,000" at Montpellier, founded and directed by Emberger. The Russians followed a similar development to the Europeans while the American studies, following Clements, lacked a precisely defined terminology for their detailed vegetation units. The American mapping tended to be more pragmatic than the scientific concepts used in Europe and Russia. Presently, vegetation maps have been prepared for many parts of the world. The variation in the maps and mapping approach reflects the variation of the vegetation under study and the objectives for mapping. Therefore, it is not surprising that there is no standardized method for mapping vegetation.

Assuming that discontinuities in vegetation can be revealed and that they are repeatable, vegetation may be defined as "a mosaic of plant
communities in the landscape" (Kuchler, 1967). Consequently, each plant community (tesserae) can be identified and mapped. The community-type concept, discussed above (2.1), provides a necessary framework for the mapping of natural vegetation. The purpose of a vegetation map is to show the distribution and extent of a number of vegetation units. Vegetation maps should only show features specific to vegetation (Fosberg, 1961), with the associated features (e.g. soil and climate) included as accessory items correlated in the legend, even though they may have been used as criteria for delineating map units. Similarly, the names and symbols used to identify the units should represent features of vegetation (e.g. species composition, dominance, structure, life form etc.)

As discussed earlier, vegetation is a complex phenomena which can be described in a number of ways. This not only poses difficulties in the classification of vegetation, but also in the mapping of vegetation. Four basic features have been used to map vegetation: physiognomy and structure, floristics, community dynamics, and biotopic features of the communities, or combinations of these four (Kuchler, 1973). Historically, physiognomy and structure have been a successful way of mapping natural vegetation. Physiognomic features are particularly well suited to small mapping scales (e.g. the world, continents and countries). Floristic maps require more detailed information on the species composition of a region. Consequently, floristic maps are usually presented at larger scales than those using purely physiognomic qualities of the vegetation.
Vegetation dynamics have always caused concern over the mapping and classification of vegetation. Kuchler (1961, 1967) points out that it is primarily the aperiodic natural and anthropic changes to the environment that cause the greatest difficulty to vegetation mapping: landslides, glaciers, recent fluvial deposition, forest harvesting, grazing (animals and insects) and fire. Kuchler (1967) defines "actual vegetation" (or present vegetation) as that which occurs at the time of observation. "Natural vegetation" is that vegetation unaffected by man, while "potential natural vegetation" (synonymous with climax vegetation) is defined as that vegetation resulting from the normal processes of succession without the influence of man and without any climatic change (Kuchler, 1967). The term "stable vegetation" has also been used to describe that vegetation which has been allowed to grow without disturbance and has reached a balance with the environment; in this state, the plants are able to reproduce themselves for generations until the environment changes (Zoltai and Pettapiece, 1973). The successional "state" of the vegetation adopted for mapping will always depend on the purpose of the survey. Kuchler (1961, 1967) suggests that a well defined legend can change a static map into a map which discloses the present status of the units and their relative position in the successional sequence.

Biotopic approaches to vegetation mapping use the habitat features of the plant community as criteria for defining the position and extent of the vegetation units. This use of extrinsic features for mapping was discussed above in section 2.4.2. Most mapping approaches rely on
extrinsic criteria for approximating some of the unit boundaries not readily apparent or observable.

2.4.4 Vegetation Maps in British Columbia

Relative to many European countries, remarkably few vegetation maps have been prepared for the vegetation of British Columbia. At a provincial scale (1:3,484,800), Munroe and McT. Cowan's map of "Biotic Zones" (1947, 1956) is probably the first approximation of the major vegetation zones distributed across the province. As part of a national mapping program, Halliday (1937) and later, Rowe (1959, 1972), prepared a map of "Forest Regions" at a scale of 1:6,336,000. Since 7 out of the 10 national categories (8 regions plus grasslands and tundra) occur in B.C., Rowe's map is often used as a reference for broad vegetation types in the province. A third and slightly more detailed map is the "Biogeoclimatic Zones" map of the province (Krajina, 1973) at a scale of 1:1,900,800. By definition, this is an ecological map; however, vegetation zonation is easily inferred.

Reconnaissance scale maps have recently been prepared for a number of N.T.S. map sheets by the provincial biophysical survey operation. The maps show "present vegetation condition" (physiognomy, successional status and floristic character) and the same for "climatic climax" vegetation zones and subzones at several scales ranging from 1:50,000 - 1:250,000. Pilot projects conducted by the B.C. Forest Service in the Chilliwack Provincial Forest, Toquart River and Chapman Creek, included
the mapping of biogeoclimatic subzones at a scale of 1:63,360
(Briere, 1974, 1975). MacMillan Bloedel has published a map of "The
Biogeoclimatic Subzones of Vancouver Island and Adjacent Mainland and
Islands" at a scale of 1:380,160 (Packee, 1974), and the B.C. Forest
Service is engaged in biogeoclimatic subzone mapping in selected forest
districts; the resulting maps will probably be published at a scale of
1:250,000. The Canadian Forestry Service has prepared a reconnaissance
vegetation map in the "Capital Region" at a scale of 1:125,000 (McMinn
et al., 1976).

Detailed maps of forest cover types have been prepared by the
B.C. Forest Service at a scale of 1:15,840. With a strong commercial
bias, these maps show a static inventory of B.C. forest cover stratified
by age, height, volume and site classes. The recent introduction of
resource folios by the B.C. Forest Service has necessitated the mapping
of "detailed - reconnaissance" landscape units and their associated
vegetation in selected watersheds throughout the Vancouver Forest District
(Briere, 1975 and Jones, 1976). The Canadian Forestry Service has also
conducted detailed landscape analyses (1:10,000 - 1:20,000) on two Gulf
Islands (Hirvonen et al., 1974; Hirvonen, 1976) and the Victoria highlands
(Eis and Oswald, 1975). To date, the most detailed vegetation ("eco-
systematic") map is that prepared by Klinka (1976) for the U.B.C. Research
Forest at a scale of 1:10,000.

In the United States, Pfister (1969), Daubenmire (1973) and
Deitschman (1973) have mapped "habitat-types" at a detailed scale
in several national forests of Washington, Oregon, Idaho and Montana. Deitschman's mapping technique is of particular interest, since it addresses the problem of mapping vegetation in large inaccessible areas using extrinsic landscape attributes. A similar technique is evaluated in this study.

Chapter 2 has reviewed some of the basic principles of vegetation classification; the five major traditions in vegetation classification; some of the more important features of numerical classification; and mapping procedures, the relationship between mapping and classification and the status of vegetation maps in B.C. Chapter 3 will discuss the numerical classification analysis applied in this study.

Footnotes:

1. A small piece of marble or glass, having a square face, used in mosaic work.

2. Whittaker (1973) uses the "community-type" as a general term to describe the "class concept" used in any classification system. The "community-type" is essentially synonymous with the term "plant association" (Mueller-Dombois, 1975, p. 173).

3. The suggestion that species taxonomy is "natural" is not totally agreed upon by all taxonomists.

4. Assuming a "natural" classification could ever exist.

5. Earlier studies in numerical taxonomy (Sokal and Sneath, 1963) referred to "Q" analysis or entity classification (normal analysis) and "R" analysis or attribute classification (inverse analysis).

6. The discussion in this section has been based largely on Williams (1971), Lambert and Dale (1964), Goodall (1973) and Clifford and Stephenson (1975).
7. The word "classification" in the numerical sense is synonymous with "cluster" or "grouping" (analysis).

8. The advantages of divisive techniques will be discussed in Chapter 3.

9. The term "landscape mapping" is used in a general sense to describe the mapping of any attribute of a natural landscape. This is a less specific use of the term "landscape" as applied in section 1.3.2.

10. Note: not necessarily "recognized".

11. Vegetation maps should be distinguished from maps which show the distribution of specific plant species, since these are purely taxa distribution maps and not vegetation maps.

12. In a more recent publication used to describe B.C.'s flora, Lyon's (1971) uses this map to introduce the major vegetation zones of the province.

13. N.T.S. -- National Topographic Series.
CHAPTER 3. DISSIMILARITY ANALYSIS
3.1 Dissimilarity Analysis as a classification strategy

Dissimilarity Analysis is a numerical classification analysis initially conceived by Macnaughton-Smith et al., (1964) to facilitate investigations into the causes of delinquency and the treatment of offenders. The "individuals" in Macnaughton-Smith's research were actual people; the "attributes", any physical or mental character of a human being. Although his study was concerned with the classification of people, Dissimilarity Analysis, like any other classification procedure, can be applied to a variety of things for a variety of purposes. As Macnaughton-Smith (1965) points out, "the individuals may be people, animals, plants, words, items in tests or questionnaires, or physical materials; indeed any object suitable for scientific observation."

Figure 2.1 shows the relative position of Dissimilarity Analysis in the dichotomous hierarchy of classification strategies. To reiterate, Dissimilarity Analysis is "exclusive" - the individual is a member of only one class; "intrinsic" - the classification is based on inherent features of the individuals; "hierarchical" - there is a classification structure between individuals, groups and the initial population; "divisive" - the initial population is successively divided into smaller and smaller groups; and "polythetic" - divisions are based on a measure of dissimilarity applied to all attributes.

Polythetic-divisive classification strategies have several advantages over the more common polythetic-agglomerative approaches:
a. a divisive strategy begins with the maximum information available over the whole population to determine the critical top-most divisions\(^1\) (Lambert and Dale, 1964; Williams and Lambert, 1966; Williams, 1971; Goodall, 1973);

b. a divisive strategy quickly reveals the higher levels of the hierarchy, which are often of greatest interest, without having to establish a complete hierarchy from the individual to the population as in agglomerative techniques;

c. related to "b" above, a divisive operation can be terminated at any convenient level;

d. if initial subdivisions of the population have been missed by chance, they are usually recognized at lower hierarchical levels in a divisive classification strategy, whereas agglomerative techniques are prone to irrevocable allocation at the inter-individual level where the possibility of errors is greatest (Williams, 1971); and

e. a divisive strategy maximizes differences between groups and defines limits to classes.

The main disadvantages of polythetic-divisive classification strategies are that:

a. the necessary calculations frequently require more computing time than agglomerative techniques and methods which attempt to reduce the number of calculations do not allow consideration of all potential divisions;

b. sets may be partitioned by chance too early in the process, forming hierarchies which do not completely reflect the structure of the population; and
c. there is an inability to distinguish internal variation from variation between groups which may lead to "artificial" divisions.

In the past, most numerical, divisive strategies have been limited to the computationally more favourable monothetic analyses: positive interspecific correlation (Goodall, 1953), Association Analysis (Williams and Lambert, 1959, 1960; Noy-Meir et al., 1970) and Group Analysis (Crawford and Wishart, 1968). Surprisingly few attempts have been made to develop a satisfactory polythetic-divisive strategy (Williams, 1971; Lambert et al., 1973). Edwards and Caralli-Sforva (1965) were probably the first to describe a polythetic-divisive analysis and rather admirably elected to consider all possible dichotomous subdivisions of the population. Although this form of analysis is the most ideal it is highly impractical. In a divisive analysis, the total number of possible subdivisions at any level of the hierarchy is $2^{n-1} - 1$ or as Williams (1967) rather appropriately illustrated: "suppose we had 600 individuals... The number of ways we can divide these into two groups is represented by a figure 4 followed by 180 zeros; the earth is unlikely to exist long enough for the job to be completed." It is therefore not surprising that the method of Cavalli-Sforva has been restricted to data sets of less than about 16 individuals (Lambert et al., 1973).

It soon became apparent that polythetic-divisive analyses require a method to reduce the total number of "potential divisions" considered at any level of the hierarchy. This reduction method has been called a "restriction rule" (Macnaughton-Smith, 1965) or a " 'directed search' to limit the number of splits examined" (Lambert et al., 1973). At the present, relatively few
techniques are available which institute a restriction rule or directed search. A divisive strategy which reduces the number of potential divisions to be considered has been introduced in the Dissimilarity Analysis scheme proposed by Macnaughton-Smith (1964, 1965). His approach forms a "restricted family" of potential divisions for each subdivision of the population or subpopulation. Lambert et al. (1973) describes two polythetic-divisive analyses ("AXER" and "MONIT") which either classify (monotheistically) or ordinate the population first, and then, relocate the individual to improve the split. Dissimilarity Analysis will be discussed below.

3.2 The analysis

Polythetic-divisive classification strategies have four basic requirements:

a. a "restriction rule" or "restriction procedure" which limits the number of "potential divisions" that are to be considered at any level of the classification (these potential divisions form the "restricted family");

b. a dissimilarity function or measure to define the "likeness" and "unlikeness" between two individuals, an individual and a group and two groups so that a choice can be made between the members of the restricted family;

c. a "stopping rule" to designate when groups are final and require no further subdivision; and

d. an allocation rule to assign new individuals (not included in the initial data set) to an already established group (class).
The first three requirements will be discussed in more detail below. The allocation rule is discussed in detail by Macnaughton-Smith (1965) and will not be discussed below, since it is not required for this particular investigation.

3.2.1 Restriction rule or restriction procedure

Since there are \(2^{n-1}-1\) possible ways of subdividing a population of "n" individuals, Macnaughton-Smith developed a step-like procedure to form a restricted family. Given an initial set with "n" members, that individual which is most unlike the rest of all other members is selected out. Next, this selected member is combined with each member of the remaining set to form "n-1" possible pairs and the pair most unlike the set of all other pairs is chosen. Next, the chosen pair is combined with each member of the remaining set to form "n-2" possible triads and the triad most unlike the set of all other triads is selected. This procedure is iterated until "the addition of one more individual to the increasing set reduces the between-set dissimilarity instead of increasing it" (Macnaughton-Smith, 1965).

3.2.2 The information statistic as a dissimilarity function

As discussed earlier in section 2.3.4, a variety of similarity and dissimilarity measures are available to determine the likeness of two partitions or two agglomerations in dichotomous, hierarchical procedures. In Dissimilarity Analysis, the dissimilarity function measures the "unlikeness" between two groups formed in a potential division. Hence all potential divisions of the restricted family can be compared, choosing that division which maximizes between-set dissimilarity.
The dissimilarity function proposed for Dissimilarity Analysis (Macnaughton-Smith, 1965) uses "information theory" as a means to measure disorder. Information theory was originally developed by Shannon (1948) to solve problems in communication (message transmission, message length, number of messages and cable utilization). More recently, (since the late 1950's), information theory has been applied in biological studies concerning species diversity, evolution, classification and plant succession (Orloci, 1968,1970). In the process of classification, the initial population and the groups formed contain "information" (species presence and absence and species performance) which is a "physical property of the data related to probability." (Orloci, 1968). The greater the similarity between the members of a group, the lower the information content and the greater the difference between the members of a group, the higher the information content.

An "information statistic" (I) is used as a similarity or dissimilarity function to measure the deviation from complete entropy (disorder) both among and between a set of entities so that a reduction in entropy (relative state of order) can be created. As a dissimilarity function, the information statistic evaluates the information gain (ΔI) of each potential division of the initial set and selects that division for which the information gain is maximized between the two groups formed.

Orloci (1968), when discussing the advantages of the information statistic, points out that conventional multivariate techniques often rely on rigid assumptions about the distribution of the individual variables analysed. The information statistic, on the other hand, is free from such restrictions and can be easily applied to a variety of data types. Since the individual variables in many vegetation studies may be highly skewed,
discontinuous or polymodal, the non-parametric information statistic is particularly appropriate (Williams and Lance, 1968).

3.2.3 Stopping rule

Divisive, hierarchical classifications partition an already known initial data set into a number of groups. If the classification process continues without interference, the "groups" ultimately become each individual of the initial population (assuming there are no identical individuals). However, in most classification endeavours, the investigator is most interested in the intermediate populations of the hierarchy and designates them as "final groups". A stopping rule controls a divisive activity by assigning a level of the hierarchy beyond which no further subdivisions are undertaken. Lambert and Williams (1966) have discussed the principles and use of stopping rules in detail.

In Dissimilarity Analysis, a stopping rule is applied where there is a level in the divisive hierarchy in which the dissimilarity between two potential sets is not sufficiently great and the division should be suspended (Macnaughton-Smith, 1965). Assuming that the dissimilarity function is comparable over all stages of the analysis, then an arbitrary value can be assigned to determine sets as final. Macnaughton-Smith (1965) and Williams and Lance (1968) emphasize that tests of significance are not applicable, even when the dissimilarity measure has known statistical properties, because the groups formed are not random but have been derived using some optimal criteria. Thus, a stopping rule must always be arbitrary. The information
statistic used in Dissimilarity Analysis is related to the $\chi^2$ function in that $2I$ approximates the $\chi^2$ distribution. Macnaughton-Smith recommends using this property to provide a stopping rule. Consequently, the stopping value used in this analysis uses the $\chi^2$ statistic with $"v"$ ($v = \text{number of species minus one}$) degrees of freedom significant at the 5% level of confidence.

3.3 Development and use of Dissimilarity Analysis in British Columbia

J.W.C. Arlidge of the Research Division, B.C. Forest Service, was one of the first applied plant ecologists in British Columbia to show a special interest in the application of numerical analytical techniques to problems in vegetation classification and land survey. In conjunction with M. Kovats, a programmer analyst for the Division, Arlidge (1971) began his studies using the monothetic-divisive, Nodal Analysis following Williams and Lambert (1961). The same analysis and program was applied successfully by J. van Barneveld (1971) on vegetation data collected in the Cariboo region. Later, Arlidge became particularly interested in the polythetic-divisive classification introduced by Macnaughton-Smith (1964, 1965) and its potential advantages over the monothetic strategies. Arlidge and Kovats developed and tested the Dissimilarity Analysis program in 1972 and found it to be a useful technique for vegetation classification. Until the time of his retirement, Arlidge continued his studies with Dissimilarity Analysis by investigating the possibility of incorporating quantitative data and finding a more satisfactory stopping value.
Since Arlidge's retirement, his program has been adopted by the provincial biophysical survey operation and has been expanded into a more complete vegetation data analysis package entitled "Coenos 1". This rather complex data analysis and presentation routine was designed by J. van Barneveld and programmed by A. Češka. Additions to the original Dissimilarity Analysis include:

a. an option for conditional or unconditional entropy (Češka, 1975);
b. a mean similarity measure using Sørensen's coefficient to indicate the homogeneity of final groups (Češka, 1966, 1968);
c. a cluster analysis of species using Sørensen's coefficient;
d. a cluster analysis of final group members using Euclidean distance or Sørensen's coefficient; and
e. a cluster analysis of final groups using Češka's (1966, 1968) mean similarity coefficient.

Presently the Coenos 1 program is being applied to vegetation data operationally in provincial biophysical studies in research studies in the B.C. Forest Service and in academic studies at the University of British Columbia. It is hoped that in the near future improved documentation for the program will make it more readily transferable to other computer facilities and more easily understood by potential users.

This chapter has attempted to explain Dissimilarity Analysis as a classification strategy, the basic components of the analysis and its development and use in British Columbia. Chapter 4 will outline the methods used to implement Dissimilarity Analysis into the classification and mapping of forest vegetation at a detailed scale.
Footnotes:

1. Note: agglomerative techniques begin at the inter-individual level where information is minimal.

2. Association Analysis was described earlier in section 2.3.4.

3. In a later publication, Williams (1971) suggests that larger matrices could possibly be handled using the highly sophisticated information statistic program of Wallace and Boulton (1968), but there has been little experience of its use.

4. Most of the discussion in section 3.2 is based on a detailed account of Dissimilarity Analysis by Macnaughton-Smith (1964, 1965).

5. This relationship is discussed in detail by Kullback (1959).


8. These additions will be discussed in greater detail in Chapter 4 (section 4.3.1.).

9. Note: the original program used only unconditional entropy which is based on species presence and absence as divisive criteria; conditional entropy, on the other hand is based only on species presence as divisive criteria.

10. All clustering routines have been written by Dr. E.M. Hagmeier, Biology Department, University of Victoria.

CHAPTER 4. METHODS OF STUDY
4.1 Study strategy

In an effort to answer the four questions posed in section 1.5, the study was divided into two rather separate investigations. The first investigation was operational\(^1\) in nature, addressing the first two questions:

a. What methods can be employed for detailed vegetation mapping (scale 1:15,840) in mountainous terrain with limited access?

b. What is the value of Dissimilarity Analysis for the classification of vegetation in primary survey?

This investigation was conducted in two interior watersheds of British Columbia: Grassy Creek and Templeton River. The results from each watershed study are discussed in Chapters 5 and 6 respectively.

The second investigation addressed the second two questions posed in section 1.5:

c. What is the predictive capability of the vegetation pretyping (prestratification) approach developed for vegetation mapping?

d. What is the reliability of the vegetation maps?

This investigation, dependent in part on the results of the first investigation, used a systematic sampling method. The specific objectives, methods and results of this investigation are discussed in Chapter 7.

The methods discussed in this chapter pertain primarily to the first (operational) investigation.

The study was undertaken in conjunction with a parallel investigation of soils and surficial material.\(^2\) Watershed\(^3\) areas were selected
for study because of their conceptual value in understanding, characterizing and describing landscape patterns and their geographical practicality in providing logical and natural boundaries for areas subject to a particular tenure and forest (land) management practices (e.g. resource folios). The Grassy Creek and Templeton River watersheds were chosen for the following reasons:

a. both watersheds were located in Public Sustained Yield Units that were being inventoried for forest cover types by the B.C. Forest Service, Inventory Division, and were therefore easily studied in terms of logistics;

b. both watersheds have recent, large scale (1:15,840), black and white aerial photography;

c. both watersheds have at least one main access road along the valley bottom suitable for vehicle transport;

d. both watersheds are of suitable size and have sufficient access to permit the collection of all necessary field data within a four month field season;

e. both watersheds contain seral and climax forest vegetation so that dynamic aspects of vegetation could be considered in the classification and mapping procedure; and

f. the two watersheds are significantly different in terms of bedrock, surficial materials, climate, soils and vegetation to facilitate comparison between them.
4.2 Field studies

Prior to field investigations, existing information for each watershed was collected. This included soil reports, geological memoirs, vegetation reports and theses, climatic data, topographic maps, Canada Land Inventory maps and black and white aerial photographs.

Field studies commenced in the Templeton River valley during the second week of June, 1974. With the assistance of one full-time assistant, the field work was completed in 40 days. Seven days were spent in field reconnaissance (including one hour of helicopter reconnaissance), 5 days in the field office, and 28 days in plot sampling (including 5 days spent on the systematic sampling study). A helicopter was used on three occasions to transport the field crew to the upper elevation of a descending transect.

Field studies in the Grassy Creek valley commenced in the first week of August and continued for 24 days. Three days were spent in field reconnaissance (including one hour of helicopter reconnaissance), 4 days in the field office and 17 days plot sampling. A helicopter was used on two occasions to transport the field crew to the upper elevation of a descending transect.

4.2.1 Reconnaissance

Following a preliminary viewing of two scales of aerial photography (1:63,360 and 1:15,840), field reconnaissance was conducted in each watershed. The reconnaissance procedure consisted of: an investigation of all potential access roads; familiarization with local watershed geography; walking along selected topographic transects to obtain an...
overview of vegetation patterns; familiarization with watershed flora; and an evaluation of existing information available for the watershed (bedrock, surficial materials, soils, topography, drainage patterns and forest cover). In addition, approximately one hour of helicopter reconnaissance was carried out in each watershed.

4.2.2 Pretyping approach

The field reconnaissance provided a useful introduction to the broad scale vegetation patterns occurring in each watershed and revealed the variability that could be expected within some units. It also made apparent the problems of limited access to and the areal extent of each watershed which would make the acquisition of intensive vegetation information within the allotted time-frame (approximately 3 months) a difficult task. It therefore became evident that the methods used must rely heavily on aerial photo interpretation; the technique of predicting present vegetation condition on the basis of observable or inferred landscape features and the correlation of these features with ground observations and sampling. This approach to mapping is common in the earth sciences (Buringh, 1954; Burger, 1957; Colwell, 1960; Soil Survey Staff, 1966; Lord and McLean, 1969) and has been applied in eastern Canada to map forest vegetation and forest sites (Losee, 1942; Rinfret, 1964; Jurdant, 1964).

The pretyping approach used in this study evolved from a landscape analysis technique originally developed by Brière\(^6\) (1974, 1975) for "detailed-reconnaissance" forest site mapping using primarily aerial photo interpretation. Brière's scheme was designed for use in mountainous
regions where permanent, geographical features of slope length, slope configuration and slope aspect are integrated into landscape units. These rather permanent units of landscape are used to "tie-in" the associated characteristics of water, terrain, soils and vegetation. The study adopted most of the concepts, features and symbols from Brière's landscape analysis but modified the legend with a bias toward pretyping present vegetation condition. The pretyping legend developed for this study is shown in Table 4.1. Using this legend, the site and present vegetation condition were predicted, using observable features from aerial photographs (1:15,840) and existing information on vegetation zonation and forest cover. Each map unit was characterized by four basic components; hygrotope/slope position, aspect/exposure, present vegetation condition and any terrain features and processes having a major influence on present vegetation condition. The direct and inferred aerial photo features and other existing information used to characterize each map unit component are listed in Table 4.2 A stylized slope profile illustrating the use of the vegetation pretyping legend is shown in Figure 4.1. Using Old Delft scanning stereoscope, the aerial photographs for Grassy Creek and Templeton River were pretyped according to the legend discussed above.

4.2.3 Field sampling

Following field reconnaissance and aerial photo pretyping, vegetation sample plots were taken in each valley. The pretyped units provided the necessary stratification for locating field transects and sample plots. Due to limited access and time, transect locations were selected to include the greatest variety and number of pretyped units. High elevation areas
Composite symbols are employed within each map unit quadrant where two or three features are intermixed or occupy such small areas that they cannot be designated as separate units. Features within the quadrants are written in decreasing order of importance. If it is possible to indicate the relative amounts of each feature, the following symbols are employed:

- the components on either side of the symbol are approximately equal
- the component in front of the symbol is more extensive than the one that follows
- the component in front of the symbol is considerably more extensive than the one that follows

Table 4.1 Vegetation pretyping legend
<table>
<thead>
<tr>
<th>MAP UNIT COMPONENT</th>
<th>AERIAL PHOTO FEATURES DIRECTLY OBSERVABLE ABOUT THE MAP UNIT COMPONENT</th>
<th>AERIAL PHOTO FEATURES DIRECTLY OBSERVABLE USED TO INFERENCE THE PROPERTIES OF THE MAP UNIT COMPONENT</th>
<th>EXISTING INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLOPE POSITION/ HYGROTOPE</td>
<td>a slope position for complex and simple slopes&lt;br&gt;drainage network</td>
<td>slope position, slope length, slope configuration, present vegetation condition, aspect/exposure, terrain features (parent material drainage)</td>
<td>topographic map (1:50,000)&lt;br&gt;planimetric map (1:15,840)</td>
</tr>
<tr>
<td>ASPECT/EXPOSURE</td>
<td>slope, slope orientation, slope position, valley position, valley orientation</td>
<td>glaciers and snow, present vegetation</td>
<td>topographic map (1:50,000)</td>
</tr>
<tr>
<td>PRESENT VEGETATION</td>
<td>physiognomy, pattern, tree species identification, tone, texture, density, land use</td>
<td>land use, slope position/hygrotope, aspect/exposure, terrain features (parent material drainage)</td>
<td>forest cover map (1:15,840)&lt;br&gt;vegetation zonation map (1:50,000-1:2,000,000)</td>
</tr>
<tr>
<td>TERRAIN FEATURES AND PROCESSES (i.e.LAND-FORMS AND PARENT MATERIAL)</td>
<td>exposed talus, rock, or unconsolidated deposit, drainage network, snow, glacier, slope position, slope configuration, valley orientation, valley position</td>
<td>present vegetation condition</td>
<td>landform and soils maps (1:50,000)&lt;br&gt;geology map (1:250,000)</td>
</tr>
</tbody>
</table>

Table 4.2 Aerial photo features and other existing information used to characterize map unit components.
Figure 4.1 Stylized slope profile illustrating the use of the vegetation pretyping legend (vertical scale exaggerated). Symbols are described in Table 4.1.
had a low sampling intensity due to their limited access and, in the Templeton watershed, their limited development of vegetation. Sample plot locations, field traverses and access roads are shown in Figures 4.2 and 4.3 for Grassy Creek and Templeton River respectively. The extent of "ground truth" obtained for each valley, relative to watershed area and the number of pretyped map units, is summarized in Table 4.3 below.

Table 4.3. Extent of ground truth obtained for each valley, relative to watershed area and the number of pretyped units.

<table>
<thead>
<tr>
<th></th>
<th>Grassy Ck</th>
<th>Templeton R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of pretyped map units</td>
<td>208</td>
<td>228**</td>
</tr>
<tr>
<td>no. of pretyped map units sampled at least once*</td>
<td>62 (29%)</td>
<td>75 (33%)</td>
</tr>
<tr>
<td>no. of pretyped map units intersected by transects*</td>
<td>97 (46%)</td>
<td>105 (46%)</td>
</tr>
<tr>
<td>no. of sample plots</td>
<td>85</td>
<td>121</td>
</tr>
<tr>
<td>area of watershed (ha)</td>
<td>3240</td>
<td>3650</td>
</tr>
</tbody>
</table>

* expressed in absolute values and as a percentage of the total number of vegetated pretyped map units.

** an additional 21 pretyped map units in the watershed were mapped as non-vegetated.

Transects were marked on aerial photographs and located in the field using features observable both on the ground and in aerial photos (e.g. roads, forest openings, talus, forest type changes, etc.), and by following a compass bearing. Sample plots were located within the pretyped units on those sites observed to have a relatively homogeneous
Figure 4.2 Grassy Creek - sample plot locations, field traverses and access roads.
Figure 4.3 Templeton River - sample plot locations, traverses and access roads.
vegetation (structure and composition) and habitat (slope, microtopography, moisture regime, parent material, soil and microclimate). Any observable variations in vegetation or habitat were noted during the traverse through a particular pretyped unit. Variations felt to occur in more than 15% of the pretyped unit were sampled.

The size of a sample plot was not determined using the concept of minimum area (Poore, 1955), but varied somewhat depending on the nature of the vegetation and habitat under study. For example, sample plots located in avalanche tracks and along narrow floodplains were usually considerably smaller (e.g. .001 ha) than those located in forest stands. The average plot size for forest stands was .04 ha (1/10 of an acre) as recommended by Daubenmire (1967) for stands of similar character. Sample plots were circular in shape. The circumference of the first 20 sample plots was marked using a measured radius measure of 11.3 m (37.2 feet). A visual estimate of this radius (and circumference) was used in subsequent sample plots and only the plot centre was marked with flagging.

At each sample plot, a species list was prepared for all vascular plants and bryophytes growing in mineral soil and humus. Unfamiliar species were collected, labelled and identified later in the field office. The species list was subdivided into 8 strata based on height and growth form. A coverage estimate was obtained, for each species in each layer it occurred, using a 6-class coverage scale (Daubenmire, 1959). Stratal categories and coverage classes are defined in Appendix I. A species list for both watersheds is given in Appendix II. Additional site information recorded at each sample plot included elevation, slope, aspect, macro and micro-topography, slope configuration, site history
(e.g. logging, fire, slides, etc.), moisture regime, substrate quality (by percent cover) and an estimate of the parent material and soil development.

4.3 Data analysis interpretation and application to mapping

Following field studies, the data were assembled and checked for errors and omissions. Vegetation and physical data were coded for computer analysis and storage and a separate data set was established for each study area: Grassy Creek (85 samples), Templeton River (121 samples) and "Systematic Sampling Study" (31 samples). Vegetation data were analysed using the Coenos 1 program at the provincial government computer facility. The "output" from the Coenos 1 program, its analysis, interpretation and application to mapping are discussed.

4.3.1 Coenos 1 computer program output

As mentioned earlier in section 3.3, Dissimilarity Analysis program has been incorporated into a more complete vegetation data analysis routine entitled "Coenos 1" (Češka, 1975). The Coenos 1 program offers a number of "accessory analyses" and print-out options usually performed after an initial stratification of the data set by Dissimilarity Analysis. The analysis options selected in this study are the same as those selected by the provincial biophysical (vegetation) survey studies:

a. Dissimilarity Analysis performed using condition entropy (a qualitative analysis);
b. species clustered using Sørensen's coefficient and unweighted pair clustering;
c. plots clustered within final groups using Euclidean distance and weighted pair group clustering (a quantitative analysis); and
d. final groups (from Dissimilarity Analysis) clustered using mean similarity coefficients between final groups and weighted pair group clustering.

4.3.1.1 Dissimilarity Analysis

Due to limited computer storage, an "unmasked" species list was selected for input to the Dissimilarity Analysis program when the total number of species exceeded 200. The species "masked" were those which occurred only once in the total data set (i.e. the lowest constancy), and were retrieved again during the table printouts.

Vegetation structure is introduced into the analysis by the potential for a "layer weighting" of tree and shrub species. Weighting is accomplished by allowing any particular tree or shrub species to score a single attribute for each layer it occupies. For example, a particular tree species represented by individual plants in all tree and shrub layers (6 layers in total) would contribute a score of 6 attributes to the sample plot. Shrub species can contribute a maximum of 2 attributes per species since there are only 2 shrub layers.

Dissimilarity Analysis was performed on each data set using the stopping value discussed in section 3.2.3 ($\chi^2_{0.05(v)}$; $v =$ number of species -1). The results of the analysis showed: the divisive hierarchy
of the data set into "intermediate groups", "final groups" and "single plots"; the "chi-square" value for intermediate groups and final groups and the "mean similarity value" of each final group. This information was used to construct a Dissimilarity Analysis dendrogram (see Figure 4.4). An "intermediate group" is a subdivision of the initial set of plots whose members are not considered to be a final group at that particular level of the hierarchy (on the basis of the stopping value). A "final group" is a subdivision of the initial set of plots whose members cannot be divided any further and therefore form a final group (on the basis of the stopping value). A "single plot" is a "final group" but with only one member. The "chi-square" figure indicates the information gained (ΔI) by dividing the set of plots at an intermediate level of division (intermediate groups) or the potential information gain by dividing the set of plots within a final group. The "mean similarity measure" indicates the homogeneity among the members of a final group.

Češka (1975), suggests that values below 50 percent indicate heterogenous groups, values between 50 and 60 percent indicate reasonably homogeneous groups and values greater than 60 percent indicate very homogenous groups.

4.3.1.2 Accessory analyses

The "species cluster analysis" aggregated those species which were distributed similarly over the plots sampled. These groupings do not necessarily reflect causal relationships among species. However, the detected patterns may prove useful in studying a variety of species relationships to one another and to environmental factors. The results
Figure 4.4 The components of a Dissimilarity Analysis Dendrogram as constructed from the analysis print-out.

Figure 4.5 Examples of cluster analysis dendrograms: (a) plot cluster within a final group; (b) cluster analysis of final groups derived from Dissimilarity Analysis.
of this analysis complemented the comparative analysis procedure discussed in section 4.3.2.1 below. The results of this analysis are shown by a dendrogram in which species are not partitioned by layer.

The "plot cluster analysis" was performed on all plots of each final group with more than two members. This analysis revealed the hierarchical structure within each final group based on the similarity of the plot members to one another (see example Figure 4.5(a)).

The "final group cluster analysis" (final groups derived from Dissimilarity Analysis) displayed the hierarchical structure of final groups based on the similarity of the final groups to one another (see example Figure 4.5(b)).

4.3.1.3 Tables

Two tables were printed following the Dissimilarity Analysis and the accessory (cluster) analyses: a "synthesis table" and a "constancy table". The synthesis table presented a species x plot matrix with cover values as matrix entries. Species were arranged according to the results of the "species cluster analysis" and were partitioned by layer. The plots were arranged according to the plot cluster analysis (the arrangement of plots within a final group) and then by final group order according to the cluster analysis.

The "constancy table" presented a species x final group matrix with constancy values as matrix entries. Species were arranged in the same order as the "synthesis table" and the final groups were arranged according to the final group cluster analysis.
4.3.2 Analysis and interpretation of results

The results from the Coenos 1 program were analysed and interpreted for three main objectives:

a. to assess the homogeneity of each final group (i.e. consider a more detailed classification by subdividing a final group);

b. in conjunction with "a", to characterize each "vegetation type" (final group, single plot or subset of a final group) (defined below) in terms of its vegetation and habitat features; and

c. subsequent to "b", determine the ecological relationship between vegetation types (zonal, subzonal, successional (historical), edaphic, climatic and topographic).

To realize these objectives, the classification hierarchies from the Dissimilarity Analysis and plot cluster analysis were analysed, interpreted and translated into map unit categories.

4.3.2.1 Comparative analysis

Final group homogeneity was initially assessed by examining the mean similarity values and the plot cluster analysis. Final groups with a low mean similarity (e.g. less than 50 percent) and/or displaying relatively discrete plot clusters (within a final group) were considered for subdivision. For example, in Figure 4.5(a), final group 2 would be strongly considered for subdivision since it has a low mean similarity (31.7) and shows a strong dichotomy in the plot cluster analysis (plots C01, C02 versus plot B10).
A "vegetation type" is defined as a synthetic grouping of vegetation sample plots (in the case of a single plot the "grouping" has only one representative) which demonstrates some level of internal homogeneity but which has no assumed taxonomic rank. Vegetation types were represented by final groups, subdivisions of final groups or single plots. Vegetation types were characterized in terms of their vegetation and habitat features. The divisive hierarchy derived from the Dissimilarity Analysis was used as a basis for a comparative analysis of the floristic attributes (species composition and constancy) of each vegetation type or "branch" of the dendrogram (vegetation types) and continued up the hierarchy to the more generalized end of the dendrogram (groups of vegetation types). At each "level of division" the two resultant branches of the dendrogram were compared with respect to their species composition (presence or absence) and species constancy values. Each species present in the branch being compared (branch "a") was allocated to one of 7 categories shown in Table 4.4. This analysis revealed the floristic character of each branch throughout all levels of division in the classification hierarchy.

4.3.2.2 Characterization of vegetation types

The comparative analysis characterized each species present in a branch of the dendrogram according to its "diagnostic" or "non-diagnostic" value. This information permitted the comparison of vegetation types to one another, of vegetation types to a branch of the dendrogram (groups of vegetation types) and of branches of the dendrogram to one another.
<table>
<thead>
<tr>
<th>SPECIES CATEGORY</th>
<th>VALUES AND RATIOS OF $x_a$ AND $x_b$</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIAGNOSTIC SPECIES $(x \geq 25, x_b = 0)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSTANT</td>
<td>$x_a \geq 80, x_b = 0$</td>
<td>100</td>
</tr>
<tr>
<td>FREQUENT ASSOCIATE</td>
<td>$80 \leq x \leq 25, x_b = 0$</td>
<td>63</td>
</tr>
<tr>
<td>NON-DIAGNOSTIC SPECIES $(x \geq 25, x_b &gt; 0)$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSTANT</td>
<td>$x_a \geq 80, x_b &gt; 0, x_b \leq 2x_b$</td>
<td>93</td>
</tr>
<tr>
<td>PREFERENTIAL</td>
<td>$x_a \geq 80, x_b &gt; 0, x_b \leq 2x_b$</td>
<td>100</td>
</tr>
<tr>
<td>NON-PREFERENTIAL</td>
<td>$80 \leq x \leq 25, x_b &gt; 0, x_a \leq 2x_b$</td>
<td>72</td>
</tr>
<tr>
<td>PREFERENTIAL</td>
<td>$80 \leq x \leq 25, x_b &gt; 0, x_a \leq 2x_b$</td>
<td>36</td>
</tr>
<tr>
<td>NON-PREFERENTIAL</td>
<td>$25 \leq x \leq 0, x_b \geq 0$</td>
<td>12</td>
</tr>
<tr>
<td>OCCASIONAL ASSOCIATE</td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

NOTES: 1. $x_a$ is the constancy value (%) of a particular species in the branch being characterized (branch "a"). $x_b$ is the constancy value (%) of the same species in the branch being compared to branch "a" (branch "b").
2. The above constancy values apply to branches with 5 or more plots.
3. The above constancy value of "80" is reduced to "75" for branches with 4 plots.
4. The above constancy value of "80" is reduced to "67" for branches with 3 plots.
5. Branches with 2 plots are characterized by Constant species when $x_a = 100$ and Frequent Associate species when $x_a = 50$ ($x_b$ can have any value).
6. Branches with a single plot are characterized by Diagnostic species when $x_a$ is present and $x_b$ is absent and Non-Diagnostic species when $x_a$ is present and $x_b$ is also present. Branch "b" in this case is characterized by only diagnostic species not found in branch "a".

Table 4.4 Categories, values and ratios of species constancy used in the comparative analysis of dendrogram branches.
Vegetation types were therefore characterized by their diagnostic and preferential species and described by physiognomic features (based on species composition by layer and cover values) and their associated "recognition species" (species with a high average cover value but not necessarily characteristic of the unit).

Vegetation types were named using at least three species, usually representing the tree, shrub and herb layer. Within each layer, the species chosen for naming were, in decreasing order of choice: diagnostic constants and frequent associates with a high constancy; non-diagnostic preferential constants and frequent associated; non-diagnostic non-preferential constants and frequent associates with a high constancy and $x_a > x_b$; and species with a high cover value. Table 4.5 below demonstrates the nomenclature system used in this study.

Table 4.5 Examples of vegetation type names

<table>
<thead>
<tr>
<th>PHYSIOGNOMY</th>
<th>VEGETATION TYPE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREST (tree/shrub/herb)</td>
<td>Pinus contorta/Rhododendron albiflorum/Xerophyllum tenax (or) Tsuga$^1$-Thuja$^2$/Taxus brevifolia/Athyrium filix-femina</td>
</tr>
<tr>
<td>KRUMLOLTZ or BRUSH (/shrub/herb)</td>
<td>/Abies lasiocarpa/Phyllodoce empetriformis-Luzula glabrata$^3$</td>
</tr>
<tr>
<td>SAVANNAH (/herb)</td>
<td>//Madia glomerata-Lupinus wyethii (-Festuca idaho-hensis)$^4$</td>
</tr>
</tbody>
</table>

1. Tree species are abbreviated to the generic name only when only one species represents the genus in the study area (e.g. Tsuga = Tsuga heterophylla; Thuja = Thuja plicata).
2. "-Thuja" indicates that Thuja plicata is also a characteristic tree species for this vegetation type but had a lower characteristic value than Tsuga heterophylla.
3. Two herb species are used to name this vegetation type since a tree layer is absent.
4. Parentheses around a species indicates a species which is not particularly characteristic but gives a useful visual impression of the vegetation type.
The physical data (habitat features) for each plot were arranged according to vegetation type and summarized. Each vegetation type was characterized by terrain units, soil development, soil texture, soil drainage, elevation, slope, aspect, slope configuration and hygrotope.

4.3.2.3 Interpretation of vegetation types

Sample plot locations were plotted on the pretyped vegetation maps and labelled according to their vegetation type (membership). A knowledge of the distribution of the vegetation types together with their vegetative and physical characteristics allowed for the following interpretations:

a. successional status (history);
b. biogeoclimatic subzone character;
c. edaphic, topographic and meso-microclimatic character; and
d. the overall ecological relationship of one type to another.

These interpretations were made by integrating all available information about each vegetation type: vegetation data, tree ages and heights, physical data, forest cover maps, soils and terrain unit maps; pretyped vegetation maps, aerial photographs and topographic maps.

4.3.3 Mapping

4.3.3.1 Mapping of vegetation types

The vegetation types had a strong geographic bias within each study area, since the pretyping approach, method of data collection and
interpretation of the results all reflected the natural distribution of the vegetation across the landscape. Hence, the vegetation types were well suited to mapping. Vegetation types were arranged in a legend fashion according to biogeoclimatic subzone, successional status and moisture regime (usually a topoedaphic sequence). Letter symbols were used to indicate the climax, potential climax or disclimax vegetation of the type. Numbers following the letter symbol were used to indicate the successional status of the unit (e.g. D = climax, D-1 = approximately one sere from a climax situation, D-2 = approximately two seres from a climax condition).

The pretyped vegetation maps served as a basis to map the geographical extent of each vegetation type. The pretyped designations associated with each sample plot and its classification according to the analysis were examined to determine the predictive capability of the pretyping approach. Original pretyping concepts and mapping criteria which proved to be inconsequent were re-examined and adjusted on the aerial photographs. Once relationships were established between the pretyped map units (and their individual components) and the vegetation types, mapping proceeded quickly. Initially, mapping was concentrated in areas with better ground truth. Patterns developed in these areas were then extrapolated to adjacent landscapes using the correlations developed for the pretyped units and the vegetation types.
4.3.3.2 Mapping of biogeoclimatic subzones

After several approximations, biogeoclimatic subzone maps were prepared for each valley (Grassy Ck. — Figure 5.3; Templeton R. — Figure 6.3). The initial "model" for zonation was based on Krajina's (1973) map of "Biogeoclimatic Zones of British Columbia" (1:1,900,800) and vegetation zonation maps prepared by the provincial biophysical survey.21 As the field season progressed and more experience was gained on vegetation patterns within each valley, the original zonation units were adjusted. Forest cover types (B.C. Forest Service), aerial photographs, sample plot data and the final distribution of the vegetation types all assisted in the final approximation of subzones. The final maps were prepared at a scale of 1:50,000, indicative of the level of confidence of such mapping units.

Footnotes:

2. Study conducted by G. Utzig, graduate student, Department of Soil Science, University of British Columbia.
3. A "watershed" is defined by that area of land drained by a river or river system (Webster's New World Dictionary, College Edition, 1966).
4. Reviewing maps, aerial photo interpretation (pretyping), data organization and identification of unknown plant specimens.
5. Chapter 7 — "Systematic Sampling Study".
A statement about this feature is optional, only those features readily observable need be recorded.

"Ground truth" — ground verification of air photo interpretation.

\[ \pi(11.3m)^2 = 0.04 \text{ hectares} \quad (\pi(37.2 \text{ feet})^2 = 0.1 \text{ acre}). \]


"Cover" is defined as "the area of ground occupied by a perpendicular projection on to it of the foliage and stems of individuals of a particular species". (Shimwell, 1971).

After Krajina (1965); 8 classes - very xeric, xeric, subxeric, submesic, mesic, subhygic, hygic and subhydric.

An IBM 370 - model 158 (system VS1) computer was used.

There is an option not to perform Dissimilarity Analysis when the user wishes to specify the plot groups.

This limitation will probably be eliminated when the Coenos 1 program is improved and optimized.

Recall that \( 2I \) (I = information statistic) approximates the \( \chi^2 \) distribution (section 3.2.3).

A more simplified classification could be achieved by aggregating final groups, however this was not required in the operational studies.

The term "branch(es)" will be used to describe the lines of the dendrogram which are parallel to the "flow" of the hierarchy from detailed to general or vice versa.

The phrase "levels of division" will be used to describe the lines of the dendrogram which run perpendicular to the "flow" of the hierarchy.

This approach was developed by the Vegetation Section of the Resource Analysis Branch, Ministry of Environment, Kelowna, B.C. It is hoped that in the future this analysis will be performed automatically as part of the Coenos 1 program.

Grassy Creek: map sheet 82F (1:50,000); Templeton River: map sheet 82K (1:250,000).
CHAPTER 5. GRASSY CREEK WATERSHED STUDY
CHAPTER 5. GRASSY CREEK WATERSHED STUDY

5.1 Description of study area

5.1.1 Location and geographic setting

The Grassy Creek watershed is situated approximately 27 km southwest of Nelson within the Selkirk Mountains of southeastern British Columbia (117°23'-30' W; 49°15'-19' N) (see Figure 5.1). Its topography is characterized by gentle side slopes, rolling uplands and rounded divides (see Figures 5.2 and 5.3). The highest elevation in the study area (2180 m) is at Grassy Mountain, in the northwestern corner of the watershed (see Figure 5.2). Grassy Creek, with two main tributaries, flows in an easterly direction until it meets Erie Creek at an elevation of 910 m (see Figure 5.4). The total catchment is 8 km long (east-west), is an average width (north-south) of 4.5 km and an area of 3240 ha.

5.1.2 Bedrock geology

The Grassy Creek watershed is dominated by Lower Cretaceous, plutonic rocks of the Nelson batholith with less amounts of mixed sedimentary and volcanic rocks of the Lower Jurassic Sinemurian Beds and the Rossland Formation (Little, 1960). The plutonic rocks include porphyritic and non-porphyritic granite on the northern ridge and grade to granodiorite on the southern ridge. The eastern quarter of the watershed consists of sedimentary and volcanic rocks which include argillites,
Figure 5.1 Grassy Creek study area location.
Figure 5.2 Grassy Creek - topography (scale 1:15,840; contour interval = 100 m).
Figure 5.3  Grassy Creek - view of north and south-facing slopes (looking southeast). Note the gentle side slopes, rolling uplands (foreground) and rounded divides (background). A grassland-subalpine forest mosaic occurs in the foreground while a montane Interior western hemlock dry subzone characterizes the valley bottom and slopes to the southwest.

Figure 5.4  Grassy Creek - view of eastern end of the watershed (looking west) as it meets the south-flowing Erie Creek. Many of the lower elevations have been subject to frequent fires (open, seral forest on outwash in foreground).
siltstones, graywackes, tuffs and andesitic to basaltic lava flows. Extensive mineral exploration was and is presently being carried out in the area, particularly in the area of contact between the two rock types.

5.1.3 Surficial geology

The surficial geology of the Grassy Creek watershed reflects the most recent advance of the Cordilleran ice sheet between 26,000 yB.P. and 10,000 yB.P. (Fulton, 1971; Clague, 1975). The ice sheet flowed in a southerly direction and was of sufficient thickness to override and deposit till along ridge crests (Little, 1960). Following deglaciation, most of the study area was covered with a veneer of volcanic ash (Sneddon, 1973).

The surficial materials include till, glaciofluvial, fluvial, aeolian and colluvial deposits primarily of granitic origin. Tills can occur along ridge crests down to the valley bottom and vary in thickness from shallow veneers (less than 1 m) to greater than 10 m. Glaciofluvial deposits include ice-marginal terraces, kames, and rill complexes. Most of the glaciofluvial deposits occur in valley bottom locations except for a few, small outwash terraces in upper slope locations (1700 m). Recent fluvial materials are distributed along present water courses and include narrow, discontinuous stream terraces and floodplains and an occasional fan. Aeolian materials, composed of slope wash, reworked volcanic ash and loess, are concentrated along lower, receiving slopes throughout the valley.
5.1.4 Soils

The variation in soil development in the Grassy Creek study area is primarily a reflection of topographic position and drainage, since the parent materials are dominantly till derived from granitic materials. On tills that occur in moisture-receiving positions (depressions or gently sloping areas at the base of a long slope), soils are poorly drained Gleyed Orthic Ferro-Humic Podzols grading to imperfectly drained Gleyed Orthic Humo-Ferric Podzols. Mesic sites, commonly occupying middle slope locations, contain well drained Orthic Humo-Ferric Podzols which become gleyed with a decreasing slope. Lithic Podzols occur on shallow till deposits and are rapidly drained. On dry forested slopes with south aspects podzols are poorly expressed and grade to Dystric Brunisols.

Subalpine grasslands above 1600 m in elevation are predominantly Lithic Orthic Dystric Brunisols developed on colluvial veneers. Depressional areas, associated with these southern aspects, often develop Sombric Humo-Ferric Podzols with an improved moisture regime. Colluvial materials in forested areas have rapidly drained Mini-Humo-Ferric Podzols grading to Lithic Dystric Brunisols in shallow-to-bedrock areas.

Coarse glaciofluvial terraces are capped with fine textured material and are rapidly drained. The common soils on these deposits are Mini Humo-Ferric Podzols. Gleyed Degraded Dystric Brunisols are characteristic of coarse floodplain deposits with high water tables and poor drainage.
5.1.5 Climate

The climatic information presented for the Grassy Creek watershed has been extrapolated from data obtained from an elevational transect between Trail, Rossland and Old Glory Mountain. The general climate of the study area is strongly influenced by the prevailing easterly movement of Pacific air masses over the Columbia Mountains. However, this pattern is occasionally interrupted during the winter by south-flowing polar air or during the summer by north-flowing, hot and dry air masses from the southern Columbia plateaux. Precipitation and temperature patterns are typical of mountainous terrain: coincident with an increasing elevation there is an increase in mean annual precipitation and a decrease in mean annual temperature. Both of these parameters have been extrapolated for three elevations within the study area: 760 m, 1070 m and 1370 m.

The annual precipitation pattern is relatively even throughout the months although maxima are noted for January, June and October through December and minima for April and July through September (see Figure 5.5). Frontal cloud activity strongly affects elevational gradients in precipitation; below 1400 m they are most active and precipitation decreases slightly. Summer maxima in precipitation are primarily the result of convection storms. The amount of precipitation falling as snow and rain are shown in Figure 5.6. The percentage of snow increases upslope in response to cooler temperatures and increasing precipitation. Annual snow pack accumulation doubles from the valley bottom to the 1320 m level (February: 760 m – 86 cm; 1320 m – 170 cm).
Figure 5.5 Grassy Creek - total mean monthly precipitation at three elevations.

Figure 5.6 Grassy Creek - amount of precipitation falling as snow and rain at three elevations.
Mean monthly temperatures at three elevations are shown in Figure 5.7. Minimum temperatures generally show a decrease with increasing elevation, however an area just above the valley bottom may be slightly warmer than below as a result of cold air drainage. The winter lapse rate for minimum and maximum temperatures is low, reflecting rather stable conditions. During the summer months the lapse rate for maximum temperatures increases dramatically, reflecting unstable conditions due to snow retention at upper elevations.

These temperature and precipitation patterns result in a rapidly increasing snow pack with elevation. At lower elevations the winter maximum is reached in January while at high elevations the snow continues to accumulate into the month of April.

5.2 Results and interpretation of the classification analysis

This section presents and interprets the results of the classification analysis for the Grassy Creek watershed study. The results of the Dissimilarity Analysis and final group cluster analysis are presented first in order to discuss general trends observed in the classification hierarchy. The results of the plot cluster analysis and development of the "vegetation types" are presented second as the most detailed levels of the classification.

5.2.1 Dissimilarity Analysis

Dissimilarity Analysis was performed on the 85 sample plots using 200 species-attributes as divisive criteria. Ten species which occurred
Figure 5.7 Grassy Creek - mean monthly temperature at three elevations.
only once in the 85 plots were "masked" from the analysis in order to meet the imposed species-dimension of 200. Dissimilarity Analysis subdivided the initial set into 12 final groups and 2 single plots using a stopping value of $\chi^2 = 232.63$. Final group membership ranged from 2 to 24 plots. Final groups and single plot levels of the hierarchy were established with as few as 2 levels of division or as many as 7 levels of division. Mean similarity values for the final groups ranged from 65.9 (very homogeneous) to 32.6 (relatively heterogeneous) with 10 of the final groups having values between 50.6 and 65.9 (reasonably to very homogeneous) (mean value = 54.9). The Dissimilarity Analysis dendrogram and mean similarity values of the final groups are shown in Figure 5.8.

The comparative analysis of the Dissimilarity Analysis dendrogram revealed the vegetative character of the various levels of division in the hierarchy. The general levels of the classification hierarchy (levels of division I, II and III) exhibited successional and to a lesser extent, physiognomic features of the vegetation. Zonal and subzonal qualities of the vegetation were not displayed until the most detailed levels of division (i.e. final groups). The relationships for the first three levels of division are shown in Table 5.1 and in Figure 5.9. Two characteristic species are given for each branch of each division. The detailed levels of the Dissimilarity Analysis are discussed in sections 5.2.3 and 5.2.4 below.
Figure 5.8 Grassy Creek - Dissimilarity Analysis dendrogram and mean similarity values of final groups.
### Table 5.1 - Vegetation features and characteristic species at general levels of division in the Dissimilarity Analysis classification hierarchy.

<table>
<thead>
<tr>
<th>LEVEL OF DIVISION</th>
<th>BRANCH</th>
<th>VEGETATION FEATURE (successional status, physiognomy and subzone)</th>
<th>CHARACTERISTIC SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>a</td>
<td>disclimax, edaphic climax and early seral</td>
<td>Hieracium albiflorum, Polytrichum juniperinum</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>climax, near climax and mature seral</td>
<td>Tiarella unifoliata, Rhytidiopsis robusta</td>
</tr>
<tr>
<td>II</td>
<td>a</td>
<td>early seral (semi-open and open forest and brush)</td>
<td>Larix occidentalis, Hieracium albiflorum</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>disclimax (savannah) and edaphic climax (outcrops)</td>
<td>Aster spp., Festuca idahohensis</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>ESSF(^1) (forest) and ESSFxB (parkland) subzones</td>
<td>Abies lasiocarpa (B2), Xerophyllum tenax</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>IWH(^2)a (dry subzone)</td>
<td>Tsuga heterophylla, Athyrium filix-femina</td>
</tr>
<tr>
<td>III</td>
<td>a</td>
<td>open and semi-open forest and brush</td>
<td>Larix occidentalis, Apocynum androsaemifolium</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>logged-off</td>
<td>Ribes lacustre, Epilobium augustifolium</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>near climax and mature seral</td>
<td>Larix occidentalis, Abies lasiocarpa</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>climax</td>
<td>Rhododendron albiflorum, Thalictrum occidentale</td>
</tr>
</tbody>
</table>

1. ESSF - Engelmann spruce subalpine fir zone  
2. IWH - Interior western hemlock zone
Figure 5.9 Grassy Creek - successional and physiognomic vegetation features of the Dissimilarity Analysis dendrogram.
5.2.2 Final group cluster analysis

The final group cluster analysis formed an agglomerative hierarchy of final groups based on their floristic similarity to one another. This analysis revealed the successional features of the vegetation as stratified by broad zonal relationships (see Figure 5.10). Physiognomic relationships between the groups are also indicated in their arrangement. This analysis assisted in determining the successional relationships between the vegetation types within a particular subzone.

5.2.3 Plot cluster analysis and mean similarity values

The plot cluster analysis was performed on those final groups (from Dissimilarity Analysis) with more than 2 members (9 final groups in total). Similar to the final groups cluster routine, this analysis formed an agglomerative hierarchy of the sample plots within one final group, based on their floristic similarity to one another. Following an examination of the mean similarity values, the plot cluster analysis dendrograms and the geographic distribution of sample plots constituting each final group, 4 final groups (1, 8, 9 and 10) were considered for subdivision. A comparative analysis of each potential branch of these subdivisions demonstrated they were significantly different with respect to their floristic attributes (see Figure 5.12). As an example of this procedure, the cluster analysis dendrogram of final group 9 is shown in Figure 5.11. With a low mean similarity value of 32.6, final group 9 displayed 3 potential subdivisions according to its plot cluster analysis dendrogram. A comparative analysis of each potential branch indicated
Figure 5.10 Grassy Creek – zonal, successional, and physiognomic vegetation features of the final group cluster analysis dendrogram.
Figure 5.11 Grassy Creek – plot cluster analysis of final group 9 showing three potential subdivisions (a, b and c).
Figure 5.12 Grassy Creek - formation of vegetation types using Dissimilarity Analysis and the plot cluster analysis.
that only branch "a" could be floristically differentiated from "b" and "c".  

5.2.4 The vegetation types and their description

As a result of the detailed examination of the final groups derived from the Dissimilarity Analysis, 17 "vegetation types" were distinguished for the Grassy Creek watershed (see Figure 5.12). Each vegetation type was characterized according to its vegetative and physical features and arranged according to zone, subzone, successional status and moisture regime (see Table 5.2). Each "type" was named according to the nomenclature system outlined in section 4.3.2.2 and given a map unit symbol according to the system discussed in section 4.3.2.1. A biophysical summary of the vegetation types is given in Table 5.3 (in back pocket). Two stylized landscape profiles of the Grassy Creek watershed have been prepared to illustrate the geographic relationships between the biogeoclimatic subzones, vegetation types, soil development and soil parent materials (terrain units) (see Figures 5.13 - 5.13.1 and 5.13.2). The vegetation features and commonly associated physical characteristics of each vegetation type are described below.

**Englemann spruce - subalpine fir parkland subzone (ESSF xB)**

A. *Abies lasiocarpa/Phyllodoce empetriformis - Luzula glabrata*  
(open krumholtz forest, subxeric-submesic)

Type A was derived from a subdivision of final group 9 and is represented by 2 plots. It occurs along ridges and shedding zones at the highest elevations in the study area (1920 m - 2075 m)
<table>
<thead>
<tr>
<th>BIOGEOCLIMATIC SUBZONE</th>
<th>MAP SYMBOL</th>
<th>VEGETATION TYPE</th>
<th>PHYSIOGNOMY</th>
<th>MOISTURE REGIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESSFxB</td>
<td>A</td>
<td>Abies lasiocarpa/Phyllodoce empetriformis - Luzula glabrata</td>
<td>open krumholtz forest</td>
<td>subxeric-submesic</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Abies lasiocarpa/Rhododendron albiflorum/ Luzula glabrata</td>
<td>low subalpine forest</td>
<td>subxeric</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Abies lasiocarpa/Sorbus sitchensis/Luzula glabrata</td>
<td>semi-open forest islands</td>
<td>submesic</td>
</tr>
<tr>
<td>ESSFxx</td>
<td>D</td>
<td>Abies lasiocarpa/Rhododendron albiflorum/ Xerophyllum tenax</td>
<td>semi-open forest</td>
<td>subxeric-submesic</td>
</tr>
<tr>
<td></td>
<td>D-1</td>
<td>Pinus contorta/Rhododendron albiflorum/Xerophyllum tenax</td>
<td>semi-open and closed forest</td>
<td>xeric-subxeric</td>
</tr>
<tr>
<td></td>
<td>D-2</td>
<td>Pinus contorta/Sorbus sitchensis/Aster spp.</td>
<td>open and semi-open forest</td>
<td>xeric-subxeric</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>Abies lasiocarpa/Vaccinium membranaceum/ Tiarella unifoliata</td>
<td>closed forest</td>
<td>subhygric-mesic</td>
</tr>
<tr>
<td>ESSFx-Disclimax</td>
<td>F</td>
<td>/Madia glomerata-Lupinus wyethii (-Festuca idahohensis)</td>
<td>savannah and outcrops</td>
<td>xeric (-submesic)</td>
</tr>
<tr>
<td>ESSFxx-IWHa</td>
<td>G</td>
<td>Picea(^1) (Tsuga(^2))/Rhododendron albiflorum/Rubus pedatus</td>
<td>closed forest</td>
<td>mesic</td>
</tr>
<tr>
<td></td>
<td>G-1</td>
<td>Larix(^3)-Picea/Sorbus sitchensis/Trillium ovatum</td>
<td>semi-open and closed forest</td>
<td>mesic-subhygric</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>Tsuga/Pachistima myrsinfolia/Chimaphila umbellata</td>
<td>closed forest</td>
<td>mesic</td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td>Larix-Pseudotsuga(^4)/Tsuga/Pedicularis bracteosa</td>
<td>semi-open and closed forest</td>
<td>submesic</td>
</tr>
<tr>
<td>IWHa</td>
<td>H-2</td>
<td>Larix/Apocynum androsaemifolium/Clintonia uniflora</td>
<td>open forest and brush</td>
<td>subxeric</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>Tsuga-Thuja(^5)/Taxus brevifolia/Anthryum filix-femina</td>
<td>closed forest</td>
<td>mesic-subhygric</td>
</tr>
<tr>
<td></td>
<td>I-1</td>
<td>Abies grandis/Taxus brevifolia/Adenocaulon bicolor</td>
<td>closed forest</td>
<td>mesic</td>
</tr>
<tr>
<td></td>
<td>I-2</td>
<td>LOGGED/Rubus parviflorus/Hieracium albiflorum (-Clintonia uniflora)</td>
<td>brush and herbs</td>
<td>mesic</td>
</tr>
<tr>
<td></td>
<td>J</td>
<td>Thuja (-Tsuga)/Ribes lacustre (-Oplopanax horridus)/ Veratrum eschscholtzii</td>
<td>closed forest</td>
<td>hygric</td>
</tr>
</tbody>
</table>


Table 5.2 Grassy Creek - vegetation types arranged according to zone, subzone, successional status and moisture regime for use in the map legend.
Figure 5.13 Grassy Creek - key figure for stylized landscape profiles (Figures 5.13.1 and 5.13.2 following) 
Footnotes are explained on the following page.
Figure 5.13 Footnotes: 1. Vegetation types are described in section 5.2.4.

2. Terrain Unit symbols (surficial materials and landform) are described in Appendix III.

3. Soils are classified according to the System of Soil Classification for Canada, 1974 (Revised); abbreviations are described in Appendix III.

4. Abbreviations for soil drainage and horizon are described in Appendix III.
Figure 5.13.1 Grassy Creek - transect "A₁ - A₂" - approximate north-south cross section of the western half of the watershed.
(see Figure 5.13.1). Additional characteristic species include Antennaria roseus, Hieracium gracilis and Carex spp. Festuca idahohensis and Antennaria roseus are recognition species of moderate average cover (40%). The commonly associated soils are Sombric Melanic Ferro-Humic Podzols and Alpine Dystric Brunisols with (gravelly) silt loam textures. These soils have developed on gently sloping (5-13%) aeolian veneers and colluvial blankets and are moderately well to well drained. Depending on local topography, snow can remain on these habitats well beyond the middle of summer (July - August). Type A is discontinuous and occurs in close association with Type F.

B. Abies lasiocarpa/Rhododendron albiflorum/Luzula glabrata

(low open subalpine forest, subxeric)

Type B was derived from final group 2 with 2 plots. It occurs in two situations: as a somewhat continuous forest immediately below ridges on north aspects and as a discontinuous forest on upper, convex shedding slopes with south aspects (1830 m - 1980 m) (see Figure 5.13.1). Additional characteristic species include Sorbus sitchensis and Arnica cordifolia. Recognition species are Rhododendron albiflorum, Vaccinium membranaceum and Luzula glabrata. Soils on these type are moderately well to imperfectly drained Gleyed Orthic Ferro-Humic Podzols.

C. Abies lasiocarpa/Sorbus sitchensis/Luzula glabrata (semi-open forest islands, submesic)

Type C was derived from a subdivision of final group 10 and is represented by 1 plot. It occurs in middle slope depressional areas with a south aspect (1800 - 1980 m) (see Figure 15.13.1). Additional
species in Type C include *Vaccinium membranaceum*, *Ribes lacustre* and an almost continuous cover of *Xerophyllum tenax*. Since it occurs in close association with Type F (savannah), *Madia glomerata*, *Lupinus spp.* and *Aster spp.* are also present. Sombric Melanic Ferro-Humic Podzols developed on silty aeolean veneers characterize these habitats.

**Engelmann spruce - subalpine fir forest subzone (ESSFx∞)**

D. *Abies lasiocarpa*-*Picea/Rhododendron albidorum/Xerophyllum tenax*  
(semi-open forest, subxeric-submesid)

Type D was derived from final group 3 with 2 plots. It occurs in gently sloping shedding areas and upper slopes (1430 m - 1920 m) within the subalpine forest (see Figure 5.13.1). Additional characteristic species include *Sorbus sitchensis*, *Pyrola secunda* and *Rhytidiopsis robusta*. *Rhododendron albidorum, Vaccinium membranaceum* and *Xerophyllum tenax* are recognition species for this type. Soils on these types are Lithic Orthic Dystric Brunisols on colluvial veneers and Mini Humo-Ferric Podzols on colluvial blankets.

D-1. *Pinus contorta/Rhododendron albidorum/Xerophyllum tenax*  
(semi-open and closed forest, xeric-subxeric)

Type D-1 was derived from final group 5 with 4 plots. It is a mature seral type which will likely climax to type D. It occurs in approximately the same landscape positions as type D (1430 m - 1950 m) (see Figure 5.13.1). Additional characteristic species include *Picea engelmannii*, *Pyrola secunda*, *Erigonium subalpinum* (on lithic habitats) and *Pleurozium schreberi*. Recognition species include *Pinus contorta* and those species listed for Type D. Soils in this type are the same as in Type D.
D-2. Pinus contorta/Sorbus sitchensis/Aster spp. (open and semi-open forest, xeric-subxeric)

Type D-2 was derived from final group 11 with 2 plots. It is an early successional stage of Type D and occurs in about the same landscape positions as Type D and D-1 (1465 m - 1950 m). Additional characteristic species include Vaccinium membranaceum, Amelanchier alnifolia, Xerophyllum tenax, Hieracium albiflorum, Erigonium subalpinum and Polytrichum juniperinum. Xerophyllum tenax is a recognition species. Soils in this type are well to rapidly drained Mini Humo-Ferric Podzols and Lithic Mini Humo-Ferric Podzols developed on coarse textured colluvial veeneers and morainal blankets.

E. Abies lasiocarpa-Picea/Vaccinium membranaceum/Tiarella unifoliata (closed forest, subhygric-mesic)

Type E was derived from final group consisting of 10 plots. It occurs in seepage zones associated with subalpine drainages and on cool, moist, north aspects receiving seepage waters from upslope snow melt (1400 m - 1770 m) (see Figure 5.13.1). Additional characteristic species include Vaccinium membranaceum, Rhododendron albiflorum, Arnica cordifolia, Xerophyllum tenax and Veratrum eschscholtzii. Vaccinium membranaceum and Clintonia uniflora are recognition species. The dominant soils on this type range from well to imperfectly drained Gleyed Orthic Ferro-Humic Podzols, Orthic Ferr-Humic Podzols and Gleyed Mini Humo-Ferric Podzols, all developed on morainal blankets.
Engelmann spruce - subalpine fir - Disclimax (ESSFx-Disclimax)

F. //Madia glomerata-Lupinus wyethii (-Festuca idahohensis) 
(savannah and outcrops, xeric (-submesic))

Type F was derived from a subdivision of final group 9 and is represented by 6 plots. As discussed earlier in section 5.2.3, this subdivision contains two closely associated communities: extensive south facing, rolling savannah (approximately 1615 m - 2100 m) and outcrop communities (1200 m - 1600 m) (see Figure 5.13.1 and 5.12.2). Additional characteristic species include Campanula rotundifolia, Sedum divergens, Eriogonum subalpinum, Selaginella sitchensis and Cryptogramma crispa. Recognition species are Festuca idahohensis, Madia glomerata and Aster spp.

The soils associated with the savannah are well drained (Lithic) Alpine Dystric Brunisols developed on gravelly colluvial veneers. Outcrop communities are non-soils.

Engelmann spruce - subalpine fir forest subzone — Interior western hemlock dry subzone transition (ESSFx-IWHa transition)

G. Picea (-Tsuga)/Rhododendron albiflorum/Rubus pedatus (closed forest, mesic)

Type G was derived from final group 6 with 3 plots. It occurs on shedding slopes and slopes receiving temporary seepage between the ESSF and IWH zones (1370 m - 1770 m) (see Figure 5.13.1). As a transitional type it contains species characteristic of both zones. Additional characteristic species include Abies lasiocarpa (tree and shrub layers), Arnica cordifolia and Pedicularis bracteosa. Recognition species are Rhododendron albiflorum, Vaccinium membranaceum, Pachistima myrsinites, Xerophyllum tenax and Clintonia uniflora. Soils are well to rapidly drained (Lithic) Mini Humo-Ferric Podzols developed on morainal blankets.
Figure 5.13.2 Grassy Creek - transect "B₁ - B₂" - approximate north-south cross section of the eastern half of the watershed.
G-1. Larix-Picea/Sorbus sitchensis/Trillium ovatum (semi-open and closed forests, mesic-subhygric)

Type G-1 was derived from a subdivision of final group 8 and is represented by 3 plots. It is a mature seral type which will likely climax to Type G. It occurs in the same landscape positions and has the same physical features as Type G (1340 m - 1770 m). Additional characteristic species include *Pinus monticola*, *Abies lasiocarpa*, *Rhododendron albiflorum*, *Goodyera oblongifolia* and *Pyrola secunda*. Recognition species include *Vaccinium membranaceum*, *Pachistima myrsinites*, *Xerophyllum tenax* and *Arnica cordifolia*.

**Interior western hemlock dry subzone (IWHa)**

H. Tsuga/Pachistima myrsinites/Chimaphila umbellata (closed forest, mesic)

Type H was derived from a subdivision of final group 1 and is represented by 5 plots. It occurred predominantly on shedding and middle slope positions within the IWHa subzone (1030 m - 1525 m) (see Figure 5.13.1). Additional characteristic species are *Pyrola secunda* and *Clintonia uniflora*. Recognition species include *Tsuga heterophylla* (shrub layer), *Pachistima myrsinites*, *Clintonia uniflora* and *Rhytidiopsis robusta*. The soils associated with this type are primarily well drained Orthic and Mini Humo-Ferric Podzols developed on aeolean veneers overlying moraine and glacial fluvial deposits.
H-1. Larix-Pseudotsuga/Thuja/Pedicularis bracteosa (semi-open and closed forest, submesic)

Type H-1 was derived from a subdivision of final group 8 and is represented by 4 plots. It is a mature seral type which will likely climax to Type H. It occurs in approximately the same landscape positions and has the same physical features as Type H (975 m - 1525 m) (see Figure 5.13.1 and 5.13.2). Additional characteristic species include Pinus contorta, Linnaea borealis, Alnus sinuata, Pedicularis bracteosa and Hieracium albiflorum. Recognition species include Vaccinium membranaceum, Pachistima myrsinites, Rubus parviflorus and Clintonia uniflora.

H-2. Larix/Apocynum androsaemifolium/Clintonia uniflora (open forest and brush, subxeric)

Type H-2 was derived from final group 12 and 12 plots. It is an early seral type which will likely climax to Type H. It occurs in roughly the same landscape positions and has similar physical features as Type H (950 m - 1585 m) (see Figure 5.13.2). Additional characteristic species include Salix spp., Rubus parviflorus, Epilobium augustifolium, Pteridium aquilinum and Solidago canadensis. Recognition species include Larix occidentalis, Vaccinium membranaceum, Pachistima myrsinites, Apocynum androsaemifolium and Pteridium aquilinum.

I. Tsuga-Thuja/Taxus brevifolia/Athyrium filix-femina (closed forest, mesic - subhygric)

Type I was derived from a subdivision of final group 1 and is represented by 8 plots. It generally occurs in lower slope positions with deep soils and a temporary seepage influence (1090 m - 1525 m) (see Figure
5.13.1). Additional characteristic species include *Acer glabrum*, *Asarum caudatum*, *Trillium ovatum*, *Osmorhiza chilensis*. Recognition species include *Clintonia uniflora*, *Gymnocarpium dryopteris*, *Streptopus amplexifolius*, *Tiarella unifoliata* and *Athyrium filix-femina*. The dominant soils are Gleyed Humo-Ferric Podzols and Gleyed Ferro-Humic Podzols on moraine.

I-1. Abies grandis/Taxus brevifolia/Adenocaulon bicolor (closed forest, mesic-subhygric)

Type I-1 was derived from final group 7 with 6 plots. It is a mature seral type which will probably climax to Type I. It occurs in similar landscape positions to Type I (1190 m - 1585 m). Additional characteristic species include *Tsuga heterophylla* (tree and shrub layer), *Streptopus amplexifolius*, *Rubus pedatus*, *Chimaphila umbellata*, *Pyrola asarifolia* and *Trillium ovatum*. Recognition species include *Vaccinium membranaceum*, *Pachistima myrsinites*, *Xerophyllum tenax* and *Clintonia uniflora*. The associated soils are well drained Mini Humo-Ferric Podzols developed on aeolian veneers overlying moraine.

I-2. LOGGED/Rubus parviflorus/Hieracium albiflorum (-Clintonia uniflora) (brush and herbs, mesic)

Type I-2 was derived from a subdivision of final group 10 and is represented by 2 plots. It is a very early seral type which will likely climax to Type I. It occurs in about the same landscape position and has the same associated soils and parent materials as I-1 (1130 m - 1400 m). Additional characteristic species include *Chimaphila umbellata*, *Tiarella unifoliata*, *Linnaea borealis* and *Anaphalis margaritacea*. Recognition species include *Hieracium albiflorum*, *Clintonia uniflora* and *Epilobium augustifolium*. 


J. Thuja (-Tsuga)/Ribes lacustre (-Oplopanax)/Veratrum eschschlotzii (closed forest, hygic)

Type J is derived from a subdivision of final group 1 and is represented by 10 plots. It occurs in valley bottom seepage zones and depressional areas and in association with smaller tributary draws along valley sides (1095 m - 1585 m) (see Figures 55.13.1 and 5.13.2). Additional characteristics species include Smilacina racemosa, Galium triflorum, Athyrium filix-femina and Streptopus amplexifolius. Recognition species include Oplopanax horridus, Clintonia uniflora, Streptopus amplexifolius and Athyrium filix-femina. Morainal blankets are the dominant parent material for the associated soils: Gleyed Ferro-Humic Podzols, Ferro-Humic Podzols and Gleyed Mini Humo-Ferric Podzols.

5.3 Correlation with existing vegetation classifications

Bell (1964), Krajina (1969)\(^{12}\), Daubenmire (1952), Daubenmire and Daubenmire (1968), Pfister et al. (1974), Ogilvie (1969) and Franklin and Dyrness (1973)\(^{13}\) have developed vegetation classifications partially applicable in the Grassy Creek study area. For reasons discussed earlier in section 1.4.1, these classifications have limited applications for the more pragmatic concerns of vegetation inventory and mapping at a detailed scale. The results of this vegetation study were compared subjectively with the various existing classifications. The comparison was based on the author's general ecological and phytosociological understanding of the vegetation types derived from this study and the associations or habitat types discussed in the existing classifications.
Bell (1964) studied the Interior western hemlock dry subzone and recognized five plant associations. Grassy Creek watershed occurred just within the southern extension of Bell's study area. The following plant associations (Bell, 1964) and/or biogeocoenoses (Krajina, 1969) are felt to be approximately equivalent: Type H — the "moss" association and biogeocoenose 65b; Type H-2 — biogeocoenose 65a; Type I — the "Aralia oakfern" association and biogeocoenose 62; and Type J — the "devil's club" association and biogeocoenose 61. Bell also describes two "southern variants" of the moss and Aralia oakfern associations which are consistent with data obtained in the Grassy Creek watershed; notably the occurrence of *Abies grandis*. Biogeocoenose 76a is roughly equivalent to Type E in the Engelmann spruce - subalpine fir zone.

Daubenmire and Daubenmire (1968) have studied the "Tsuga heterophylla Series" in eastern Washington and northern Idaho and Pfister et al. (1974) have studied the "Thuja plicata" and "Tsuga heterophylla" series in western Montana. Two of the habitat types recognized by these authors are roughly the same as those characterized in Grassy Creek: Type I — the "Tsuga heterophylla -- Pachistima myrsinites" (Daubenmires') or "Tsuga heterophylla/Clintonia uniflora" (Pfister et al.); and Type J — the "Thuja plicata -- Oplopanax horridus" (Daubenmires') or "Thuja plicata/Oplopanax horridus" (Pfister et al.).

In the subalpine forest and subalpine forest - montane transition area (Type G and G-1), Daubenmire and Daubenmire (1968), Pfister et al. (1974) and Ogilvie (1969) recognize several roughly equivalent habitat types: Type D, D-1 and D-2 — the "Abies lasiocarpa - Xerophyllum tenax" habitat types (Daubenmires', Pfister et al.) or the "Picea - Abies/
Xerophyllum tenax" association (Ogilvie) on south aspects and/or seral, subalpine forests; and the "Abies lasiocarpa -- Menziesia ferruginea" habitat types (Daubenmires', Pfister et al.) or "Picea -- Abies/Menziesia ferruginea -- Tiarella unifoliata" association on north aspects and/or climax, subalpine forests. The "Abies lasiocarpa -- Pachistima myrsinites" habitat type (Daubenmire's) or "Picea -- Abies/Pachistima myrsinites" association (Ogilvie) have qualities expressed in both Types G and E. Pfister et al.'s study is more definitive: Type G (and G-1) correspond to the "Menziesia ferruginea" phase of the "Abies lasiocarpa/Clintonia uniflora" habitat type; Type E is somewhat synonymous with the "Abies lasiocarpa/Calium triflorum" habitat type with minor inclusions of the "Abies lasiocarpa -- Oplopanax horridus" habitat type (a "devil's club variant" of the "Picea -- Abies/Heracleum -- Equisetum" association described by Ogilvie.

In the parkland subzone, Pfister et al.'s (1974) "Abies lasiocarpa/Luzula hitchcockii" habitat type, "Menziesia ferruginea" phase and Ogilvie's (1969) "Picea -- Abies/Luzula wahlenbergii" association roughly correspond to Type B. The "Vaccinium scoparium" phase of the "Abies lasiocarpa -- Luzula hitchcockii" habitat type (Pfister et al.) is analogous to Type A in the subalpine parkland.

The subalpine grassland disclimax Type F is consistent with similar "grassy parks" or "balds" reported by Daubenmire and Slipp (1943), Daubenmire and Daubenmire (1968), Franklin and Dyrness (1973) and Tiedemann (1972).
5.4 Mapping of vegetation

5.4.1 Pretyping

A "pretyped vegetation" map was prepared for the Grassy Creek watershed using the methods discussed earlier in section 4.2.2. The pretyped vegetation map units were delineated on the black and white aerial photographs (1:15,840) and were later transferred onto two base maps: a visual transfer onto an uncontrolled photo mosaic base at an approximate scale of 1:8,000 (see Figure 5.13 in rear map pocket) and Kail 16 plot transfer onto B.C. Forest Service (Inventory Division) planimetric base maps at a scale of 1:15,840. Sample plot locations were also plotted on the planimetric base map.

5.4.2 Vegetation types and biogeoclimatic subzones

Using the procedure outlined earlier in section 4.3.3.1, map units (both pure and complex) were identified and delineated using the pretyped vegetation map as a basis. In most instances, there was good correlation between the attributes and distribution of the vegetation types (sample plots) and the pretyped unit designations. Inconsistencies were re-examined to determine any initial pretyping errors (unit designation and boundaries) and to determine the potential for complex units or unit inclusions. The greatest agreement occurred on upland lithic sites, distinct physiognomic vegetation types (e.g. grasslands, climax mature forest, subalpine parkland) and valley bottom seepage types. Conversely, middle slope locations with relatively uniform vegetative cover and uniform slope configuration contained the greatest number of anomalies and were therefore the most
Figure 5.15 Grassy Creek - biogeoclimatic subzones.
difficult to map. When ground truth information was absent in these locations, a strong emphasis was placed on known vegetative patterns and sequences on comparable slopes. Thus the pretyped vegetation map units were adjusted where necessary and labelled according to the vegetation type legend. A final map of the natural vegetation of the Grassy Creek watershed was prepared using the planimetric base at a scale of 1:15,840 (see Figure 5.12 in rear map pocket).

A knowledge of the distribution of the final vegetation map units allowed for an improvement of the earlier biogeoclimatic subzone models discussed in section 4.3.3.2. The extensive grasslands occurring at high elevations on south aspects are believed to be the result of fire followed by the successive wind transfer of snow and soil drought (Franklin and Dyrness, 1973). These areas have been delineated and labelled as "grassland disclimaxes" within the Engelmann spruce subalpine fir zone. A final map of biogeoclimatic subzones was prepared at a scale of 1:50,000 (see Figure 5.15 and the inset map on Figure 5.14 in rear map pocket).

Footnotes:

1. A more detailed account of surficial geology and soils is given by G. Utzig, graduate student, Department of Soil Science, University of British Columbia; Master's thesis in progress entitled: "An evaluation of detailed soils mapping in forested, mountainous terrain".
2. yB.P. - years before present.
3. Climatic information is summarized from a report prepared by R. Chilton, Climate and Data Services Division, Environment and Land Use Committee Secretariat, Province of B.C., Victoria.
4. Characteristic species are either very diagnostic or very preferential to the branch according to the comparative analysis.
5. The term "significantly" is not used in a statistical sense. A significant subdivision was judged as one in which there were obvious differences (i.e. diagnostic or preferential) in species composition and/or vegetation structure between the two potential branches.

6. Note - the outcrop communities often occurred in association with the savannah (see Figure 5.8).

7. Vegetative features include the diagnostic and preferential species, "recognition species", physiognomy, successional status, zone and subzone.

8. Physical features include terrain units, soil development, soil texture, soil drainage, elevation, slope, aspect, slope configuration and hygrotope (see section 4.3.2.2).

9. The term "type" will sometimes be used for an abbreviation of "vegetation type".

10. In addition to those used to name the type.

11. A species list for the Grassy Creek watershed is given in Appendix II.

12. Krajina's classification of the Interior western hemlock zone (p. 19-23, 45-47) included the original studies conducted by Bell (1964).

13. Franklin and Dyrness' publication of the natural vegetation of Oregon and Washington included the original studies conducted by Daubenmire (1952, 1968).

14. Ogilvie (1969) calls his classification units "associations".

15. *Luzula hitchcockii* = *Luzula glabrata* (Pfister, 1974)

CHAPTER 6. TEMPLETON RIVER WATERSHED STUDY
CHAPTER 6. TEMPLETON RIVER WATERSHED STUDY

6.1 Description of study area

6.1.1 Location and geographic setting

The Templeton River watershed is situated approximately 34 km northwest of Radium Hot Springs within the Purcell Mountains (Septet Range) of southeastern British Columbia (116° 25'-36' W; 50° 46'-49' N) (see Figure 6.1). The Septet Range forms an easterly-flowing shoulder of the Purcell Mountains and borders on the Rocky Mountain Trench. The highest elevation in the study area (3000 m) is Mt. Ethelbert in the southwestern portion of the catchment (see Figure 6.2). The western region of the study area contains a series of recently active cirque basins between 2,400 and 2,500 m in elevation in addition to a lower cirque basin (1950 m) and tarn (Templeton Lake) (see Figure 6.3). Templeton River descends sharply from the tarn to the main valley (1800 m). Continuing east, the river flows along a relatively uniform gradient through a deeply incised, U-shaped valley. At about 1350 m in elevation, the river enters the trench and begins a sinuous path across a drumlinized terrain to the Columbia River (see Figure 6.4). There are no main tributaries to Templeton River other than two small streams which originate from cirque basins on the south side of the valley. The total catchment is 10 km long (east-west), is an average width of 4 km and has an area of 3650 ha.
Figure 6.1 Templeton River - study area location.
Figure 6.2 Templeton River - topography (scale 1:15,840; contour interval = 100 m).
Figure 6.3 Templeton River - view of western half of watershed (looking west). Note the U-shaped valley, the alternating forest and avalanche track vegetation pattern and the extent of rock and snow at the higher elevations.

Figure 6.4 Templeton River - view of eastern portion of watershed (looking west) as it opens into the dryer and warmer Rocky Mountain Trench.
6.1.2 Bedrock geology

The Templeton River watershed consists of primarily argillite bedrock. Dolomite, limestone, quartzite and slate are associated bedrocks which occur to a limited extent in the watershed. These bedrocks are included in the Dutch Creek and Mt. Nelson formations of the Purcell System (Reesor, 1973). These Precambrian Rocks generally dip to the east, although minor folds and a north-striking normal fault occurring just below Templeton Lake complicate the regional trend (Utzig, personal communication). The argillites are distributed throughout the entire study area. The quartzites and dolomite are restricted to the upper elevations and the slates and minor dolomite occur along the northern ridge at the mouth of the valley.

6.1.3 Surficial geology

The surficial materials occurring throughout the Templeton River area are typical of the extensive and complex glaciation during the Pleistocene Epoch. During major glacial advances, the trench served as an outlet valley for the southerly flowing Cordilleran Ice Sheet (Clague, 1975). Numerous side valley glaciers coalesced with the main trench ice including one from the Templeton River Valley. Clague (1975) suggests there were three distinct stades during the last major (Pinedale) glaciation in the southern (B.C.) trench region. Studies by Utzig\(^2\) in the Templeton River area also indicate a sequence of three, successively reduced glacial advances.
The surficial materials deposited in the study area are therefore a consequence of a complex glacial history during the Pleistocene followed by recent fluvial, colluvial and aeolian activity. Utzig (personal communication) has identified five tills in the watershed: a compact gravelly silt loam till from the first advance; a non-compact gravelly sandy loam till overlying the compact till; a gravelly loam to silt loam till absent from the eastern quarter of the valley bottom; a recent, coarse moraine occurring in active cirques; and a highly compacted, cemented, calcareous, gravelly sandy loam till situated along the eastern (trench) portion of the watershed.

Glaciofluvial sands and gravels and glaciolacustrine silts, which occur to a limited extent near the mouth of the valley, are representative of the complex deglacial phases of the Pleistocene Epoch. Recent fluvial deposits comprise a narrow floodplain within the trench segment of the river and a single fan on the southern slope of the valley. Colluvial terrain features prevail over most of the watershed. Coarse, rubbly, colluvial aprons and fans are particularly extensive in the western half of the watershed and are closely associated with recurring avalanche activity (see Figure 6.4). Colluvial materials also overlie morainal deposits in areas with steep slopes and upland bedrock sources. Aeolian silt and silt loams cap a majority of the unconsolidated deposits in the study area. The thickness of these materials varies significantly due to their redistribution by colluvial and fluvial activity.
6.1.4 Soils

A wide range of soils occur in the Templeton River watershed resulting from the diversity of parent materials and variability in local climate (e.g. aspect, proximity to the trench, snow and avalanching). Luvisols with a brunisolic development at their surface occur along the eastern portion of the study area in a dry (trench) climate and on calcareous parent materials. South facing slopes near the valley mouth, which also experience a dry and warm climate, develop Eutric Brunisols (in calcareous parent materials) and Dystric Brunisols (in argillaceous and slate-derived parent materials). At higher elevations and on slopes further to the west in the watershed, the influence of a southern exposure becomes significantly modified with increasing snowfall and avalanche activity. Forested slopes in these locations develop Humo-Ferric Podzols on deep materials and Brunisols on lithic sites. A complex mosaic of soils occurs in subalpine basins and upper reaches of avalanche tracks: Alpine Dystric Brunisols, Lithic Folisols, Gleyed Ferro-Humic Podzols and Gleyed Humo-Ferric Podzols. Avalanche track soils vary with avalanche periodicity, vegetative cover and aspect. In general, avalanche tracks with frequent activity display Regosols while those with only occasional activity display Brunisols. Soil development on glaciofluvial deposits is primarily Orthic Humo-Ferric Podzols. Gleyed Regosols are the major soils associated with the narrow floodplain.
6.1.5 Climate

The climatic information presented for the Templeton River watershed has been extrapolated from data obtained from an elevational transect between Golden and Glacier National Park and recalculated using Brisco as a base. Located adjacent to the trench, the study area is affected by both Pacific and polar air masses. The prevalent Pacific air flow is relatively dry at this point in its easterly flow having deposited most of its moisture on the intervening mountain range. Cool, south flowing polar air masses occasionally inundate the trench region during the winter season. Summer temperatures in the study area are sometimes influenced by warm air originating from the interior plateau of Washington State. Within the watershed, the lower elevations near the mouth of the valley experience a warm and dry climate similar to that of the trench. Higher elevations towards the west show precipitation and temperature patterns typical of mountainous landscapes: coincident with an increase in elevation there is an increase in mean annual precipitation and a decrease in mean annual temperature.

The Templeton River area experiences the effect of two precipitation shadows: the general influence of the Purcell Mountain Range and the more local impact of the Septet Range. Mean monthly precipitation values have been plotted for five different elevations (see Figure 6.5). The two lowest elevations (760 m and 1070 m) are representative of trench precipitation values while the three upper elevations (1370 m, 1680 m and 1980 m) are representative values for the study area. The monthly pre-
Figure 6.5 Templeton River - mean monthly precipitation at five elevations.

Figure 6.6 Templeton River - amount of precipitation falling as snow and rain at five elevations.
cipitation pattern shows maximum amounts in December-January and again in May-June. March has the lowest mean monthly precipitation. Precipitation values show a gradual increase with elevation and hence, distance (west) from the trench (41.9 cm - 63.0 cm). This trend maybe in part due to an easterly drift of rain beyond the crest of the rain shadow and into the drier trench air. The rain falling from higher elevations at this point may evaporate before reaching the lower elevations (observed during field work). In addition, most summer precipitation originates from convection storms which usually form over the ridges. Winter precipitation patterns, however, result from primarily low level frontal systems which yield a maximum precipitation at about 1500 m with virtually no increase above this elevation.

The proportion of precipitation falling as rain and snow is shown in Figure 6.6. Both snowpack and snowfall increase with elevation concomittant with increases in precipitation and decreases in temperature. The snowpack at low elevations in the study area reaches a maximum in January-February while at higher elevations, snow continues to accumulate until the latter part of March. Wind and avalanche activity at the higher elevations make snowpack estimates difficult and highly variable.

Mean monthly temperatures at four elevations are shown in Figure 6.7. In the winter months, minimum temperatures are coldest in the valley bottom, increase rapidly over the next one hundred meter increase in elevation and then remain essentially constant with increasing elevation. This temperature column results from stable inversion conditions when cold
Figure 6.7 Templeton River - mean monthly temperature at four elevations.
air (derived from radiation cooling or incoming polar air) is trapped under the warm air above. Spring and fall seasons show the reverse situation when temperatures cool slowly with increasing elevation. During the summer months, minimum temperatures fluctuate in response to a greater number of clear nights and radiation cooling. The coldest minimum temperatures occur in the valley bottom.

Maximum winter temperatures show little change with increasing elevation due to the more stable conditions created by increased cloud cover. Spring and summer maximum temperatures decrease with elevation primarily as a result of greater depth and persistence of snowpacks at higher levels. Autumn temperatures are inconsistent but display a definite inversion at higher elevations.

Diurnal fluctuations are the greatest in summer at low elevations in the watershed. Cloud cover and stable conditions limit the diurnal range in temperature in the winter.

6.2 Results and interpretation of the classification analysis

This section presents and interprets the results of the classification analysis for the Templeton River watershed study. The results of the Dissimilarity Analysis and final group cluster analysis are presented first in order to discuss general trends observed in the classification hierarchy. The results of the plot cluster analysis and development of "vegetation types" are presented second, being the most detailed levels of the classification.
6.2.1 Dissimilarity Analysis

Dissimilarity Analysis was performed on the 121 sample plots using 200 species-attributes as divisive criteria. Two species which occurred only once in the 121 plots were "masked" from the analysis in order to meet the imposed species-dimension of 200. The analysis subdivided the initial set into 13 final groups and 4 single plots using a stopping value of $\chi^2 = 232.63$ (see Figure 6.8). Final group membership ranged from 4 to 21. Final groups and single plot levels of the hierarchy were established with as low as 3 and as high as 9 levels of division. Mean similarity values for the final groups ranged from 32.8 to 64.6 (mean value = 51.6). Six mean similarity values were less than 50 (heterogeneous, 3 were less than 60 (reasonably homogeneous) and 4 were greater than 60 (very homogeneous).

Unlike the Grassy Creek analysis, the Dissimilarity Analysis dendrogram for Templeton River did not show any vegetative characteristics (successional, physiognomic or zonal) at the more general levels of division in the hierarchy. Definitive vegetation features were only revealed at the final group level of the comparative analysis.

6.2.2 Final group cluster analysis

The final group cluster analysis formed an agglomerative hierarchy of final groups based on their floristic similarity to one another. This analysis revealed zonal and physiognomic relationships that existed between the final groups derived from Dissimilarity Analysis (see Figure
Figure 6.8 Templeton River - Dissimilarity Analysis dendrogram and mean similarity values and final groups.
Figure 6.9 Templeton River - zonal and physiognomic vegetation features of the final group cluster analysis dendrogram.
6.9). The results of this analysis assisted in the arrangement of the classification units within the final vegetation legend (Table 6.1).

6.2.3 Plot cluster analysis, mean similarity values and geographic assessment of classification units

The plot cluster analysis was performed on all final groups with more than 2 plot members (13 final groups in total) (see Figure 6.9). This analysis formed an agglomerative hierarchy of the sample plots within each final group based on their floristic similarity to one another. The mean similarity value given for each final group was a useful guide to determine the relative homogeneity among the members of a particular final group. Following an examination of the plot cluster analyses, mean similarity values and the geographic distribution of sample plots within each final group, 4 final groups (1, 9, 10 and 11) were considered for subdivision. A comparative analysis of each potential branch of these subdivisions showed that only 2 of the subdivisions (final groups 1 and 11) were significantly different with respect to their floristic attributes (see Figure 6.10).

Final group 13 was a heterogeneous group representing plots which contained more than one community type within them. This was due to poor selection of the sample plot location. Since the plot cluster analysis showed almost no relationship among the plots and there was no apparent geographic association with the plot members, final group 13 did not form a vegetation type.
Final group 13 is a heterogeneous group whose members each contained more than one community type within them.

These divisions were not used since they were represented by only one sample plot and occurred to a very limited extent in the watershed.

Figure 6.10 Templeton River - formation of vegetation types using Dissimilarity Analysis and the plot cluster analysis.
<table>
<thead>
<tr>
<th>BIODEOCLIMATIC SUBZONE</th>
<th>MAP SYMBOL</th>
<th>VEGETATION TYPE</th>
<th>PHYSIOGNOMY</th>
<th>MOISTURE REGIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESSFxB</td>
<td>A</td>
<td>Larix¹-Picea²/Larix/Cassiope mertensiana</td>
<td>open forest</td>
<td>subxeric-mesic (subhygric)</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Rhododendron albiflorum-Vaccinium scoparium/Senecio triangularis-Claytonia lanceolata</td>
<td>meadow and discontinuous forest</td>
<td>subhygric-hygric</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Larix-Picea/Pinus albicaulis (-Vaccinium scoparium)/Saxifraga bronchialis</td>
<td>open forest and low regeneration forest</td>
<td>xeric-submesic</td>
</tr>
<tr>
<td>AVALANCHE ZONE</td>
<td>C-1A</td>
<td>AV³/Abies⁴-Pinus albicaulis-Vaccinium membranaceum/Saxifraga bronchialis</td>
<td>krumholtz shrub-forest patches</td>
<td>xeric-mesic</td>
</tr>
<tr>
<td></td>
<td>D-1A</td>
<td>AV/Picea-Pinus albicaulis-Menziesia ferruginea/Hylocomium splendens</td>
<td>low regeneration forest</td>
<td>submesic-mesic</td>
</tr>
<tr>
<td>ESSFx(d)</td>
<td>D</td>
<td>Picea-Pinus albicaulis/Menziesia ferruginea/Hylocomium splendens</td>
<td>closed forest</td>
<td>submesic-mesic</td>
</tr>
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<td></td>
<td>E</td>
<td>Picea/Vaccinium scoparium-Rhododendron albiflorum/Picea-Abies/Lonicera involucrata/Rubus pedatus</td>
<td>closed forest</td>
<td>mesic</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>Picea-Vaccinium scoparium-Rhododendron albiflorum/Picea-Abies/Lonicera involucrata/Rubus pedatus</td>
<td>closed forest</td>
<td>subhygric-hygric</td>
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<td>AVALANCHE ZONE</td>
<td>G</td>
<td>AV/Alnus sinuata/Athyrium filix-femina-Claytonia lanceolata</td>
<td>dense, continuous brush</td>
<td>subhygric (-hygric)</td>
</tr>
<tr>
<td></td>
<td>I-1A</td>
<td>AV/Populus tremuloides-Amelanchier alnfolia/Frageria virginiana-Thalictrum occidentalis</td>
<td>discontinuous brush and herbs</td>
<td>subxeric-mesic</td>
</tr>
<tr>
<td>ESSFx(df)</td>
<td>H</td>
<td>? not represented in the study area at the time of mapping</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H-1</td>
<td>Pinus contorta-Pseudotsuga⁵/Juniperus scoporum/Epilobium angustifolium-Arnica cordifolia</td>
<td>semi open and closed forests</td>
<td>xeric-submesic</td>
</tr>
<tr>
<td></td>
<td>I</td>
<td>? not represented in the study area at the time of mapping</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I-1</td>
<td>Pseudotsuga-Abies/Acer glabrum/Smilacina racemosa</td>
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<td>mesic</td>
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<tr>
<td></td>
<td>I-2</td>
<td>Pseudotsuga-Abies/Alnus sinuata/Cornus canadensis</td>
<td>closed forest</td>
<td>submesic-subhygric</td>
</tr>
<tr>
<td></td>
<td>J</td>
<td>Abies-Picea/Ribes lacustre/Goodyera oblongifolia</td>
<td>closed forest</td>
<td>mesic-subhygric</td>
</tr>
<tr>
<td></td>
<td>J-1</td>
<td>Pseudotsuga-Picea/menziesia ferruginea/Cornus canadensis</td>
<td>closed forest</td>
<td>mesic-subhygric</td>
</tr>
</tbody>
</table>

5. Pseudotsuga - Pseudotsuga menziesii var glauca.

Table 6.1 Templeton River - classification units arranged according to zone, subzone, successional status and moisture regime for use in the map legend.
6.3.4 The vegetation types and their description

As a result of the detailed examination of the final groups derived from Dissimilarity Analysis, 15 "vegetation types" were distinguished for the Templeton River watershed (see Figure 6.10). Each vegetation type was characterized with respect to its vegetative and physical features and arranged in the form of a map legend according to zone, subzone, successional status and moisture regime (see Table 6.1). Each type was named according to the nomenclature system discussed in section 4.3.2.2 and given a map unit symbol according to the method discussed in section 4.3.2.1. A summary "biophysical" table of the units is given in Table 6.2 (in back pocket). The vegetation features and commonly associated physical characteristics of each unit are described below. Three stylized landscape profiles of the Templeton River watershed have been prepared to illustrate the geographic relationship between the biogeoclimatic subzones, vegetation types, soil development and soil parent materials (terrain units) (see Figures 6.11 - 6.11.1 to 6.11.2). The vegetation features and commonly associated physical characteristics of each vegetation type are described below.

Engelmann spruce - subalpine fir parkland subzone (ESSFxB)

A. Larix-Picea/Larix/Cassiope mertensiana (open forest, subxeric-mesic (subhygric)

Type A was derived from a subdivision of final group 1 (la) and is represented by 8 plots. It occurs in two distinct situations in the watershed: windswept ridges with steep rock and colluvial slopes and more protected cirque basins on deep hummocky colluvium and moraine (1830 m -
Figure 6.11 Templeton River - key figure for stylized landscape profiles (Figures 6.11.1, 6.11.2 and 6.11.3) following. Footnotes are explained on the following page.
Figure 6.11 Footnotes: 1. Vegetation types are described in section 6.3.4.
2. Terrain Unit symbols (surficial materials and landform) are described in Appendix III.
3. Soils are classified according to the System of Soil Classification for Canada, 1974 (Revised); abbreviations are described in Appendix III.
4. Abbreviations for soil drainage and horizon texture are described in Appendix III.
Figure 6.11.1 Templeton River - transect "A₁ - A₂" - approximate north-south cross section of the western half of the watershed.
Figure 6.11.2 Templeton River - transect "B1 - B2" - approximate north-south cross section of the eastern half of the watershed.
2285 m) (see Figure 6.11.1 and 6.11.2). Additional characteristic species of these open, parkland forests include Phylloclode empetri-formis, Phylloclode glanduliflora and Pinus albicaulis. The recognition species are Pinus albicaulis and Larix lyallii (tree layer), Abies lasiocarpa (shrub layer), Vaccinium membranaceum, Cassiope mertensiana and Dicranum spp. Commonly associated soils on Type A are well to rapidly drained Orthic Humo-Ferric Podzols and Orthic Regosols on rubbly colluvium and imperfectly drained Gleyed Orthic Ferro-Humic Podzols on colluvial veneers overlying moraine. Type A is often adjacent to or is complexed with Types C or B.

B. /Rhododendron albiflorum - Vaccinium scoparium/Senecio trian-gularis - Claytonia lanceolata (meadow and discontinuous forest, subhygric-hygric)

Type B was derived from a subdivision of final group 11 (1lb) and is represented by 3 plots. It occurs in two situations in the study area: open receiving areas within cirque basins (meadow) and on gently sloping or flat seepage areas at the base of steep rock and colluvial slopes (1920 m - 2165 m) (see Figures 6.11.2 and 6.11.1 respectively). These types receive most of their moisture from upslope and/or on-site snow meltwaters. Additional characteristic species are Pinus albicaulis and Larix lyallii (shrub layer), Pedicularis bracteosa, Valeriana sitchensis, Anemone multifida and Veratrum eschschotzii. Recognition species include Abies lasiocarpa (shrub layer), Vaccinium scoparium, Rhododendron albiflorum
and *Claytonia lanceolata*. Soils on these types are imperfectly drained Gleyed Orthic Humo-Ferric Podzols and Gleyed Orthic Ferro-Humic Podzols developed on colluvial veneers overlying moraine. Type B occurs to a very limited extent in the watershed and is usually complexed with Type A. Although it was not mapped, Type B also occurs along very narrow drainages within the subalpine avalanche zones.

C.  

*Larix-Picea/Pinus albicaulis (-Vaccinium scoparium)/Saxifraga bronchialis* (open forest and low regeneration forest, xeric-submesic)

Type C was derived from final group 2 with 14 plots. It occurs on steep, wind-swept, colluvial slopes often adjacent to areas with frequent avalanching (Type C-1A). In many parts of the watershed, particularly the north-facing slopes and ridges, this unit represents the highest elevation forest community (1740 m - 2285 m) (see Figures 6.11.1 and 6.11.2). *Juniperus scopulorum* is an additional characteristic species. Recognition species include *Larix lyallii*, *Abies lasiocarpa* (shrub layer), *Vaccinium membranaceum*, *Vaccinium scoparium* and *Dicranum species*. The soils associated with this unit are quite variable including Lithic, Alpine and Degraded Dystric Brunisols and Orthic Regosols. All soils are developed on coarse colluvium.

**Avalanche zone (AV)**

C-1A.  

AV/Abies - *Pinus albicaulis - Vaccinium membranaceum/Saxifraga bronchialis* (Krumholtz shrub-forest patches, xeric-mesic)

Type C-1A was derived from final group 8 with 4 plots. It occurs at the uppermost elevations of avalanche tracks and in isolated niches.
throughout the highest, wind-swept rock and colluvial terrain (1920 m - 2500 m) (see Figure 6.11.1). Its distribution in the watershed is primarily limited to south-facing slopes. Additional characteristic species include *Vaccinium scoparium*, *Penstemon fruticosis*, *Cryptogramma crispa*, *Cassiope mertensiana*, *Phyllodoce empetriformis* and *Carex spp*. Recognition species are *Abies lasiocarpa* (a procumbent shrub), *Vaccinium membranaceum*, *Vaccinium scoparium* and *Pinus albicaulis* (shrub layer). Soils are well drained Alpine Dystric Brunisols developed on colluvium. Type C-1\(^A\) is frequently complexed with Types R and U (rock and unconsolidated deposits) in the extreme upper elevations of the north slope.

D-1\(^A\). AV/Pincea - *Pinus albicaulis* - *Menziesia ferruginea/Hylocomnium splendens* (low regeneration forest, submesic-mesic)

Type D-1\(^A\) was derived from a subdivision of final group 1 (lb) and is represented by 4 plots. It occurs on all aspects in the upper, treed elevations of avalanche tracks (1615 - 2100 m) (see Figure 6.11.1). Reoccurring avalanche activity maintains these types as low regeneration forests with a theoretical climax of Type D (described below). Recognition species include *Menziesia ferruginea*, *Vaccinium scoparium*, *Rhododendron albiflorum*, *Dicranum spp*. and *Pleurozium schreberi*. The associated soils in these types are moderately well to well drained Orthic Regosols developed on rubbly colluvium. These units typically dissect forests characterized by Type D.
Engelmann spruce subalpine fir forest subzone (Douglas fir not usually a seral species) (ESSFxoc)

D. Picea - Pinus albicaulis/Menziesia ferruginea//Hylocomnium splendens (closed forest submesic-mesic)

Type D was derived from a subdivision of final group 1 (lc) and is represented by 9 plots. It occurs on both north and south facing slopes in the upper and cooler elevations of the forest subzone (1525 - 2050 m) (see Figures 6.11.1 and 6.11.2). With a herb layer almost completely absent, the recognition species include *Picea engelmannii*, *Pinus albicaulis*, *Abies lasiocarpa*, *Vaccinium membranaceum*, *Menziesia ferruginea*, *Vaccinium scoparium*, *Rhododendron albiflorum*, *Dicranum spp.* and *Pleurozium schreberi*. Orthic Humo-Ferric Podzols and Bisequa Orthic Humo-Ferric Podzols developed on well drained colluvium and colluvium overlying moraine are commonly associated with these types.

E. Picea/Vaccinium scoparium - Rhododendron albiflorum/(closed forest, mesic)

Type E was derived from final group 3 and is represented by 7 plots. It occurs sporadically throughout the cooler elevations of the forest subzone (see Figures 6.11.1 and 6.11.2). Other than where it was noted during field sampling, it was difficult to predict the occurrence of Type E. It was often intimately associated with Type D in cool subalpine forests and with Type F in valley bottom locations under the influence of cold air drainage and long snow duration. Additional characteristic species include *Abies lasiocarpa*, *Alnus sinuata* and *Barbilophosia spp.* Recognition species are
Abies lasiocarpa (shrub layer), Vaccinium membranaceum, Menziesia ferruginea, Dicranum spp. and Pleurozium schreberi. Commonly associated soils are well to rapidly drained BisequaOrthic Humo-Ferric Podzols and Orthic and Degraded Dystric Brunisols.

F. Picea-Abies/Lonicera involucrata/Rubus pedatus (closed forest, subhygric-hygric)

Type F was derived from final group 12 and is represented by 6 plots. Its occurrence is limited to cool, valley bottom seepage zones and floodplains with high moisture regimes and cold air drainage (and/or pooling) (see Figures 6.11.1 and 6.11.3). Additional characteristic species include Rhododendron albiflorum, Lycopodium annotinum, Dryopteris austriaca, Equisetum arvense, Osmorhiza chilensis and Streptopus amplexifolius. Recognition species are Abies lasiocarpa, Picea engelmannii, Menziesia ferruginia, Cornus canadensis, Rubus pedatus, Pleurozium schreberi and Hylocomnium splendens. Soils on these types include poorly drained Gleyed Orthic Regosols developed on floodplain deposits and poorly drained Gleyed Orthic Humo-Ferric Podzols developed on colluvial veneers overlying moraine.

Avalanche zone (AV)

G. AV/Alnus sinuata/Athyrium filix-femina-Claytonia lanceolata (dense, continuous brush, subhygric-hygric)

Type G was derived from final group 10 and is represented by 9 plots. It occupies lower slope locations in avalanche tracks that are under relatively cool and moist conditions (1400 - 1900 m) (see Figure 6.11.1). The dominant
shrub in the type is *Alnus sinuata* which forms a dense resilient brush. Additional characteristic species include *Veratrum eschschotzii*, *Senecio triangularis*, *Sambucus racemosa*, *Streptopus amplexifolius* and *Thalictrum occidentale*. Below the dense canopy of *Alnus sinuata*, further recognition species are *Ribes lacustre*, *Streptopus amplexifolius*, *Athyrium filix-femina* and *Claytonia lanceolata*. Moderately well drained Orthic Regosols developed on rubbly colluvium are characteristic soils for Type G.

I-1\textsuperscript{A}. AV/Populus tremuloides – *Amelanchier alnifolia*/*Fragaria virginiana* (discontinuous brush and herbs, subxeric–mesic)

Type I-1\textsuperscript{A} was derived from final group 9 and is represented by 8 plots. It occurs on dry south aspects between 1500 and 1800 m elevation below steep rock ridges (see Figure 6.11.2). Both rock (colluvium) and snow avalanching maintain these types in a brushy and herbaceous state (disclimax). The hypothetical climax on these sites is Type I. Although the species composition of these types is often quite variable, some additional characteristic species include *Rubus parviflorus*, *Viola canadensis*, *Allium cernuum*, *Achillea millefolium* and *Thalictrum occidentale*. The recognition species are *Populus tremuloides*, *Amelanchier alnifolia*, *Shepherdia canadensis*, *Juniperus scopulorum*, *Thalictrum occidentale*, *Fragaria virginiana* and *Epilobium augustifolium*. The associated soils are rapidly drained Orthic Regosols developed on rubbly colluvium.
Engelmann spruce subalpine fir forest subzone (Douglas fir often a seral species and persistant in mature forests) (ESSFxoc(df))

H. Type H is a hypothetical climax of Type H-1. Type H was not represented in the study area at the time of mapping.

H-1. Pinus contorta-Pseudotsuga/Juniperus scopulorum/Epilobium augustifolium-Arnica cordifolia (semi open and closed forests, xeric-submesic)

Type H-1 was derived from final group 6 and is represented by 10 plots. It occurs on dry south aspects and shedding zones usually influenced by the dry trench climate (1300 - 1900 m) (see Figure 6.11.3). This unit becomes established after fire and has a hypothetical climax of Type H. Additional characteristic species are Alnus sinuata, Carex concinnoides and Spiraea betulifolia. Recognition species include Pseudotsuga menziesii, Spiraea betulifolia and Calamagrostis rubescens. Type H-1 occurs on a variety of well to rapidly drained soils: Lithic Dystric Brunisols on gravelly colluvial veneers, Bisequa Grey Luvisols on colluvial veneers over moraine and Orthic Dystric Brunisols on glaciofluvial deposits.

I. Type I is a hypothetical climax of Type I-1 and I-2. Type I was not represented in the study area at the time of mapping.

I-1. Pseudotsuga-Abies/Acer glabrum/Smilacina racemosa (closed forest, mesic)

Type I-1 is derived from a subdivision of final group 11 (11a) and is represented by 2 plots. It occurs on dry south facing slopes in
Figure 6.11.3 Templeton River - transect "C_1 - C_2" - approximate west-east cross section of the valley mouth and upland trench region.
approximately the middle of the watershed (1600 - 1750 m) (see Figure 6.11.2). This unit is characterized by veteran forests of Pseudotsuga menziesii which probably became established following a fire several hundred years ago (400 - 500 years?). Additional characteristic species are Rubus parviflorus, Amelanchier alnifolia, Disporum hookeri, Clematis columbiana and Thalictrum occidentale. Acer glabrum, Rubus parviflorus, Smilacina racemosa and Thalictrum occidentale are recognition species. The associated soils for Type I-1 are rapidly drained Orthic Eutric Brunisols developed on rubbly colluvial blankets overlying moraine.

I-2. Pseudotsuga-Abies/Alnus sinuata/Cornus canadensis (closed forest, submesic-subhygric)

Type I-2 was derived from final group 7 and is represented by 10 plots. It occurs in the same landscape positions as Type I-1 in addition to lower slope locations on south aspects and on the channelled upland terrain of the trench region (1250 - 1800 m) (see Figures 6.11.2 and 6.11.3). It is a seral type which could potentially develop into the mature seral Type I-1 and hypothetical climax Type I. Additional characteristic species are Ribes lacustre, Amelanchier alnifolia, Rubus parviflorus, Spiraea betulafolia, Lonicera involucrata, Aster conspicuosus, Calamagrostis rubescens, Prilium crisoma-castrensis and Polytrichum juniperinum. Recognition species include Pinus contorta, Pseudotsuga menziesii, Abies lasiocarpa, Cornus canadensis, Pleurozium schreberi and Dicranum spp. The commonly associated soils include Brunisolic Grey Luvisols developed on colluvial veneers overlying
moraine and morainal veneers overlying glaciofluvial deposits; and
Orthic Humo-Ferric Podzols developed on glaciofluvial deposits. All
soils associated with Type I-2 are moderately well to well drained.

J. Abies-Picea/Ribes lacustre/Goodyera oblongifolia (closed forest,
mesic-subhygric)

Type J was derived from final group 4 and is represented by 8
plots. It generally occurs on both north and south aspects in locations
influenced by cooler subalpine conditions than Types I-1 and I-2 (lower
slopes on southern aspects subject to shading; landscapes adjacent to areas
of longer snow duration and northeastern aspects; floodplains and depressional
areas where cooler air may drain and pool) (1250 – 2000 m) (see Figures 6.11.2
and 6.11.3). An additional characteristic species is Menziesia ferruginea.
Recognition species include Picea engelmannii, Ribes lacustre, Menziesia
ferruginea, Dicranum spp. and Pleurozium schreberi. The commonly associated
soils are well drained Orthic Humo-Ferric Podzols developed on colluvial
veneers overlying moraine and glaciofluvial deposits.

J-1 Pseudotsuga-Picea/Menziesia ferruginea/Cornus canadensis (closed
forest, mesic-subhygric)

Type J-1 was derived from final group 5 and is represented by 11
plots. It occurs in essentially the same landscape as Type J. It is a
seral type which will likely climax to Type J. Additional character species
are Pyrola virens, Ribes lacustre and Ptilium crista-castrensis. Recognition
species are Pseudotsuga menziesii, Picea engelmannii, Abies lasiocarpa (shrub
layer), Vaccinium membranaceum, Menziesia ferruginea, Cornus canadensis,
Ptilium crista-castrensis, Dicranum spp., Pleurozium schreberi and Hylocomnium splendens. A variety of soils are associated with Type J-1, none of them dominant.

6.3 Correlation with existing vegetation classification

Ogilvie (1962, 1969), Pfister et al. (1974), Franklin and Dyrness (1973), Arlidge (1955) and Krajina (1969) have developed classifications partially applicable in the Templeton River study area. The results of this vegetation study were subjectively compared with these existing classifications. The comparison was based on the author's general ecological and phytosociological understanding of the vegetation types derived from this study and the taxa discussed in the existing classifications.

Arlidge (1955) conducted a preliminary classification and evaluation of the Engelmann spruce subalpine fir forest (ESSF) in the Bolean Lake area of B.C. Three of Arlidge's associations might be considered analogous: Type E — the "Picea engelmannii — Abies lasiocarpa — Vaccinium membranaceum — Rubus pedatus" association; and Type F — a complex of the "Picea engelmannii — Abies lasiocarpa — Vaccinium ovalifolium — Dryopteris linnaeana" and the "Picea engelmannii — Abies lasiocarpa — Equisetum arvense — Sphagnum recurvum" association. Krajina (1969) describes 15 biogeocoenoses for the ESSF zone of which 10 may be considered roughly similar: Type A — biogeocoenoses 83 a & b; Type D — biogeocoenose 80; Type E — biogenocoenose 79; Type F — a complex of biogeocoenose 76 a & b, 87 and 88; hypothetical Type H — biogeocoenose 82; and Type H-1 — biogeocoenose 84.
Ogilvie (1969) and Pfister et al. (1974) have described the "Picea-Abies/Calamagrostis rubescens" association and "Abies lasiocarpa/Calamagrostis rubescens" habitat type respectively. Pseudotsuga menziesii and Pinus contorta seral forests are the main representative tree species of these types making them roughly equivalent to Type H-1. Ogilvie's classification for the mountain forest and alpine zones of Alberta most closely corresponds to that developed for this study area. He describes 6 other associations, in addition to the one above, which are very similar:

Type A -- the "Picea-Abies/Vaccinium scoparium" association; Type B -- the "Phyllodoce" association and the "Cassiope" association; Type D -- the "Picea-Abies/Hylocomnium splendens -- Cornus canadensis" association; Type E -- the "Picea-Abies/Menziesia ferruginea -- Lycopodium annotinum" association; and Type F -- the "Picea-Abies/Equisetum" association.

Franklin and Dyrness (1973) describe a number of "subalpine meadow" communities which are partially analogous to Type B. They also describe some of the complexities of the Larix lyallii forests (Types A and C) originally reported by Arno (1972).

6.4 Mapping of vegetation

6.4.1 Pretyping

A "pretyped vegetation" map was prepared for the Templeton River watershed using the methods discussed earlier in section 4.2.2. The pretyped vegetation units were delineated on the black and white aerial
photographs (1:15,840) and were later transferred onto two base maps:
a visual transfer onto an uncontrolled photo mosaic base at an approximate
scale of 1:8,000 (see Figure 6.12, in rear map pocket) and a Kail plot
transfer onto B.C. Forest Service (Inventory Division) planimetric base
maps at a scale of 1:15,840. Sample plot locations were also plotted on
the planimetric base map.

6.4.2. Vegetation types and biogeoclimatic subzones

Using the procedure outlined in section 4.3.3.1, map units (both
pure and complex) were identified and delineated using the pretyped
vegetation map (Figure 6.12) as a basis. Some of the concepts developed
for pretyping the vegetation were proven to be of lesser significance than
in the Grassy Creek study. In particular, the hygrotope/slope position
concept was often masked by the effect of a drier and cooler, continental
macroclimate and by the predominance of coarse, freely drained parent
materials and their effect on seepage waters. Several important vegetation
breaks (the "present vegetation condition" component of the pretype unit)
were overlooked during the pretyping due to an initial inexperience at
photo interpreting. Consequently, the necessary corrections were made on
the aerial photographs and were then transferred to the planimetric base.
The amended map units were labelled according to the vegetation type legend
in a similar manner to the Grassy Creek study (see section 5.4.2). A final
map of the natural vegetation of the Templeton River watershed was prepared
using the planimetric base at a scale of 1:15,840 (see Figure 6.13 in rear
map pocket).
BIOGEOCLIMATIC SUBZONES

ESSFxJ (parkland subzone)

ESSFxK (forest subzone)
Douglas fir not usually a seral species.

ESSFxK(df) (forest subzone)
Douglas fir often a seral species and persistent in mature forests.

AVALANCHE ZONE (ESSFxK-Disclimax)
Vegetation subject to recurring avalanche activity.

Figure 6.14 Templeton River - biogeoclimatic subzones.
The classification and mapping of the vegetation provided a better understanding of the pattern of biogeoclimatic subzones in the watershed. Following a careful examination of the individual plot data and classification analyses, all of the continuous forest areas were included within the ESSF forest subzone (ESSFxoc). Because of climatic influences from the trench and of the insolative properties of the steep south-facing slope, the northern portion of the forest subzone was distinguished from the rest on the basis of *Pseudotsuga menziesii* (Douglas fir) existing as a seral species and persisting in mature forests (see Figure 6.14). Partitioning the subalpine forest in this way is consistent with concepts expressed by McLean and Holland (1958), Pfister *et al.* (1974) and van Barneveld (1969).

The extensive avalanche zones which are distributed throughout most of the study area have been delineated and labelled as "ESSFx - Disclimax". The vegetation inhabiting these sites is subject to recurring avalanche activity. It is interesting to note that nearly half of the watershed is essentially non-vegetated due to a severe climate and an inhospitable substrate of rock, snow and glaciers. A final map of biogeoclimatic subzones was prepared at a scale of 1:50,000 (see Figure 6.14).

1. The "Rocky Mountain Trench" will hereafter be simply referred to as the "trench".

2. A more detailed account of surficial geology and soils is given by G. Utzig, graduate student, Department of Soil Science, University of British Columbia; Masters thesis in progress entitled: "An evaluation of detailed soils mapping in forested, mountainous terrain".
3. Same as footnote "2" above.

4. The location of Brisco is shown in Figure 6.1

5. Climatic information is summarized from a report prepared by R. Chilton, Climate and Data Services Division, Environment and Land Use Committee Secretariat, Province of B.C., Victoria.

6. An example of this procedure was given earlier in section 5.2.3.

7. The term "significantly" is not used in a statistical sense. A "significant" subdivision was judged as one in which there were obvious differences (i.e. diagnostic or preferential) in species composition and/or vegetation structure between the two potential branches of the hierarchy.

8. For example: an abandoned skid road and a selectively logged site; a floodplain with complex microrelief; a highly variable avalanche track vegetation.

9. Vegetative features include the diagnostic and preferential species, "recognition species", physiognomy, successional status, zone/subzone.

10. Physical features include terrain units, soil development, soil texture, soil drainage, elevation, slope, aspect, slope configuration and hygrotope (see section 4.3.2.2.).

11. In addition to those used to name the type.

12. A species list for Templeton River watershed is given in Appendix II.

13. The original subzone model included a "tongue" of ESSF-IDF transition (IDF = Interior Douglas fir zone) into the ESSF forest subzone.
CHAPTER 7. SYSTEMATIC SAMPLING STUDY
CHAPTER 7. SYSTEMATIC SAMPLING STUDY

7.1 Introduction and objectives

Chapters 5 and 6 described the application of Dissimilarity Analysis\(^1\) to detailed vegetation classification and mapping in two mountainous watersheds. The procedures employed in these study areas were of an "operational"\(^2\) nature suited to practical considerations in the acquisition, analysis, interpretation and presentation of vegetation inventory data. This chapter describes an independent, more detailed study of two representative areas in the Templeton River watershed. Two aspects of vegetation mapping are investigated: The predictive capability of the vegetation pretyping approach (described in section 4.2.2) and the reliability of the final vegetation maps (Figures 5.14 and 6.13). The latter investigation employed a post-mapping, systematic sampling procedure.

As in most natural resource inventory schemes conducted in inaccessible areas, the mapping approaches developed for the operational studies placed a strong emphasis on aerial photo interpretation—the extrapolation of known landscape attributes and patterns\(^3\) into unknown areas possessing similar visual features (e.g. those features listed in Table 4.2). The quality of such an inventory\(^4\), in this instance\(^5\), is measured by the reliability of the information obtained: for any map unit labelled as "x", the difference between the predicted probability
of occurrence of "x" and the actual occurrence of "x".

It is only more recently that map reliability has been an issue of concern in natural resource inventories. Usually reliability is assessed subjectively through consideration of a number of factors: breadth of the surveyor's experience; the inherent complexity of the landscape; the nature of the resource under consideration (i.e. ease of recognition and identification); the amount and availability of existing information; the availability of topographic base maps and useful remote sensing information; the number and distribution of observations relative to the extent of area being mapped; and the scales of both field mapping and final map presentation (publication). In some surveys, attempts have been made to indicate map reliability in a qualitative way. Small scale "reliability" inset maps, qualified map unit boundary lines (dotted, dashed or solid lines) or different map unit symbols (light, medium or bold face type, upper and lower case, variable character size) are used to indicate the degree of confidence in maps and map units. However, few studies have attempted to quantify mapping reliability (e.g. by percentages or probabilities) by comparing the predicted occurrence of landscape attributes with their actual occurrence.

This study employs a post-mapping, systematic sampling procedure to quantitatively determine map reliability. Four interrelated factors which contribute to the reliability of the final vegetation maps are examined:
a. the predictive capability and consistency of application of the pretyping approach;
b. the intensity and distribution of ground observations relative to the number of pretyped map units and final vegetation map units delineated;
c. in conjunction with "a" and "b" above, the application of the classification analysis to the pretyping concepts and distribution of the pretyped map units; and
d. the homogeneity of the final vegetation map units and the overall mapping reliability.

These factors are discussed below within the context of the pretyping aspect of vegetation mapping (section 7.3.1) and the reliability aspect of vegetation mapping (section 7.3.2).

7.2 Methods of study

The methods used in this study were independent from the operation mapping procedures used in Templeton River watershed and involved field sampling followed by data analysis and interpretation.

7.2.1 Field sampling

Following the collection of sample plot data for the Templeton River watershed study, two areas were selected for detailed systematic sampling. One north and one south-facing slope were selected as repre-
sentative of the predominant patterns of vegetation, soil, and parent material occurring in the watershed. The selected areas were examined on the aerial photographs and an appropriate grid pattern (interval and configuration) was determined. Thirty-one grid points (19 on the south aspect and 12 on the north aspect) were plotted on the aerial photographs using a square grid interval of approximately 200 m.

Given an approximate starting point, compass bearing and grid configuration, B.C. Forest Service Inventory Division personnel surveyed the field location of the 31 grid points (see Figure 7.1). A standard vegetation sample plot was taken at each grid point using the method described in section 4.2.3. The sample plot radius (11.3 m) and circumference were estimated visually.

The two grid areas and the sample plot data were used to examine the two aspects of the systematic sampling study.

### 7.2.2 Data analysis and interpretation

To examine the predictive capability of the pretyping approach, the pretyped map units were superimposed onto the final vegetation map within the grid areas (see Figure 7.2). The operational sample plots within and adjacent to the grid areas which contributed to the mapping procedure were also indicated in Figure 7.2. A summary table of comparisons is presented to examine the relationships between the pretyping approach and the formation of final vegetation map units (see Table 7.1).
Figure 7.1 - Systematic Sampling Study - sample plot locations in the Templeton River watershed (scale 1:15,840; contour interval = 100 m).
The vegetation data from the 31 sample plots were analysed using the Coenos 1 program described in section 4.2. The results of the Dissimilarity Analysis and cluster analyses were used to evaluate the reliability of the operational mapping of the Templeton River watershed. A comparative analysis (described in section 4.3.2.1) of the Dissimilarity Analysis dendrogram was conducted and the characteristic species for each branch were compared with those of the operation vegetation types of the Templeton River study. The divisive (Dissimilarity Analysis dendrogram) and agglomerative (final group and plot cluster analysis dendrograms) classification hierarchies were interpreted at different levels of detail consistent with the character of the operational vegetation types. The resulting "systematic" vegetation types were then considered the "most correct" regarding the classification of vegetation within the grid areas.

The reliability of the operational vegetation map within the grid area was determined by the percent agreement occurring between the operational vegetation map units and the groups of grid points (systematic sample plots) representing the systematic vegetation types of the grid area. The reliability values (percentages) are reported relative to a purely independent chance of agreement and relative to an optimum chance of agreement based on the most frequently occurring systematic vegetation type.
Results and discussion

Predictive capability of the pretyping approach

As previously discussed in sections 4.3.3.1, 5.4 and 6.4 the pretyped map units were used as a basis to form the final vegetation maps. The relationships between the pretyped map units, the operational vegetation map units and the operational sample plots are shown in Table 7.1 and Figure 7.2. The north and south aspects are discussed separately below.

North Aspect (refer to Table 7.1 and Figure 7.2)

The pretyping of vegetation on the north aspect was particularly difficult since variations in the forest cover were only clearly evident in the upper parkland elevations and the selectively logged forests (D_{SL}) in the valley bottom. Between these elevations, pretyping relied strongly on the "hygrotope/slope position" concept (discussed in section 4.2.2 and illustrated in Figure 4.1) as inferred from slope configuration, slope orientation, slope angle, slope length, drainage network, and to a lesser extent forest height and density. Two pretyped map units were recognized on the basis of "terrain features and processes having a major influence on present vegetation condition": map unit #9 -- exposed colluvium and map unit #1 -- fluvial fan (see Figure 7.2).

Three of the 9 pretyped map units (8 vegetated, 1 non-vegetated) contained an operational sample plot within the grid area (map units #1, #2 and #4). The 9 pretyped map units were modified to form 8 final
### Table 7.1

<table>
<thead>
<tr>
<th>Identification no of FVU(s)</th>
<th>Identification no of PTU(s)</th>
<th>no. of PTU's within FVU(s)</th>
<th>no. of plots contributing to FVU delineation</th>
<th>no. of plots contributing to PTU delineation</th>
<th>no. of boundary lines created by boundary lines in above components</th>
<th>no. of boundary lines created by boundary lines in above components</th>
<th>no. of boundary lines created by boundary lines in above components</th>
<th>no. of boundary lines created by boundary lines in above components</th>
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</tr>
</tbody>
</table>

**Legend:**
- FVU: Field Vegetation Unit
- PTU: Plot Transportation Unit
- Grid Area: (Aspect)

**Notes:**
- Table 7.1: Field Vegetation Unit (FVU) and Plot Transportation Unit (PTU) delineation and identification numbers are listed on the corresponding pages.
- Identification numbers are assigned to each component and its cooperating (or supporting) component.
- Cross-references between the FVU and PTU maps (and other components) are provided in the text.
Table 7.1 continued.

**COMMENTS:**

1. At high elevations in the parkland forest, landscapes are dominated by rock and colluvium. The distinction between a "shedding ridge zone" (SR) and a "shedding zone" (SH) had little significance in predicting present vegetation condition.

2. Easterly and westerly trends in aspect on a dominantly north-facing slope have approximately the same potential influence on vegetation condition. A "valley bottom" exposure (V) within subalpine forest regions is roughly analogous to a cool "north aspect".

3. Improved photo interpretation with a greater concentration on subtle variations in crown density and pattern may have facilitated a better distinction of parkland forest Vegetation Types A and C.

4. Gullied terrain (−V) commonly contains "linear inclusions" of vegetation characteristic of higher moisture regimes.

5. The influence of a "fluvial fan" (Ff) on present vegetation condition (increased moisture) was overestimated. Only the lower distributary water channels and apron locations had vegetation typical of higher moisture regimes. Middle and apex locations on the fan were usually well drained and supported vegetation similar to the main slope (Vegetation Type D).

6. The hygrotope/slope position concept (SR,SH,SM) was inconsistent due to the overriding influence of a steep south aspect and the complex topography occurring at the valley mouth.

7. The lower slopes of the grid area thought to be influenced by "a valley bottom exposure" (S) showed little variation in vegetation from those with only a dominantly "southern exposure" (S).

8. An eastern "trench" aspect (E) was similar to the "southern aspects" (S) at the valley mouth in terms of their influence on present vegetation condition.

9. Initial confusion over vegetation zonation on the south aspect caused inconsistencies in assigning the status of the present vegetation condition of these map units. "Pyral" influence (P) was reserved for stands of dominantly Pinus contorta. Variations in canopy closure appeared to have less influence on the present vegetation condition than originally thought.

10. The influence of "glacial channels" (E) on present vegetation condition are recognized by a complex map unit (J-I-2). Vegetation Type I-2 occurs on knolls while Type J-1 occurs in the channels.

11. The "glaciofluvial terrace" top (Ft) provided a slightly cooler habitat than most of the south-facing slope in this part of watershed.
Figure 7.2 Systematic Sampling Study—pretyped vegetation map units (thick dashed line and numbered units) superimposed onto the final vegetation map units (thin solid line and letter-number symbols) within the grid areas. Solid dots represent operational sample plots within or in the immediate vicinity of the grid areas.
vegetation map units based on the operational vegetation type classification of the 13 contributory sample plots within or adjacent to the grid area (see Figure 7.2). Table 7.1 highlights some of the relationships and anomalies between the pretyped map unit designations and the final vegetation map units. South Aspect (refer to Table 7.2 and Figure 7.2).

Vegetation pretyping on the south aspect was easier than the north aspect due to the more readily observable variation in forest cover and topography. Some difficulties arose when delineating the "shedding" map units along the divide between the Templeton River watershed and the trench region to the east (map units #8 and #9). The increased effect of evapotranspiration on a steeply sloping south aspect reduced the effect of seepage water in receiving slope positions.

Five of the 14 pretyped map units were represented by an operational sample plot within the grid area (units #4, #6, #12, #13 and #14). The 14 pretyped map units were modified to form 6 final vegetation map units based on the operational vegetation types of the 13 contributory sample plots within or adjacent to the grid area (see Figure 7.2). Table 7.1 highlights some of the relationships and anomalies between the pretyped map unit designations and the final vegetation map units.

This section has attempted to demonstrate the application of the pretyping approach to the operational mapping of final vegetation units and the capability of this approach to predict variation in
vegetation. On both grid areas the pretyped map was more detailed (more map units) than the final vegetation map. Some of the criteria responsible for the greater detail (e.g. variation in aspect and terrain features and processes) did not correlate well with changes in the present vegetation condition. The hygrotope/slope position concept provided only a rough stratification of the topoedaphic moisture sequence down the slope. Weaknesses in this aspect of the pretyping method are probably due to the combined effect of several factors: the overriding influence of cooler (meso) climates on vegetation development at higher elevations and on north aspects, the predominance of well drained overburden (colluvium) on the valley slopes, a relatively dry continental macroclimate (relative to the coast and interior wet belt) and the insolative properties of the steep south-facing slopes. Nevertheless, the pretyping approach approximated many of the final vegetation map unit boundaries. It provided a methodical, preliminary stratification of the landscape upon which improved mapping criteria could be added to better predict present vegetation condition.

7.3.2 Reliability of the final vegetation map

Dissimilarity Analysis subdivided the 31 systematic sample plots into 8 final groups and 4 single plots (see Figure 7.3). Mean similarity values of the final groups ranged from 56.0 to 87.8 with a mean value of 73.0 (very homogeneous) (see Figure 7.3). Final group and single plot
Figure 7.3  Systematic Sampling Study - Dissimilarity Analysis dendrogram and mean similarity values. Note final group 8 has the lowest mean similarity value.

Figure 7.4  Systematic Sampling Study - final group cluster analysis, plot cluster analysis of final group 8 and the formation of vegetation types using 3 levels of interpretation.
levels of the divisive hierarchy were established with as few as 2 and as many as 8 levels of division. A clear distinction between the sample plots from the north and south aspect was reflected in the initial dichotomy of both the divisive (Dissimilarity Analysis) and agglomerative hierarchies (see Figures 7.3 and 7.4). Below this level of generalization however, there are few similarities between the two hierarchies.

Following a comparative analysis of the Dissimilarity Analysis dendrogram, relationships were established between the final groups of the systematic sample plots and the operational vegetation types of the Templeton River watershed study (see Table 7.2). It is important to note that the comparisons did not employ a numerical analysis. Rather, relationships were established by comparing (visually) their general vegetation structure, character species, constant species, recognition species and their total species composition. Unlike soil science, in which a number of taxonomies have been developed, vegetation science (phytosociology) has no single accepted taxonomy in this region to facilitate a more objective comparison of communities, community-types, or vegetation types.

The final group and plot cluster analyses revealed the more generalized and more detailed similarity levels of the classification hierarchy respectively. Since there is no assumed taxonomic rank to the classification structures (Clifford and Williams, 1973) (Clifford and Stephenson, 1975), the agglomerative hierarchies were truncated at levels consistent with the relationships shown in Table 7.2. Eight systematic vegetation types (the seven shown in Figure 7.4 and the single
Table 7.2 Relationships between the final groups of systematic sample plots and the operational vegetation types of the Templeton River watershed study.

<table>
<thead>
<tr>
<th>Final Group Number</th>
<th>Similar Operational Vegetation Types</th>
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<tbody>
<tr>
<td>1</td>
<td>&quot;H-1&quot;, but with pure <em>Pinus contorta</em> tree layer and more subalpine</td>
</tr>
<tr>
<td></td>
<td>(<em>Vaccinium scoparium</em>)</td>
</tr>
<tr>
<td>2</td>
<td>&quot;H-1&quot;</td>
</tr>
<tr>
<td>3</td>
<td>&quot;H-1&quot;</td>
</tr>
<tr>
<td>4</td>
<td>&quot;I-2&quot;</td>
</tr>
<tr>
<td>5</td>
<td>&quot;A&quot;</td>
</tr>
<tr>
<td>6</td>
<td>&quot;D&quot;</td>
</tr>
<tr>
<td>7</td>
<td>&quot;D&quot;, and to a lesser extent &quot;E&quot;</td>
</tr>
<tr>
<td>8</td>
<td>&quot;D&quot; and &quot;F&quot;</td>
</tr>
<tr>
<td>Single plot 1.6</td>
<td>&quot;J&quot;</td>
</tr>
</tbody>
</table>

plot 1.6 in Figure 7.3) were established with 3 different levels of interpretation of the classification hierarchy. Single plots arising from the Dissimilarity Analysis dendrogram are discussed in Table 7.3. The final groups, single plots and vegetation types of the systematic classification analysis were plotted onto the final, operational vegetation map units within the grid areas (see Figure 7.5). The reliability of the operational map units was determined by the percentage of agreement occurring between the groups of grid points (systematic sample plots) representing the systematic vegetation types (an estimate
Table 7.3 Agreement between the groups of grid points (systematic sample plots) representing the systematic vegetation types and the final operational vegetation map units.

<table>
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<tr>
<th>Systematic Sample Plot</th>
<th>Final Vegetation Map Unit</th>
<th>Final Group</th>
<th>Systematic Vegetation Type</th>
<th>Agreement</th>
<th>Comment #</th>
<th>Systematic Sample Plot</th>
<th>Final Vegetation Map Unit</th>
<th>Final Group</th>
<th>Systematic Vegetation Type</th>
<th>Agreement</th>
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<td>8b</td>
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<td>1</td>
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<td>F</td>
<td>8</td>
<td>8a</td>
<td>Yes</td>
<td>4</td>
</tr>
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<td>8b</td>
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<td>DSL</td>
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<td>8b</td>
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<td>2</td>
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<td>IDi</td>
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NOTE: SP(4) = single plot (similar to final group 4)

Summary of Agreement

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<th></th>
<th>Agreement</th>
<th>Max.</th>
<th>%</th>
<th>North Aspect</th>
<th>South Aspect</th>
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<td>South aspect</td>
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<td>31</td>
<td>79.0</td>
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</table>

Independent chance of agreement (%): 12.5
Chance of agreement if only:
• Systematic Vegetation Type 6+7 chosen (%): 41.6
• Systematic Vegetation Type 4 chosen (%): 47.3
Table 7.3 continued.

COMMENTS:

1. Systematic Vegetation Type 8a and operational map unit D are similar.
2. Systematic Vegetation Type 6+7 and operational map unit D are similar.
3. Systematic Vegetation Type 5 and operational map unit A are similar.
4. Systematic Vegetation Type 8b and operational map unit F are similar.
5. Disagreement may be a result of a plotting-boundary problem.
6. Disagreement may be due to a map unit inclusion.
7. Systematic Vegetation Type 4 and operational map unit I-2 are similar.
8. Systematic Vegetation Type 2+3 and operational map unit H-1 are similar.
9. I-2 component of complex operational map unit is similar to Vegetation Type 4.
10. Single plot 1.3 is more similar to final group 4 (see Figure 7.3) and is therefore similar to operational map unit I-2.
11. Single plot 3.4 is second most similar to final group 4 (see Figure 7.3) and is therefore similar to map unit I-2.
12. Single plot 1.6 is least similar to final group 4 (see figure 7.3) and is therefore considered a separate, systematic vegetation type similar to operational map unit J.
13. Single plot 3.3 is most similar to final group 2 (see figure 7.3) and is therefore similar to operational map unit H-1.
14. Disagreement probably due to mapping error.
15. Disagreement probably due to insufficient operational sampling at this elevation on the south aspect and therefore lack of appropriate vegetation type. The pretyped map units indicated a potential difference in vegetation between sample plots 3.1 - 3.2 and 2.2 - 2.3.
Figure 7.5 Systematic Sampling Study - final groups, single plots and vegetation types plotted onto the operational vegetation map units within the grid areas.
of the actual vegetation types occurring within the grid areas) and the final, operational vegetation map units (a prediction of the vegetation types occurring within the grid areas). For each grid point (systematic sample plot) a comparison was made between its final, operational vegetation map unit label and its systematic vegetation type membership (see Table 7.3). The percentage of agreement for both grid areas together was 79% relative to an independent chance of agreement of 6.2% and an optimum chance of agreement of 29.0% (by choosing the most common Vegetation Type 4 for all systematic sample plots). The north aspect (83.3%) showed a slightly better agreement than the south aspect (76.3%). The comments included in Table 7.3 have attempted to explain the reasons for agreement and disagreement between the units. In general, disagreements were the result of 4 factors:

a. exact boundary location (comments 5 and 10);

b. map unit inclusions (comment 6);

c. definite mapping error (comment 14); and

d. lack of ground truth in the operational survey to facilitate the formation of separate operational vegetation types and/or a difference in scale (i.e. number of samples, number of species and extent of area under study between the grid areas and the watershed area).
Problems concerning the "exact boundary location" are usually a result of cartographic limitations (plotting errors and inaccuracies related to scale) and are difficult to avoid. "Map unit inclusions" are areas within a map unit which are different from the rest of the map unit, which occur in not more than 15 to 20% of the map unit area and which cannot be delineated and labelled at the adopted map scale. Anomalies of this nature are common to any mapping activity conducted in natural landscapes and are seldom avoided by the selection of larger mapping scales. "Definite mapping errors" result from wrongly extrapolating accepted mapping concepts into areas lacking ground information.

In the operational studies, extrapolations were made using recognizable features on black and white aerial photographs viewed in stereo. Grid points 1.4 and 1.5 on the south aspect should have been included within the operational map unit I-2 (see Figure 7.5). This kind of error can be avoided with a greater sampling intensity and improved aerial photo interpretation.

The fourth factor noted above (d) may explain the inclusion of grid points 3.1 and 3.2 (south aspect) within the operational map unit H-1. If additional samples had been taken in this area during the operational survey, a separate operational vegetation type similar to systematic Vegetation Type 1 may have been formed (depending upon their impact on the total classification analysis). On the other hand, any additional samples in this region may still have fallen within the
acceptable variation of the operational map unit H-1. This would indicate the disagreement was more a result of a difference of scale (number of species, number of plots and extent of area under study) between the two classifications and the resulting maps. A more detailed stratification of the south-facing slope indicates the existence of a separate upper elevation vegetation type (#1).

Very few studies have been conducted on mapping reliability using a post-mapping, systematic sampling procedure. Traditionally, reliability has been determined subjectively by the surveyor based on the factors listed earlier in section 7.1.1. Post-mapping, objective sampling studies have been conducted on soil surveys in Michigan State (Whiteside, 1977). These studies have found that the soil series designations agreed 52 to 62% of the time and that selected soil properties (texture, slope class and erosion class) agreed 64 to 98% of the time. Studies concerning reliability of terrain (landform and surficial materials) and soil association mapping in British Columbia suggest that agreement values between 55 and 75% are about average for reconnaissance (1:50,000 - 1:100,000) surveys (Valentine et al., 1971; Valentine and Hawkins, 1975; Alley, personal communication). These percentages suggest that the values achieved in this study fall well within an acceptable level of mapping reliability. It is still difficult to judge how "good" the results of this study are without comparing them to several similar investigations. Unfortunately, no such investigations have been conducted to date.
This chapter has examined two aspects of the operational mapping of vegetation in the Grassy Creek and Templeton River watersheds: the predictive capability of the vegetation pretyping approach and the reliability of the final vegetation maps. A detailed examination of two representative areas within the Templeton River watershed revealed the merits and inadequacies of the vegetation pretyping approach. An analysis of sample plots collected on a systematic basis within the same representative areas indicated an operational mapping reliability of 79%.

Footnotes:

1. The "accessory analyses" of the Coenos program were also applied (see section 4.3.1.2).

2. Hereafter the term "operational" will be used to describe any aspect of the classification and mapping of vegetation in the Grassy Creek and Templeton River watersheds (Chapters 5 and 6 respectively).

3. Known landscape attributes and patterns are obtained with ground truth (sample plot data) and the correlation of ground truth with visible features on aerial photographs.

4. In this study, the results of an inventory are presented in the form of a map and legend.

5. In other instances, the quality of an inventory may be measured by its interpretability, usefulness, presentation etc.

6. For example: dotted lines, light type face or short character size would indicate low confidence; solid lines, bold type face or tall character size would indicate high confidence.

7. An analogous soil and parent material study was conducted by G. Utzig, graduate student, Department of Soil Science, University of British Columbia.

8. Considerations in the selection of the grid pattern included the known variability (from operational field sampling) and inferred variability (from the aerial photographs) of these landscapes and the time required to collect the field data.
9. A grid point was formed by the intersection of two perpendicular grid lines. Each grid point became the centre point location of a sample plot.

10. Hereafter the term "systematic" will be used to describe any aspect of the classification and mapping of vegetation in the grid areas based on the independent field sample plots.

11. It is recognized that the existence of several soil classifications causes difficulties in comparative studies in soil science. However comparisons can usually be accomplished by making them relative to a particular taxonomy or by establishing the exact relationship between the taxonomies.

12. The independent chance of agreement = 12.5%; the optimum chance of agreement (Vegetation Type 6 and 7) = 41.6%.

13. The independent chance of agreement = 12.5%; the optimum chance of agreement (Vegetation Type 4) = 47.3%.
CHAPTER 8. SUMMARY DISCUSSION
CHAPTER 8. SUMMARY DISCUSSION

8.1 Review

Concomittant with an increasing trend towards the ecological classification of forest land is the need for more detailed vegetation inventories and larger mapping scales (1:15,840). Although the existing land classification schemes (biogeoclimatic, provincial biophysical and habitat type classification) may present an initial stratification of broad zonal patterns, they seldom provide, or were intended to provide a vegetation classification suitable for detailed vegetation inventory and mapping in particular study areas. In most instances, primary vegetation data must be collected and classified at a level of detail compatible with the scale of mapping and the variability of the vegetation landscape. Limited access and steep mountainous terrain are additional problems contributing to the acquisition, classification and mapping of vegetation at large scales.

In British Columbia there is no standardized approach for vegetation classification. Both traditional and numerical methods of classification are employed by practising plant ecologists. Numerical classification approaches have several advantages over the subjective, traditional methods of classification but still require accreditation for the practical concerns of operational vegetation survey.

Dissimilarity Analysis is a numerical classification analysis conceived by Macnaughton-Smith (1964, 1965) which has been programmed and studied by the provincial government as a means to stratify large volumes
of vegetation data in a relatively fast and objective manner. Dissimilarity Analysis is a divisive-polythetic classification strategy which demonstrates some advantages over other numerical analyses. Although it is now used as a routine analysis by the provincial biophysical survey, it has not yet been thoroughly evaluated or formally presented with regard to its suitability for vegetation classification and mapping on an operational basis.

In view of the problems in the classification and mapping of vegetation outlined above, this study attempted to answer four related questions:

a. What methods can be employed for detailed vegetation mapping (scale 1:15,840) in mountainous terrain with limited access?

b. What is the value of Dissimilarity Analysis for the classification of vegetation in primary survey?

c. What is the predictive capability of the pretyping (prestratification) approach developed for vegetation mapping?

d. What is the reliability of the vegetation maps?

In order to answer these questions the study was divided into two separate but related investigations: the operational classification and mapping of vegetation in the Grassy Creek and Templeton River watersheds; and a systematic sampling study of two representative areas in the Templeton River watershed to assess the vegetation mapping procedure and map reliability.

A summary discussion of results from the two investigations is presented below under the topics of vegetation classification and vegetation mapping.
8.2 Vegetation classification

There were three objectives of classification in this study: data reduction, hypothesis generation and hypothesis testing. The primary objective of the operational inventories was data reduction — the stratification of the data set into groups. The second function of classification was hypothesis generation — a postulation regarding the existence of certain vegetation types and, in the case of mapping, the geographic extent of the vegetation types. Hypothesis testing was an objective of classification in the map reliability study — an independent classification used to test the existence and areal extent of the operational vegetation types.

Data reduction is an essential operation in any vegetation inventory. If an appropriate classification system is in existence then the inventory procedure becomes an "identification" process in which sample plots are simply allocated into existing classes. If on the other hand, an appropriate classification is not in existence then the inventory procedure will depend on the formation of some classification. During the collection of primary inventory data an experienced surveyor is usually capable of mentally stratifying the sample plots into a series of tentative types. However as the number of observations increase it becomes increasingly more difficult to "pigeon-hole" each additional observation. At this stage of a vegetation inventory, classification becomes an imperative operation. In floristic classification the aim is usually simple: to assemble those sample plots (individuals) most similar to one another and to partition those sample plots most dissimilar to one another in terms of their species composition (qualitative) and possibly species performance (quantitative). Classification can be achieved through traditional approaches or numerical analyses.
In this study vegetation classification was accomplished using a numerical analysis. Numerical techniques have several important advantages over traditional approaches to classification. Firstly, they provide a more objective basis for classification. In primary vegetation survey objectivity reduces personal bias developed before, during or after data collection which can unjustly influence the classification. In this respect classification should "reveal" discontinuities in vegetation rather than "impose" them (Lambert and Dale, 1964). Secondly, numerical analyses are repeatable. For a given data set the same results will always be obtained using the same analysis procedure. Thirdly, numerical techniques are fast and efficient. The complex and repetitive calculations are performed quickly and are capable of extracting the maximum amount of information available from the data set in forming the classification. The inherent inadequacies of vegetation data from primary surveys in remote areas (i.e. limited distribution and replication of samples) are improved by the efficiency of numerical analyses which ensure an optimum and consistent utilization of the information contained in the data set.

Dissimilarity Analysis is a divisive-polythetic strategy which has several advantages over (polythetic-) agglomerative analyses for the classification of vegetation in primary surveys. In primary survey there is frequently a lack of replication of certain "types" due to a number of reasons (e.g. poor access, limited time or low priority). In agglomerative strategies representative plots from these "types" can be incorrectly united with clusters at an early stage of analysis and will no longer be recognized as unique types. In divisive strategies on the other hand, classification begins
with the maximum information over the whole data set and successively subdivides until these "types" are usually partitioned from the remaining group. In Dissimilarity Analysis, these types are represented by either "single plots" or final groups with a very low mean similarity. By maximizing differences between groups, Dissimilarity Analysis does not give a potentially false impression of "similarity" between groups that should be considered distinct.

A second advantage of Dissimilarity Analysis over agglomerative techniques is that it defines limits to the classes formed. This quality of divisive classification in vegetation survey facilitates an objective, distinctive characterization of groups by their diagnostic species and an hierarchical identification procedure (key) for allocating new plots into existing groups. A key can then be employed for the future "identification" of vegetation types within the study area or in adjacent areas where the classification is still applicable. This discriminant feature of Dissimilarity Analysis is also useful for any mapping programs following the primary survey. Unfortunately, this approach to mapping could not be evaluated since the objectives of this study required that the primary survey contribute to both the classification and mapping of the vegetation.

In Chapter 7 the comparison of the systematic vegetation types with the operational vegetation types in the grid areas was accomplished using an identification procedure (i.e. comparisons were made between character species and their diagnostic value)(see section 7.3.2).

"Vegetation types" were established and described following the interpretation of the numerical analysis (Dissimilarity Analysis and the cluster analyses). The vegetation type is a useful classification concept in primary vegetation survey since it does not confine the classes to a
specific taxonomic rank and level of homogeneity. Rather, vegetation types simply reflect distinct variations in the vegetation as revealed by the analysis of the data set. In some cases the vegetation types may approximate a "plant association" or "community-type" level of homogeneity, while in other cases it may only represent one sample plot of a different vegetation type which warrants further investigation (hypothesis generation). As discussed earlier in section 2.3.1 it is difficult to test (hypothesis testing) the existence ("significance") of vegetation types since the nature of probability concepts in numerical classification are not clearly understood by statisticians. Intuitively, the vegetation types in the two watershed studies were "logical" and were consistent with the landscape patterns and habitat features observed in the field and on aerial photographs. In some respects, the classification analysis of the systematic sample plots supported the existence of vegetation types similar to the operational vegetation types in the grid areas (see section 7.3.2). However, even if comparisons has been more objective by employing a numerical analysis, the same problem arises over the degree of similarity -- namely at what "level of significance" are the two types considered similar? ...

When the results of the classification analysis were interpreted every effort was made to be as objective as possible and to dismiss any preconceived notions of classification. Initial peculiarities or anomalies noted in the classification were always explained following a careful review of the data. In this respect, numerical classification often forces the surveyor to consider the less obvious classes of vegetation which would have otherwise not been considered or would have been discarded due to subjective
bias developed during field sampling.

Both divisive and agglomerative hierarchies were used to reveal relationships between sample plots, groups of sample plots and the entire set of sample plots. The Dissimilarity Analysis dendrogram defined the divisive route between the initial set and the final groups and provided a framework for the "comparative analysis" (section 4.3.2.1). In the Grassy Creek watershed successional and physiognomic features of the vegetation could be interpreted at general levels of the divisive hierarchy. In the Templeton River watershed these features were not as evident at general levels of the dendrogram. It is unlikely that the divisive hierarchy will consistently demonstrate broad-scale similarities in the vegetation features since its composition is based on differences between the groups.

The agglomerative hierarchies are constructed on the basis of the more tangible concept of similarity. General levels of these hierarchies were useful for revealing general patterns of zonation, succession and physiognomy in the vegetation data (see Figures 5.10 and 6.9). In this regard, a more generalized classification of the systematic sample plots was accomplished by interpreting the final group cluster analysis (Figure 7.4) and uniting those final groups most similar to one another. Although the plot cluster analysis hierarchy was used to further subdivide final groups, it did not always clearly indicate the distinctions felt to exist. In this respect, a divisive hierarchy would have probably provided a better basis for further subdivision of final groups and would have overcome some of the difficulties inherent to agglomerative classification strategies.
8.2 Vegetation mapping

The operational mapping of vegetation in the mountainous terrain of the Grassy Creek and Templeton River watersheds relied heavily on aerial photo interpretation. Field sampling was organized as efficiently as possible in order to make optimum use of the time and manpower available. To this end, it was essential that some form of vegetation prestratification precede the field program since this would provide the necessary framework for allocating the quantity and distribution of the sample plots. Field work involved primarily the collection of sample plot data and the description of vegetation patterns along topographic sequences. The mapping procedure developed for the two operational studies is summarized below.

1. Develop a vegetation pretyping legend to stratify mountainous landscapes according to potential variation in present vegetation condition. The legend should incorporate the following features (directly observable on or inferred from black and white aerial photographs), concepts and information for predicting present vegetation condition:
   a. Permanent physiographic landscape features (e.g. slope, slope length, slope configuration, slope orientation (macro and meso aspect and exposure), surficial terrain features (gullies, channels, outcrops)).
   b. A simple concept relating permanent physiographic landscape features to the available moisture for vegetation (e.g. hygric conditions in lower concave slope positions, xeric conditions on convex slope positions).
c. Macro and meso physiognomic features of the present vegetation cover. (e.g. macro: forest vs. grassland; meso: closed forest vs. open forest canopy).

d. Existing vegetation information regarding dominant species composition (e.g. forest cover maps) and vegetation zonation (e.g. biogeoclimatic zone and subzone maps).

2. Pretype the detailed (scale 1:15,840) black and white, stereo aerial photographs of the survey area according to the vegetation pretyping legend. Correlate mapping between adjacent aerial photographs and form a photo map of the "pretyped vegetation".

3. Sample the vegetation according to the distribution and variability of the pretyped vegetation map units and stratify the sample plots according to some classification procedure.

4. Establish relationships between the pretyped vegetation map units and the classification of the sample plots. If necessary, modify the original pretyping criteria to accommodate these relationships.

5. Adjust the pretyped vegetation map units where necessary according to the relationships mentioned in "4" above. Prepare a final vegetation map at a scale of 1:15,840.

As mentioned above (section 8.2), the field data in this study contributed to both the classification and mapping of the vegetation in each watershed. In this respect, map reliability was very dependent on the capability of the pretyping approach to predict vegetation change. This aspect of the mapping procedure will not be discussed any further since it has already been analysed in considerable detail in Chapter 7. It was concluded that the pretyping approach approximated many of the
vegetation boundaries and provided a methodical, preliminary stratification of the landscape upon which improved mapping criteria could be added.

Physiognomy is a vegetation feature that is seldom given adequate consideration in vegetation mapping approaches which are based primarily on floristic classification. In this study, an effort was made to correlate physiognomic features with floristic variation. Physiognomic features and patterns recognizable on the aerial photographs were used for extrapolating known physiognomic-floristic relationships into areas with no ground observations. Physiognomic information in detailed vegetation mapping could be improved by the use of low level (70 mm) stereo photo transects. Features noted at this scale (e.g. the structural variation of the vegetation strata) could be used to enhance the interpretation of the smaller scale photography (1:15,840).

The term "detailed" has been used throughout this study to describe the "level of detail" of the vegetation classification and mapping in the two operational surveys. In early soil surveys the term "detailed" implied mapping scales of 1:20,000 and 1:15,840 in which the "boundaries are sketched from observations of their entire occurrence on the ground (Soil Survey Staff, 1951). "Reconnaissance survey" implied mapping scales of between 1:31,680 and 1:63,360 in which "only a part of the soil boundaries are actually seen by the field scientist" while "detailed reconnaissance" surveys were slightly less detailed than detailed surveys (Soil Survey Staff, 1951). Applying these definitions to this study would indicate that the operational surveys were "detailed reconnaissance" -- a detailed scale of presentation (1:15,840) with (at best) a reconnaissance level of ground verification of map boundaries. Recently, more definitive
classes of map scales have been proposed (U.S. Dept. of Agriculture, Soil Conservation Service, 1977, in preparation). This new proposal would identify the scales in this study as "mesodetailed" (scales between 1:7,920 and 1:24,000)\(^3\).

It is important to note that most of the ranges in scale and terms used to describe survey intensity have evolved primarily from soil survey experience on agricultural lands. The application of these standards to surveys conducted in mountainous forest regions requires some qualification.

Essentially there are three elements to consider with map scales: cartographic detail — the number and size of delineations in relation to land area (Cline, 1977); categorical detail — the definition of map units in relation to the range of sets of (soil) properties in the area (Cline, 1977); and map reliability — the difference between the predicted probability of occurrence of the map units and the actual occurrence of the map units \(^4\). Ideally all three factors should be somewhat interrelated and interdependent, however this is not always the case. For example, the final vegetation maps in this study (Figures 5.15 and 6.13) could tolerate a cartographic level of detail of approximately 1 cm\(^2\) and the map unit symbols are concise and legible at a scale of 1:15,840. On the other hand the pretyped vegetation maps (Figures 5.14 and 6.12) could only tolerate a cartographic level of detail of no smaller than approximately 1"8,000 since the map symbols are large and complex.

The taxonomic rank of the vegetation legend would normally permit an assessment of the categorical map scale (e.g. Can plant associations
be mapped at a scale of 1:15,840 in this study area?) Since the "vegetation type" assumes no particular taxonomic rank it is difficult to assess the categorical level of detail of the operational surveys. However, assuming that the sample plots approximated plant communities (that the established vegetation classifications represented the major variation in the vegetation of the watersheds, and that a reasonable level of map reliability was achieved) then the scale of 1:15,840 was compatible with the level of detail of the classifications (categorical detail). Since the reliability of the mapping in the grid areas was 79% it is reasonable to suggest that the map scale of 1:15,840 is also compatible with mapping confidence.

Chapter 8 has attempted to summarize and discuss some of the more pertinent subjects concerning this investigation. It is felt that other topics which might have been discussed have already been dealt with in considerable detail in the preceding chapters. Chapter 9 will present the conclusions to the study.

Footnotes:

1. These final groups would have been subdivided if a lower stopping value had been assigned for the analysis.
2. A key is formed by simply expanding the comparative analysis procedure described in section 4.3.2.1. In polythetic analyses the key is also polythetic in that several species criteria are reported for each step of the key.
3. "Ultradetailed" are scales greater than 1:7,920 and "macrodetailed" are scales between 1:24,000 and 1:62,500.
4. The use of the term "map reliability" in this context is usually considered in terms of the quantity and distribution of the ground observations.
CHAPTER 9. CONCLUSIONS
CHAPTER 9. CONCLUSIONS

This study has investigated two aspects of vegetation science: vegetation classification and vegetation mapping. Following a study of vegetation classification and mapping in two interior watersheds, the four questions posed in Chapter 1 are answered below.

1. What methods can be employed for detailed vegetation mapping (scale 1:15,840) in mountainous terrain with limited access?

   The methods used for detailed vegetation mapping in mountainous terrain with limited access should utilize permanent, physiographic landscape features directly observable or inferred from black and white stereo aerial photographs (scale 1:15,840); macro and meso physiognomic features of the present vegetation cover; a simple concept relating the above mentioned features to the available moisture for vegetation; and information about existing vegetation regarding species cover types and vegetation zonation.

2. What is the value of Dissimilarity Analysis for the classification of vegetation in primary survey?

   Dissimilarity Analysis provides a more objective basis for classification than traditional methods by reducing personal bias and by revealing discontinuities in the data set based entirely on the information contained therein. Dissimilarity analysis is an appropriate technique for stratifying primary
vegetation data in remote areas because it is efficient at ensuring an optimum and consistent application of the available information in the data set; it maximizes differences between groups that should be considered distinct; and it defines limits to classes and facilitates the objective characterization of groups, the determination of diagnostic species and the formation of a hierarchical identification procedure (key).

3. What is the predictive capability of the vegetation pretyping (prestratification) approach developed for vegetation mapping?

A qualitative assessment of the predictive capability of the vegetation pretyping approach indicated that the criteria for pretyping resulted in a more detailed stratification of the landscape than in the final vegetation map and that the "hygrotepe/slope position" concept provided only a rough approximation of the topoedaphic moisture sequence down a slope. However, the vegetation pretyping approach provided a methodical, preliminary stratification of the landscape upon which improved mapping criteria could be added to better predict present vegetation condition.

4. What is the reliability of the vegetation maps?

A quantitative assessment of map reliability in two representative areas of the Templeton River watershed resulted in a value of 79% relative to an independent chance of agreement of 6.2% and an optimum chance of agreement of 29%. It is reasonable
to suggest that this value (79%) is representative of map reliability in the remainder of Templeton River watershed. A value of 79% represents the upper limits of the range of map reliabilities reported in similar studies. Map reliability in the Grassy Creek watershed was not determined.
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REFERENCES CITED


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APPENDIX I

Definition of vegetation strata and coverage classes
1. Vegetation strata categories

A0 Veteran trees - trees considerably older than the trees of the main canopy which have often survived one or more fires; often occur singly and are usually well above the main tree canopy.

A1 Taller trees - trees which protrude above the main tree canopy but of approximately the same age class as the main canopy.

A2 Main tree canopy - trees which form a more or less continuous crown canopy.

A3 Secondary tree canopy - trees occurring below the main tree canopy but of approximately the same age as the main canopy and greater than 8 m (25 feet).

B1 Tall shrubs and regeneration layer - all non-herbaceous species reaching heights between 2m (6 feet) and 8m (25 feet).

B2 Low shrub and regeneration layer - all non-herbaceous species reaching heights no greater than 2m (6 feet).

C Herb layer - all vascular non-woody plants regardless of height.

D Moss layer - bryophytes (non-vascular).

2. Vegetation coverage classes (Daubenmire, 1959).

<table>
<thead>
<tr>
<th>Class</th>
<th>Range (% cover)</th>
<th>Midpoint (% cover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-5</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>5-25</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>25-50</td>
<td>37.5</td>
</tr>
<tr>
<td>4</td>
<td>50-75</td>
<td>62.5</td>
</tr>
<tr>
<td>5</td>
<td>75-95</td>
<td>85</td>
</tr>
<tr>
<td>6</td>
<td>95-100</td>
<td>97.5</td>
</tr>
</tbody>
</table>

1. Vegetation Section, Resource Analysis Branch, Ministry of Environment, British Columbia.
APPENDIX II

Plant species list for the Grassy Creek and Templeton River watersheds

TEMPLETON RIVER WATERSHED

Vascular Plants

Abies lasiocarpa (Hook.) Nutt.
Acer glabrum Torr.
Achillea millefolium L.
Actaea rubra (Ait.) Willd.
Allium cernuum Henry
Alnus sinuata (Regel) Rydb.
Amelanchier alnifolia Nutt.
Anaphalis margaritacea (L.) B. & H.
Anemone multifida Poir.
Anemone parviflora Michx.
Antennaria racemosa Hook.
Antennaria rosea Greene
Aquilegia flavescens Wats.
Arabis drummondii Gray
Aralia nudicaulis L.
Arctostaphylos uva-ursi (L.) Spreng.
Arenaria capillaris Poir
Arnica cordifolia Hook.
Aster conspicuous Lindl.
Aster spp. L.
Athyrium filix-femina (L.) Roth
Berberis repens Lind.
Calamagrostis rubescens Buckl.
Calypso bulbosa (L.) Dakes
Carex concinnoides Mack.
Carex spp.
Cassiope mertensiana (Bong.) G. Don
Castilleja spp. Mutis ex L.
Chimaphila umbellata (L.) Bart.
Circuta douglasii (DC.) Coult. & Rose
Claytonia lanceolata Pursh
Clematis columbiana (Nutt.) T. & G.
Clintonia uniflora (Schult.) Kunth
Cornus canadensis L.
Cornus stoliniferum Michx.
Cryptogramma crispa (L.) R. Br.
Delphinium glareosum Greene
Disporum hookeri (Torr.) Nicholson
Draba aureola Wats.
Dryas octopetala L.
Dryopteris australis (Jacq.) Woynar ex Schinz & Thell.
Epilobium augustifolium L.
Equisetum arvense L.
Fragaria glauca Rydb.
Fragaria virginiana Duchesne
Galium triflorum Michx.
Goodyera oblongifolia Raf.
Gymnocarpium dryopteris (L.) Newm.
Habenaria saccata Greene
Heracleum lanatum Michx.
Helenium cylindrica Dougl. ex Hook.
Helenium parvifolia Nutt. ex T. & G.
Hieracium albiflorum Hook.
Hypochaeris radicata L.
Juniperus scopulorum Sarg.
Kalmia polifolia Wang.
Larix lyallii Parl
Linnaea borealis (Cronov) L.
Listera caurina Piper
Lomatium ambiguum (Nutt.) Coulter & Rose
Lonicera involucrata (Rich.) Banks
Lonicera utahensis Wats.
Lycopodium annotinum L.
Mentha arvensis L.
Menziesia ferruginea Smith
Mitella nuda L.
Moneses uniflora (L.) A. Gray
Myosotis sylvatica Hoffm. Deutschl.
Oplopanax horridum (J.E. Smith) Miq.
Osmorhiza chilensis H. & A.
Pedicularis bracteosa Benth.
Pedicularis racemosa Dougl.
Penstemon fruticosus var scouleri (Lindl.) Cronq.
Petasites palmatus (Ait.) A. Gray
Phyllodoce empetriformis (Sm.) D. Don
Phyllodoce glanduliflora (Hook.) Coville
Picea engelmannii Parry ex Engelm.
Pinus albicaulis Engelm.
Pinus contorta Dougl. ex Loud.
Polystichum lonchitis (L.) Roth
Populus tremuloides Michx.
Populus trichocarpa Torr. & Gray
Potentilla fruticosa L.
Potentilla gracilis Dougl. ex Hook.
Prunus emarginata Dougl.
Pseudotsuga menziesii (Mirbel) Franco
Pyrola secunda L.
Pyrola virens Schweigg.
Ranunculus eschscholtzii Schlecht.
Rhododendron albiflorum Hook.
Ribes lacustre (Pers.) Poir
Rosa gymnocarpa Nutt.
Rubus parviflorus Nutt.
Rubus pedatus J.E. Smith
Rubus spp.
Salix drummondii Baratt in Hook.
Salix spp. L.
Sambucus racemosa L.
Saxifraga bronchialis L.
Saxifraga lyallii Engl.
Sedum lanceolatum Torr.
Sedum laxum (Britt.) Berger
Senecio triangularis Hook.
Shepherdia canadensis (L.) Nutt.
Smilacina racemosa (L.) Desf.
Sorbus scopulina Greene, Pitt.
Sorbus sitchensis Roemer
Spiraea betulifolia Pall.
Spiraea spp. L.
Streptopus amplexifolius (L.) D.C.
Streptopus streptopoides (Ledeb.) F. & R.
Thalictrum occidentale Gray
Thuja plicata D. Don
Tiarella unifoliata Hook.
Tolmiea menziesii (Pursh) T. & G.
Trollius laxus Salisb.
Tsuga heterophylla (Raf.) Sarg.
Tsuga mertensiana (Bong.) Carr.
Vaccinium membranaceum Doug1. ex Hook.
Vaccinium scoparium Leiberg
Valeriana sitchensis Bong.
Veratrum eschscholtzii A. Gray
Viburnum edule (Michx.) Raf.
Viola adunca Smith
Viola canadensis L.
Viola glabella Nutt.
Viola nuttallii Pursh
Viola orbiculata Geyer ex Hook.
Bryophytes

Aulacomnium androgynum (Hedw.) Schaegr.
Aulacomnium turgidum (Wahlenb.) Schaegr.
Barbiliophosia spp.
Cratoneuron commutatum (Hedw.) Ross
Dicranum spp.
Hylocomnium splendens (Hedw.) B.S.G.
Isothecium stoliniferum (Hook.) Brid.
Plagioiunum drummondii (Bruch & Schimp) Koponen
Pleurozium schreberi (Brid.) Mitt.
Polytrichium juniperinum Hedw.
Ptilium crista-castrensis (Hedw.) De Not.
Rhytidiadelphus triquetrus (Hedw.) Warnst.
Sphagnum spp.
GRASSY CREEK WATERSHED

Vascular Plants

Abies grandis (Dougl.) Lindl.
Abies lasiocarpa Torr.
Acer glabrum Torr.
Achillea millefolium L.
Aconitum columbianum Nutt.
Actaea rubra (Ait.) Willd.
Adenocaulon bicolor Hook.
Agoseris glauca (Pursh) Raf.
Alnus sinuata (Regel) Rydb.
Amelanchier alnifolia Nutt.
Anaphalis margaritacea (L.) B. & H.
Anemone occidentalis Wats.
Antennaria racemosa Hook.
Antennaria rosea Greene
Antennaria spp. Gaertn.
Apocynum androsaemifolium L.
Aquilegia flavescens Wats.
Aralia nudicaulis L.
Arenaria capillaris Poir.
Arnica cordifolia Hook.
Asarum caudatum Lindl.
Aster conspicuos Lindl.
Aster spp. L.
Athyrium felix-femina (L.) Roth
Berberis repens Lindl.
Betula papyrifera Marsh.
Calochortus lyallii Baker
Campanula rotundifolia L.
Carex spp.
Castilleja spp. Mutis ex L.
Ceanothus velutinus Dougl. ex Hook.
Cheilanthes gracillima D.C. Eat.
Cheilanthes siliquosa Maxon
Chimaphila umbellata (L.) Bart.
Circuta douglasii (D.C.) Coult & Rose
Clintonia uniflora (Schult.) Kunth
Corallorhiza mertensiana Bong.
Cornus stolinifera Michx.
Corylus cornuta Marsh.
Cryptogramma crispa (L.) R. Br.
Delphinium spp. L.
Disporum trachycarpum (Wats.) Benth. & Hook
Dryopteris austriaca (Jacq.) Wynnar ex Schinz & Thell.
Epilobium augustifolium L.
Eriogonum umbellatum var. subalpinum (Greene) Jones
Erythronium grandiflorum Pursh.
Festuca idahohensis Elm.
Fragaria vesca L.
Fragaria virginiana Duchesne
Galium triflorum Michx.
Gaultheria ovatifolia Gray
Geum triflorum Pursh
Goodyera oblongifolium Raf.
Gymnocarpium dryopteris (L.) Newm.
Habenaria hyperborea (L.) R. Br.
Heracleum lanatum Michx.
Heuchera cylindrica Dougl.
Hieracium albiflorum Hook.
Hieracium gracile Hook.
Holodiscus discolor (Pursh) Maxim.
Juniperus scopulorum Sarg.
Larix occidentalis Nutt.
Ligusticum canbyi Coult. & Rose
Lilium columbianum Hanson
Linnaea borealis (Gronov.) L.
Listera caurina Piper
Lonicera involucrata (Rich.) Banks
Lonicera utahensis Wats.
Lupinus spp. L.
Luzula glabrata (Hoppe) Desv.
Lycopodium annotinum L.
Madia glomerata Hook.
Mentha arvensis L.
Moneses uniflora (L.) A. Gray
Oplopanax horridum (J.E. Smith.) Miq.
Osmorhiza chilensis H. & A.
Pachistima myrsinoides
Pedicularis bracteosa Benth.
Pedicularis groenlandica Retz.
Pedicularis racemosa Dougl.
Penstemon fruticosus (Lindl.) Cronq.
Phacelia heterophylla Pursh
Phyllodoce empetriformis (Sm.) D. Don
Picea engelmannii Parry ex Engelm.
Pinus albicaulis Engelm.
Pinus contorta Dougl. ex Loud.
Pinus monticola ex D. Don
Polygonum sawatchense Small
Populus tremuloides Michx.
Populus trichocarpa Torr. & Gray
Polystichum lonchitis (L.) Roth.
Prunus emarginata Dougl.
Pseudotsuga menziesii (Mirb.) Franco
Pteridium aquilinum (L.) Kuhn
Pyrola asarifolia Michx.
Pyrola secunda L.
Rhododendron albiflorum Hook.
Ribes lacustre (Pers.) Poir
Rosa gymnocarpium Nutt.
Rubus parviflorus Nutt.
Rubus pedatus J.E. Smith
Salix spp. L.
Sambucus racemosa L.
Saxifraga bronchialis L.
Sedum divergens Wats.
Selaginella densa Rydb.
Senecio integerrimus Nutt.
Senecio triangularis Hook.
Sheperdia canadensis (L.) Nutt.
Smilacina racemosa (L.) Desf.
Solidago canadensis L.
Sorbus sitchensis Roemer
Spiraea betulifolia Pall.
Spiraea spp. L.
Spiranthes romanzoffiana Cham.
Streptopus amplexifolius (L.) D.C.
Taxus brevifolia Nutt.
Thalictrum occidentale Gray
Thuja plicata D. Don
Tiarella unifoliata Hook.
Tolmiea menziesii (Pursh) T. & G.
Tragopogon dubius Scop.
Trillium ovatum Pursh
Tsuga heterophylla (Raf.) Sarg.
Vaccinium membranaceum Dougl. ex Hook.
Valeriana sitchensis Bong.
Veratrum eschscholtzii A. Gray
Viola adunca Smith
Viola canadensis L.
Viola glabella Nutt.
Xerophyllum tenax Pursh Nutt.
Bryophytes

Aulacomnium androgynum (Hedw.) Schaegr.
Barbiliophosa spp.
Cratoneuron commutatum (Hedw.) Ross
Dicranum spp.
Hylocomnium splendens (Hedw.) B.S.G.
Isothecium stoliniferum (Hook.) Brid.
Plagiomnium drummondii (Bruch & Schimp) Koponen
Plagiothecium denticulatum (Hedw.) B.S.G.
Pleurozium schreberi (Brid.) Mitt.
Polytrichum juniperinum Hedw.
Rhytidiopsis robusta (Hook.) Broth.
APPENDIX III

Description of symbols and abbreviations for Terrain Units, Soil Classification, Soil Drainage and Soil Texture.
TERRAIN CLASSIFICATION SYSTEM

Example of Terrain Unit Symbol:

qualifying descriptor

<table>
<thead>
<tr>
<th>genetic material</th>
<th>surface expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>texture</td>
<td></td>
</tr>
<tr>
<td>stratigraphic indicator</td>
<td></td>
</tr>
<tr>
<td>modifying process</td>
<td></td>
</tr>
<tr>
<td>underlying surficial material</td>
<td></td>
</tr>
</tbody>
</table>

Genetic Materials:

C colluvial        L lacustrine
E Eolian           M morainal
F Fluvial

Surface Expression:

a apron           t terraced
b blanket         v veneer
r ridged

texture:

c clayey        s sandy

g gravelly      $ silty

calc = calcareous

1. Developed by the Environment and Land Use Committee Secretariat, Province of British Columbia (May, 1976).
Qualifying Descriptors:

A active

G glacial

Modifying Processes:

-F failing

SOIL CLASSIFICATION (soil subgroups)²

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>BRGL</td>
<td>Brunisolic Grey Luvisol</td>
</tr>
<tr>
<td>GLBRGL</td>
<td>Gleyed Brunisolic Grey Luvisol</td>
</tr>
<tr>
<td>BIGL</td>
<td>Bisequa Grey Luvisol</td>
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<tr>
<td>GLOFHP</td>
<td>Gleyed Orthic Ferro-Humic Podzol</td>
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<tr>
<td>GLMFHP</td>
<td>Gleyed Mini Ferro-Humic Podzol</td>
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<tr>
<td>SMFHP</td>
<td>Sombric Ferro-Humic Podzol</td>
</tr>
<tr>
<td>OHFP</td>
<td>Orthic Humo-Ferric Podzol</td>
</tr>
<tr>
<td>BIOHFP</td>
<td>Bisequa Orthic Humo-Ferric Podzol</td>
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<tr>
<td>GLOHFP</td>
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<tr>
<td>GLMHFP</td>
<td>Gleyed Mini Humo-Ferric Podzol</td>
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</table>

2. System of Soil Classification for Canada, 1974 (Revised). The soils listed are all soils occurring in both the Templeton River and Grassy Creek watersheds (described by G. Utzig).
OEB Orthic Eutric Brunisol
LOEF Lithic Orthic Eutric Brunisol
ODYB Orthic Dystric Brunisol
LODYB Lithic Orthic Dystric Brunisol
BLDGYB Gleyed Degraded Dystric Brunisol
DGDYB Degraded Dystric Brunisol
ALDYB Alpine Dystric Brunisol
LALDYB Lithic Alpine Dystric Brunisol
OR Orthic Regosol
GLOR Gleyed Orthic Regosol
LFO Lithic Folisol

SOIL DRAINAGE

R Rapid I Imperfect
W Well P Poor
MW Moderately Well VP Very Poor

SOIL TEXTURE

S sand SC sandy clay
LS loamy sand SiC silty clay
SL sandy loam C clay
L loam O organic
SiL silty loam G gravelly
Si silt VG very gravelly
<table>
<thead>
<tr>
<th>Soil Code</th>
<th>Description</th>
<th>Texture</th>
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</thead>
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<tr>
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<td>CO</td>
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<tr>
<td>CL</td>
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<td>B</td>
</tr>
<tr>
<td>SiCL</td>
<td>silty clay loam</td>
<td>R</td>
</tr>
</tbody>
</table>

- cobbly
- bouldery
- rubbly