FOREST SOILS AND THEIR RELATIONSHIP TO FOREST MANAGEMENT IN BRITISH COLUMBIA

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ABSTRACT

FORREST SOILS AND THEIR RELATIONSHIP TO FOREST MANAGEMENT IN BRITISH COLUMBIA

by Michael James Romaine

The purpose of this presentation is to outline a method and provide guidelines by which the forester, with consultation of a trained soils specialist, can readily separate forest land areas into units for future land management. The suggested method and guidelines are based upon: (1) previous classification methods employed in the Province and elsewhere and (2) field data collected and observations made on forest-soil relationships, while the author was involved with the soil capability for Forestry Classification Program being conducted in the interior of the Province during the 1965-1967 field seasons.

A drainage sequence developed from glacial till was selected in the Princeton study area, while a drainage sequence developed from glacial lacustrine deposits was selected in the Quesnel study area. Based upon field observations and stand measurements, a number of forest-soil relationships were found to be influenced predominately by the topographic position of these soils along with their related soil drainage.

The rapidly to well drained soils situated on convex slopes and tops of knolls had a low to medium productivity suitable for the growth of lodgepole pine (Pinus contorta). Existing stands were either poorly or over-stocked. The over-stocked stands had a tendency to stagnate on these soils. The major limiting factors to forest growth were attributed to soil moisture deficiency and restriction of the rooting zone by the proximity to bedrock.

The moderately well to imperfectly drained soils had a high to medium productivity for both lodgepole pine (Pinus contorta), and engelmann spruce (Picea engelmanni) and white spruce (Picea glauca). The topographic positions of the well drained soils were primarily convex or flat lying areas and upper slopes, while the imperfectly drained soils were located predominately on concave lower slopes. The availability of seepage water and nutrients moving down slope from adjacent upland soils, as well as the protection offered from climatic extremes by the topographic position of these soils were considered the major factors favorable to forest growth.

The poorly drained to very poorly drained soils generally had a low to very low forest productivity rating. These soils were found in concave and depressional areas to extensive flat areas with poor surface drainage. Forest growth was predominately limited to either engelmann spruce (Picea engelmanni), or white spruce (Picea glauca). Black spruce (*Picea mariana*) predominated on the very poorly drained soils in the northern portions of the Quesnel study area.

Some guidelines have been discussed as to how the landscape might be delineated into systematic units which can serve as a base for future management interpretations and plans. In applying the guidelines, the following observations as a minimum requirement are suggested in delineating land units: (1) general topographic features, (2) natural soil drainage, (3) parent materials, including observed variations, or closely associated different kinds of parent materials, (4) soil classification at the subgroup level, and (5) physical soil properties, most important of which are effective soil depth, texture, and structure.

It is suggested that the guidelines outlined in this thesis, or comparable methods will be more useful in determining forest productivity and will have broader application (such as on logged and cleared areas) than the conventional site index methods presently employed. In addition, the guidelines will serve as a tool to have practicing foresters take an even greater interest in their soils.

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Michael James Romaine

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CHAPTER I

INTRODUCTION

British Columbia's economy is closely linked to its forest resources. The estimated net value of forest products in 1966 was $1,037 million or approximately 35 per cent of the total net value of all commodity production.[1] Sales of forest products are primarily dependent upon the world market. In 1964, for example, approximately 74 per cent of total forest products produced were sold on the foreign scene.[2] Foreign sales therefore, are a large and important part of the forest industries economic life and it is important that they remain competitive on the world market.

At present, the forest industries are concerned over the cost-price squeeze facing them.[3] Their costs are rising steadily, while the ability of the industry to raise prices

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[1]British Columbia, Bureau of Economics and Statistics, Manual of Resources and Development, British Columbia, Department of Industrial Development, Trade and Commerce, (Victoria B. C.: Queens's Printer, 1967), p. 15.

[2]The British Columbia Forest Industries 1965-66 Yearbook, (Vancouver B. C.: Mitchell Press Limited, 1966), p. J18.

[3]British Columbia, Department of Industrial Development, Trade and Commerce, British Columbia Business Outlook 1968, (Victoria B. C.: Queen's Printer, 1968), p. 5.

is limited by the fact that its products must compete in world markets. A reduction in average log size, decrease in quality of operatable timber being logged, higher wages--while the proportional increase in output per worker has not kept pace with other manufacturing industries, and the move towards more distant and difficult areas in search of merchantible forest stands have been cited as contributing factors to this cost-price squeeze.[1]

As the supply of old growth timber continues to diminish, forest industries will have to move towards more intensive management of readily accessible and closer-to-market lands. At this stage of forest management, it will be necessary to take a closer look at how productivity of the forest resource is interpretated and how it may be maintained or improved.

One of the fundamental factors which will require study and research at this level of management, will be the effect that soils have on the trees growing in it. This will require an inventory of the kinds and extent of forest soils in an area, and their relationships to forest growth and related management plans.

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[1]Royal Commission on Canada's Economic Prospects, The Outlook for the Canadian Forest Industries, John Davis, Chairman of the Forestry Study Group. (Hull, Ont.: Queen's Printer, March, 1968), p. 63 and 67; and Joe des Champs, "Williston tells why Forest Taxes hiked by $5.7 Million," Canadian Forest Industries, LXXXVII (March, 1968), pp. 65-66.

Unfortunately, limited forest soils survey and soils research has been conducted in the forested areas of the Province. What surveys that do exist, have been primarily extensions of agricultural soil surveys. Since they have been for agricultural purposes, their use to forestry has proven to be of limited value. On the Coast for example, most of the soil surveys extending into forested areas are of a very general nature and often the map units contain uninformative terms such as "rough mountainous lands."

Much of the forest research that has been conducted is of limited value, since it has not been conducted on previously soil surveyed lands. As a result, the extent and importance of the research is unknown, and the significance of the results obtained can only be applied with uncertainty to other areas, where soils may be quite different.

This lack of forest soils information and its limited direct use to foresters may account for part of the reason why further studies into forest soils receive such low priority. Studies from widely varied sources has shown a definite relationship between site quality, as measured by tree growth, and soil characteristics. A soils investigation program must be devised in British Columbia which is relatively simple to use, is economically feasible, and from which observations of its applicability are readily apparent.

Purpose and Guiding Hypothesis

The purpose of this study is to outline a method and provide guidelines by which the forester, with consultation of a trained soils specialist, can readily separate forest land areas into units which will serve as a basis for future forest land management.

The guiding hypothesis is: sufficient experimental information exists for the formulation of a first approximation to a method for delineating forest land areas into more appropriate units for determining forest productivity, for planning reforestation programs, and for applying forest fertilization etc., than has been heretofore used in British Columbia.

Methodology

The suggested method and guidelines are based upon: (1) previous classification methods employed in British Columbia by such research investigators as Lacate,[1] and (2) field data collected and observations made on forest-soil relationships, while the author was involved with the soil capability for Forestry Classification Program being conducted in the interior of the Province during the 1965-1967 field seasons. The soil capability for Forestry Classification Program was carried out under the auspices of the

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[1]D. S. Lacate, Forest Land Classification for the University of British Columbia Research Forest, Department of Forestry, Publication No. 1107 (Ottawa, Ont.: Queen's Printer, 1965).

Canada Land Inventory, a joint Federal-Provincial program. Some of the findings are incorporated in this study.

Limitations of the Study

This study is a proposed guide and cannot be considered as a simple solution to a complex problem. It is not proposed or even implied that the forester can find his questions or problems answered on a certain page. Instead, stress has been placed on principles and basic procedures, a knowledge of which will hopefully provide the tools that can be used to study and map specific areas, and upon which sound procedures for forest land management can be developed. The suggested method may be considered as a reconnaissance survey which lacks the refinements of a detailed soil survey. It is suggested that such a method is necessary not only to initiate an interest in soils, but also provides a means to cope with the magnitude of the area to be covered. The guidelines are quite generalized however, and will require possible modifications, delineations, and additions to each area studied.

It is not the intent to leave the reader with the impression that other techniques in classifying land or the study of other effective factors influencing productivity throughout the life of the stand should not be considered in the overall assessment and evaluation of forest land and related management practices. Their discussion however, is beyond the scope of this study.

Justification

The rational management of forest resources should be preceded not only by a knowledge of the nature and extent of the soils which trees grow in, but also by the interrelationships between forest and soils. A reconnaissance survey is a means of delineating soils at a level suitable to forest management and can be the basis for providing additional information as well.

As outlined by Lemmon, evaluation of forest land based on soil survey data can provide in addition to potential soil productivity, information on species priority, regeneration potential, degree of plant competition, trafficability, and erosion, windthrow and disease hazard.[1] Steinbrenner states that once a soil survey has been completed, it should be possible to relate problems such as brush encroachment, insect and disease attacks and wildlife damage in surveyed and mapped soil units.[2] Steinbrenner also mentions that follow-up studies can relate "certain forestry problems to soil types, will provide useful management information such as choice of appropriate techniques for silvicultural practices, forest protection and timber extraction and will

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[1]Paul E. Lemmon, "Soil Interpretations for Woodland Conservation," _First North American Forest Soils Conference_, (East Lansing, Mich.: Michigan State University, Agricultural Experiment Station, September 8-11, 1958), pp. 153-58.

[2]E. C. Steinbrenner, _Ten Years of Forest Soils Research In Retrospect and Prospect_, (Centralia, Wash.: Weyerhaeuser Forestry Research Center, April, 1961).

locate problem areas for concentrated research effort."[1] Such broad use of soil survey information suggests that the cost of an initial survey can be considered as economically feasible when pro-rated over the entire management program.

In discussing the relationship between soils and research, Scott believes it is quite possible for the future silviculturist to control the appearance as well as the productivity of a forest by altering the nutritional status of an area.[2] Scott continues "The exact nature of the cell wall, both chemically and physically, is also influenced by the nutrient status of the soil in which the tree is growing, as is the initiation and development of floral parts. Within a decade it may well be possible to control both seed crops and wood characteristics by manipulating the characteristics of the soil.[3]

The demand for sound information for forest management is certain to increase in the future. It is suggested that the method outlined in this study will not only aid in supplying the answers, but will reduce the pressure for speedy results at a sacrifice of adequate scientific standards.

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[1]Ibid., p. 16.

[2]David R. M. Scott, "Silviculture in the Douglas-Fir Region--In Prospect," Proceedings, Society of American Foresters Meeting: Resources, Foresters, and Policies for Progress, Washington, D. C.: Society of American Foresters, 1967), pp. 93-94.

[3]Ibid., p. 94.

In the future, a follow-up, more detailed soil survey and classification must be used which will further aid and will be more informative to the forest manager.

CHAPTER II

REVIEW OF THE LITERATURE

Investigators have long sought simple, precise, and practical means of classifying and evaluating forest areas in order that the production of a given species in a given area could be determined and used as a basis for management decisions. In British Columbia, as in many other areas, forest growth is usually determined by site index.[1]

For a considerable time, foresters have been inclined to believe that classifications based on site index would serve their purposes, and sets of site index curves developed from data collected for a particular species have been used widely.[2] In addition, site-predicting equations have been derived in certain geographical areas for certain species based upon information which has proven to be statistically significant.

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[1]Site index refers to the average height that the dominant or dominant and co-dominant trees of a given species, in an even-aged stand reach at a specified age.

[2]C. E. Farnsworth and Albert L. Leaf, "An Appraisal of Soil-Site Problems: Sugar Maple-Soil Relations in New York," Forest-Soil Relationships in North America, ed. by Chester T. Youngberg, (Corvallis, Ore.: Oregon State University Press, 1963), p. 283.

Limitations of Accepted Methods

Site index measurements have been appealing methods for determining forest growth, but they have the following limitations.

1. The term site itself is vague, and is too inclusive. Site has been defined by Toumey "as the sum of the effective conditions under which the plant or (plant) community live."[1] Emphasis has been rightly placed upon the effective conditions, namely those factors that in some manner support and influence the vegetation. However, site does not distinguish these effective factors, how significant they are, and how they can be measured accurately.

2. The determination of site requires actual measurements, and as Choate mentions the cost of intensive field work to satisfy most present demands for site data would be prohibitive.[2]

3. The use of dominant and co-dominant trees for determining site index is not always satisfactory. Spurr mentions the following problems:[3]

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[1]James W. Toumey, Foundations of Silviculture Upon An Ecological Basis, (second edition; New York: John Wiley and Sons, 1928), p. 7.

[2]Grover A. Choate, Estimating Douglas-Fir Site Quality From Aerial Photographs, Pacific Northwest Forest and Range Experiment Station, Research Paper 45, (Portland, Ore.: U. S. Department of Agriculture, Forest Service, 1961), p. 1.

[3]Stephen H. Spurr, Forest Ecology, (New York: Ronald Press Company, 1964), p. 128.

a) Dominant and co-dominant tree classes are subjective and two foresters may differ widely in their concept of what constitutes dominant and co-dominant trees.

b) Many of the co-dominant trees will drop out of the main canopy as the stand ages and therefore, perhaps should not be measured.

c) Thinning and other cutting operations may artificially change the average height of the dominant and co-dominant trees without changing the actual site quality.

d) It is often very difficult to see the tops of co-dominant trees in tall and dense timber and it is therefore difficult to measure their heights accurately.

4. Site determination is obviously a problem on logged over lands and as Smith and Ker mention in the Douglas fir region little information is available concerning the original site quality of stands that have been logged and burned or burned.[1]

5. Site index does not have a perfect correlation with productivity.[2] Its use, therefore in determining the growth of a specified area over a certain period of time is limited.

6. The conventional use of site index curves is subject to criticism because:

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[1]J. Harry G. Smith and John W. Ker, "Some Problems and Approaches in Classification of Site in Juvenile Stands of Douglas Fir," Forestry Chronicle, XXXII (December, 1956), 418.

[2]Farnsworth and Leaf, loc. cit.

a) Site index can be determined accurately only from trees growing in reasonably well stocked even-aged stands.[1] The height growth of open grown trees or trees growing under conditions of suppression may reflect the influence of spacing and shade rather than basic site productivity. In addition, the stands should be old enough to reflect the full impact of the site factors. For instance, if the depth of a soil is limited either by physical or physiological reasons, growth of a tree may be normal up to the point that the depth of the soil becomes a limiting factor. On another soil, the same species may grow slowly until the roots reach an underlying enriched horizon or a deep-lying water supply, after which growth will be accelerated.

b) The technique for using site index curves is sound only if the average site quality is the same for each class.[2] If, however, as is often the case, younger stands are found on generally better sites, while the remaining old growth stands are concentrated on the poorer sites, the average curves will be warped upwards at younger ages and downward at older ages.

c) A major weakness of the conventional technique used is the assumption that the shape of the height-growth

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[1]G. R. Trimble Jr., and Sidney Weitzman, "Site Index Studies of Upland Oaks in the Northern Appalachians," Forest Science, II, No. 3 (September, 1956), 162.

[2]Spurr, op. cit., p. 129.

curve is the same for all sites. Although, this generalization gives good results in many instances, it does not hold for all soil conditions.

d) Farnsworth and Leaf mention that methods of curve development which assumes similar forms for all curves within a family or curves for a given species may mask significant effects of site and species characteristics, and introduce inconsistencies that reduce their validity.[1]

7. Site prediction equations are of limited value since they are usually restricted to the geographical areas in which they were derived. In addition, often the complexity of the equations, coupled with the cost of obtaining the individual variables severely restricts their use for practical forest management.

Forest-Soil Relationships

As a result of the above limitations of site index as a measurement of productivity, many foresters have sought more precise methods of evaluating growth potential. Early approaches to this problem were to reduce observations to one or two measurable soil properties which were related to tree growth in a particular area.[2] Unfortunately, as more information becomes available it is apparent that the growth

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[1]Farnsworth and Leaf, loc. cit.

[2]Theodore S. Coile, "Soils and the Growth of Forests," Advances in Agronomy, IV (September, 1952), 330-98.

of a forest stand is controlled by a complexity of interrelated factors, not only of soil but climatic and biologic as well. In an attempt to simplify this complexing and often confusing situation, this review will be limited to the following easily observed soil factors in which previous studies have shown a significant correlation with forest growth.[1]

Topography

For simplicity the approach used by Aandahl in distinguishing different topographic features is followed.[2]

General Setting in the Landscape.--The location of soils upon a basis of relative elevation is a most useful and meaningful criteria in site classification.[3] The topographic position of the site is often closely related to the physical properties of the soil that govern soil moisture relationships. Trimble, Weitzman and Doolittle have found that relative position between ridge top and cove, is one of the factors

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[1]Throughout the review, it will be noted that the term site is still in vogue for want of a better term.

[2]Andrew R. Aandahl, "The Characteristics of Slope Positions and Their Influence on the Total Nitrogen Content of a Few Virgin Soils of Western Iowa," Soil Science Society of America Proceedings 1948, XIII (1949), 449-54.

[3]Spurr, op. cit., p. 111.

closely related to site.[1] One of the greatest values of topography is that it can be quickly recognized and evaluated.[2] Topographic differences can be easily distinguished and delineated on aerial photographs viewed sterioscopically.

Aspect.--Aspect is universally considered as having an important effect on tree growth.[3] In temperate latitudes the cool moist north and west slopes have been found to be more favorable for growth of many coniferous species than the hotter and drier south and east slopes.

Gradient.--The effect of slope gradient and length not only can have an influence on soil depth, but also is of utmost importance in soil moisture relationships.[4] This partly is attributed to the resulting climatic conditions.[5] Slope gradient also influences productivity in another manner. Since the greater the slope, the greater is the surface area per acre or other area measured horizontally. For this reason,

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[1]Trimble and Weitzman, *op. cit.*, p. 167; and Warren T. Doolittle, "Site Index of Scarlet and Black Oak in Relation to Southern Appalachian Soil and Topography," *Forest Science*, III, No. 2 (June, 1957), 123.

[2]Spurr, *loc. cit.*

[3]Choate, *op. cit.*, p. 6.

[4]James D. Curtis, *Silvicultural Limitations of Shallow Soils*, Intermountain Forest and Range Experiment Station, Miscellaneous Publication No. 24, (Ogden, Utah: U. S. Department of Agriculture, Forest Service, 1961).

[5]Choate, *loc. cit.*

good forest sites of moderate slope usually contain more trees and produce greater yields per acre (horizontally as it always is) than do comparable level sites.[1]

Curvature.--Tarrant has shown the effects that curvature of the land has on site quality.[2] In his studies, site index has been found to be significantly greater on the concave terrain characteristics of lower slopes, valleys, and basins than on the convex situations associated with upper slopes, hilltops, and ridges. Upper slopes lose moisture and solu-able salts through drainage and are depleted of fine material and humus by erosion. Also, they are generally more exposed to winds and lose a greater amount of moisture by evapora-tion than do lower slopes. Conversely sites on lower slopes benefit from deposition of fine material, soluble salts and water.

Horizontal or contourwise configuration is important because it affects the duration or frequency of exposure of the site to wind and sun, and also because it influences drainage. Choate states that a site in a depression such as a draw is usually more moist and hence more productive than one on a spur or the end of a ridge.[3] The former is

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[1]Robert F. Tarrant, "Forest Soils of the Pacific Northwest," Proceedings, Society of American Foresters Meet-ing: Converting the Old-Growth Forest, (Washington, D. C.: Society of American Foresters, 1956), pp. 73-76.

[2]Spurr, loc. cit.

[3]Choate, loc. cit.

more sheltered from the drying effects of wind and sun and, furthermore, is frequently the location of a stream or intermittent drainageway.

Physical Soil Properties

In a comprehensive review of the factors that influence tree growth, Gaines concluded that physical soil characteristics are of primary importance.[1] He found that chemical characteristics are also important, but are generally related to the physical characteristics. Of the individual physical characteristics, effective soil depth, soil textures and soil structure and the type of parent materials are listed as the most important factors in influencing forest growth.

Effective Soil Depth.--Lemmon listed effective soil depth as the most important factor in determining the productive capacity of a site.[2] Steinbrenner has found a positive relationship between effective soil depth and site index.[3]

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[1]E. M. Gaines, Soil Factors Related to the Local Determination of Forest Site Quality, A Review of literature, Southern Forest and Range Experiment Station, (Asheville, N. C.: U. S. Department of Agriculture, Forest Service, 1949).

[2]Paul E. Lemmon, "Factors Affecting Productivity of Some Lands in the Willamette Basin of Oregon for Douglas-fir Timber," Journal of Forestry, LIII, No. 5 (May, 1955), 326.

[3]E. C. Steinbrenner, "The Influence of Individual Soil and Physiographic Factors on the Site Index of Douglas-fir in Western Washington," Forest-Soil Relationships in North America, ed. by Chester T. Youngberg, (Corvallis, Ore: Oregon State University Press, 1963), p. 265.

Effective soil depth being defined as that depth of the portion of the soil that is either occupied or capable of being occupied by the roots of the tree for which the site index is desired. Choate states that effective soil depth is closely related to the internal water relationship of the profile which in turn influences plant growth.[1] In converse, the limitations of shallow soils are pointed out by Curtis.[2]

Soil Texture and Structure.--Soil texture affects site quality. It influences the chemical properties of the soil, soil moisture and air relations, and root development.[3] Physically, the texture of the soil regulates the pore space and consequently both the water and the air-holding capacity of the soil. Coarse textured soils have large pore space. As a result, they are easily drained, and are apt to be excessively dry. Carmean mentions that site quality decreases with an increase in the percentage of gravel in the soil profile.[4] The best conditions for absorption and retention of available water for plant growth are those soils having a loam to silt loam texture.[5] The relationship between texture

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[1]Choate, op. cit., p. 8.

[2]Curtis, loc. cit.

[3]Spurr, op. cit., p. 112.

[4]Willard H. Carmean, "Suggested Modifications of the Standard Douglas-fir Site Curves for Certain Soils in Southwestern Washington," Forest Science, II, No. 4 (December, 1956), 242-50.

[5]Spurr, op. cit., p. 113.

and plant available water is shown in Figure 1.

The texture of a soil has a direct influence on soil structure. Structure is most important in soils with a high silt and clay content.[1] The development of a granular structure in such soils permits good percolation of both water and air, reduces erosion, and results in a soil that has many of the desirable physical properties for forest growth. Studies such as that of Steinbrenner has found that soils with a dense impermeable structure and on the other extreme, soils with a porous single grained structure limit forest productivity; the optimum forest growth, being found on soils whose porosity lie within these two extremes.[2]

Soil Parent Material.--The properties of soils are functionally related to the soil forming factors.[3] One of these factors is parent material. The texture, structure, or fabric and mineralogical and/or chemical composition of the parent materials predetermine or at least strongly influence the properties of soils formed from them.[4] The kind of

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[1]Ibid., p. 114.

[2]Steinbrenner, op. cit., p. 268.

[3]Hans Jenny, Factors of Soil Formation, A System of Quantitative Pedology, (New York: McGraw-Hill Book Company, 1941).

[4]E. P. Whiteside, "Some Relationships between the Classification of Rocks by Geologists and the Classification of Soils by Soil Scientists," Soil Science Society of America Proceedings, XVII (1953), 138-42.

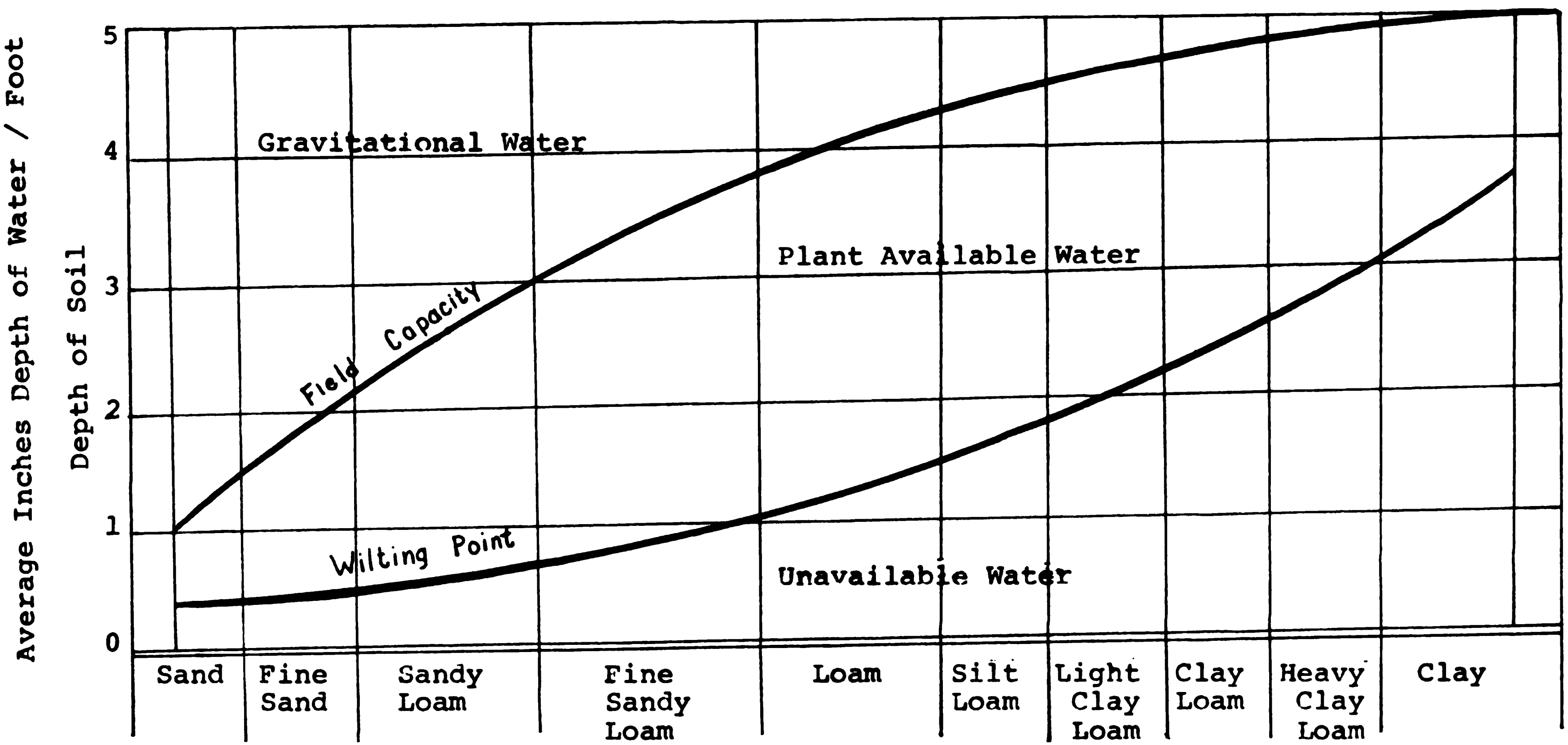

Figure 1. Typical Relationship between Soil Texture and Plant Available Water*

*Source: U.S. Department of Agriculture, Handbook on Soils, Forest Service, ([n.p.,] 1961, plus 1963 and 1966 Amendments), p. 148.

deposit often imparts a definite shape or form and other characteristics such as drainage pattern to the landscape. A landscape in which coarse outwash deposits are the major parent material may be expected to impart different properties to the soils and will respond to management differently than a landscape developed from a fine textured glacial till.

Soil Drainage.--Soil drainage reflects the natural water table and to some extent available soil moisture for plant growth in a soil. Unfortunately, the measurement of available soil moisture is still a difficult and laborious task. However, available soil moisture can be interpreted indirectly through soil texture. Auten, Coile and Young have shown the thickness of the solum is a good guide to forest growth in areas where soil moisture is a dominant growth factor.[1] In his discussion on soil drainage, Lacate mentions the "soil drainage can be assessed on the basis of differences in soil color, depth to mottling or gleying, depth to impermeable material, topographic location, size of watershed, length of slope, depth to existing water table, and the

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[1]John T. Auten, "Some Soil Factors Associated with Site Quality for Planted Black Locust and Black Walnut," Journal of Forestry, LXII, No. 8 (August, 1945), 592-98; Theodore S. Coile, Relation of Soil Characteristics to Site Index of Loblolly and Short Leaf Pines in the Lower Piedmont Region of North Carolina, Duke University Forestry School Publication No. 13 (Durham, N. C.: Seeman Printery, 1948); and Harold E. Young, "Forest Soils-Site Index Studies in Maine," Soil Science Society of America Proceedings, XVIII (January, 1954), 85-87.

texture, structure and permeability of the solum."[1]

Forest Land Classification

In the field the above soil factors and their contributing influences are all interrelated. To be of use then, these factors must be recognized, combined, or separated in some manner which will allow grouping into identifiable and reoccurring land units.

Such a method has been employed by Lacate in British Columbia.[2] Lacate's method (using aerial photographs and field checks) delineates land into divisions or units that are relatively homogeneous with respect to the more stable features of landform, surficial geology, soil and vegetation. Lacate states such a division of landforms into land units "provides a framework to which forestry information and estimates of potential for forestry purposes can be related and subsequently extended over adjacent landscapes using airphotos and airphoto interpretations."[3] Reports by Lacate and others contain interpretations and groupings of soils on the basis of mapping units applicable to forest

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[1] D. S. Lacate, Forest Land Classification for the University of British Columbia Research Forest, Department of Forestry, Publication No. 1107 (Ottawa, Ont.: Queen's Printer, 1965).

[2] Ibid.

[3] Ibid., p. 5.

management.[1] A review of other approaches used to classify land, soils, and forest sites have been prepared by Rowe and Lacate.[2]

The recent study by Keser is highly significant and will warrant close consideration in future forest management considerations once it becomes operational. The objective of his study is to "develop a system providing a basis for predicting the characteristics of a stand at a given time for a desired set of conditions that can be imposed upon the soil or stand at a specific time or stage of the development."[3]

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[1] Ibid.; and D. S. Lacate, et al., "Forest Land Classification and Interpretations for Management in the Spruce Working Circle, Tree Farm License No. 9, Okanagan Valley, B. C.," B. C. Department of Agriculture, Co-operative Interim Report, (Kelowna, B. C.: July, 1965); and P. N. Sprout, D. S. Lacate, and J. W. C. Arlidge, Forest Land Classification Survey and Interpretations for Management of a Portion of the Niskonlith Provincial Forest, Kamloops District, B. C., Department of Forestry Publication No. 1159 (Ottawa, Ont.: Queen's Printer, 1966).

[2] J. Stanley Rowe, "Soil, Site and Land Classification," Forestry Chronicle XXXVIII, No. 4 (December, 1962), 420-32; and D. S. Lacate, "Wildland Inventory and Mapping," Forestry Chronicle XLII, No. 2 (June, 1966), 184-94.

[3] British Columbia, Forest Service, The Forest Research Review, (Victoria B. C.: Queen's Printer, 1967), p. 13.

CHAPTER III

DESCRIPTION OF AREAS AND METHODS EMPLOYED

The Study Areas

Location and History

The two studied areas lie within the central and southwestern regions of the interior of the Province. The boundaries of the study areas are outlined in Figure 2. The study area in the central region of British Columbia will be called the Quesnel area, while the study area in the southwestern portion of the Privince will be called the Princeton area.[1] The Quesnel area was chosen in order to gather soils information which will aid in finding a solution to the developing agricultural forestry fringe conflicts. The Princeton area was selected because the area has a wide diversity in landform and soil features which provided an ideal opportunity to test the mapping procedures used.

During glacial times, British Columbia, except for the higher elevations was completely covered by ice. Both the Quesnel and Princeton areas were covered by the Cordilleran

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[1]Designated names, Quesnel and Princeton refer to major settlements within the study areas.

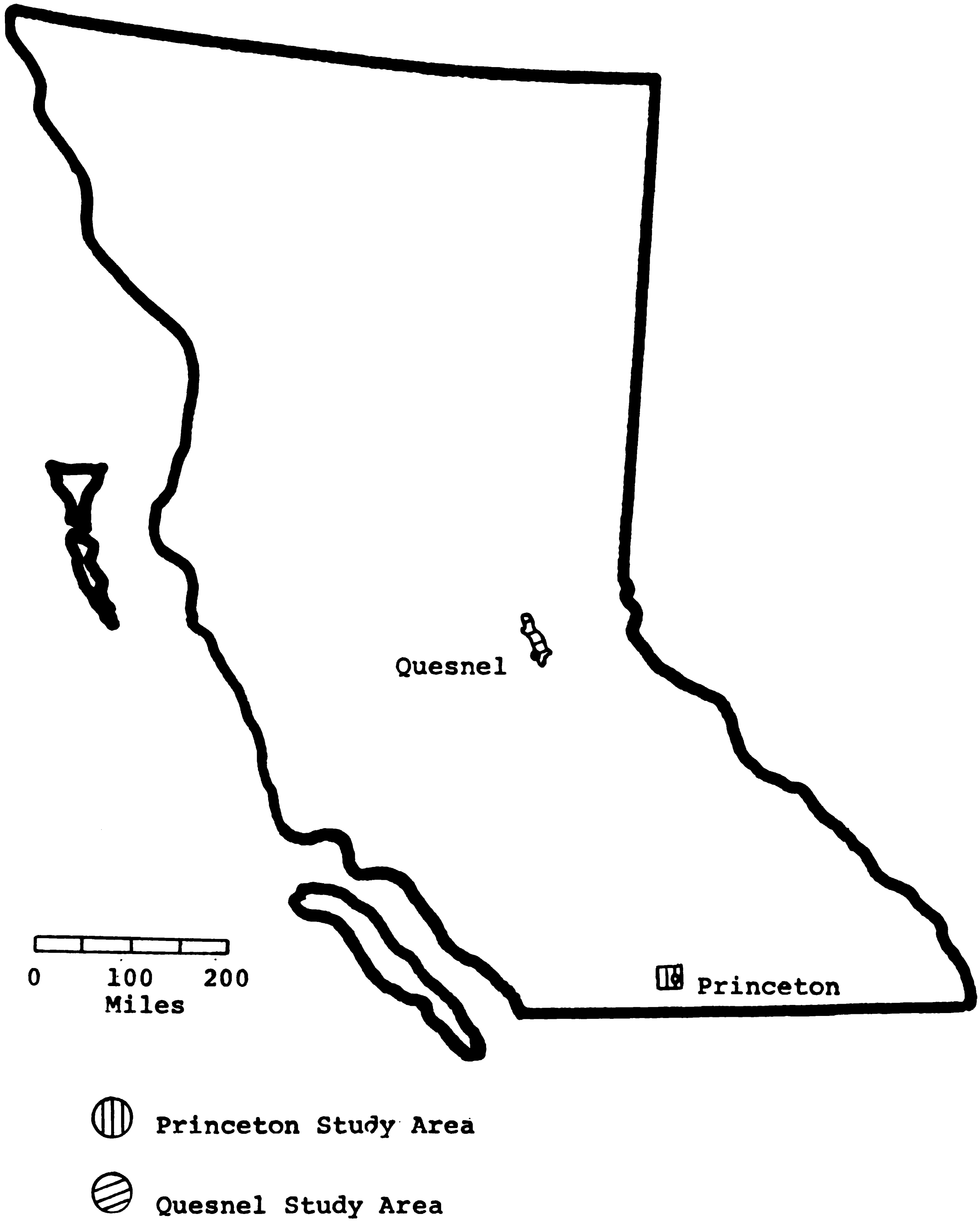

Figure 2. Location of the Princeton and Quesnel Study Areas in British Columbia

ice sheet.[1] As a result, much of these areas are covered by glacial till, varying in thickness and composition. During the glacial period, glacial lakes also formed, and the old glacial lake beds, with their deposits of silt and clay can be observed over a considerable part of the Quesnel area. Glacial lake deposits in the Princeton area, by comparison are minor, and occur in the northerly portion of the study area.

Coarse sediments carried by glacial meltwaters have been deposited in the form of sands and gravels in both of these areas. In the Princeton study area, the most notable gravel and sand deposits is in the form of a large glacial delta, which lies just to the west of the village of Princeton. In the Quesnel area, glacio-fluvial deposits, consisting primarily of terraces and beach ridges are associated with the upper elevational limits of the glacial lacustrine deposits.

Population Centers and Industries

In the Princeton area, the village of Princeton with a 1966 population of 2,151 persons is the largest population

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[1] J. D. Chapman et al., editors, British Columbia Atlas of Resources, British Columbia Natural Resources Conference, (Vancouver B. C.: Smith Lithograph Company, 1956), pp. 9-10.

center in the study area.[1] The village was an important mining center during the early decades of the present century, but with the closing of the main mine at Copper Mountain, the village has continuously declined in population and importance. Numerous other small communities in the area have suffered the same fate. Forestry and agriculture are the main remaining industries. There are two main sawmills in the area, while ranching is the primary agricultural activity. The area is hoping for renewal mining activity to improve its economy, but its greatest potential may well be in the field of recreation. The area has several small lakes and is well-known as a paradise for "rock hounds." It's proximity to the Hozameen and Okanagan mountain ranges offers potential attraction for hunters, hikers and sight-seers.

In the Quesnel area, the town of Quesnel, with a 1966 population of 5,725 persons, is the largest population center of the study area and is an important trade, transportation, administrative, and service center for the surrounding area.[2] Numerous small communities are found north and south of Quesnel strung along the Cariboo highway.

The economy of the area is closely linked with forestry, especially sawmilling, planing, and plywood manufacture.

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[1]British Columbia, Bureau of Economics and Statistics, Facts and Statistics, Department of Industrial Development, Trade and Commerce, (Victoria B. C.: Queen's Printer, 1967), p. 62.

[2]*Ibid*., p. 61.

With the near completion of a pulp mill in the area, it can be expected that there will be more stability and expansion of the forest-based industries. Agriculture is second in economic importance. Virtually all of the cultivated land is in the immediate vicinity of Quesnel at lower elevations of the Fraser Plateau. Agriculture is limited to hardy field crops, dairying and ranching. Surplus products, both wood and agriculture, are shipped from the area by rail and truck.

Climate

The study areas can be placed in two broad climatic regions.[1] These regions are very broad and do not reflect local topographic and latitudinal influences or differences. Within each of these regions, important climatic elements have essentially similar values although the great variety of topography and range of elevations may produce unexpected extremes in individual localities.

Princeton area.--This area lies in the southwest interior climatic region. Climatic values refer to the plateau area only, since this was the area in which the soils were studied.[2] Here, annual precipitation everywhere exceeds 12 inches and reaches 25-30 inches towards the western limits

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[1]*Ibid*., pp. 21-22.

[2]A fuller discussion on the physiography of the areas is given in the following section entitled Physiography and Topography.

of the region. This region includes the driest and hottest parts of the Province.

Quesnel area.--The study area lies in the transition zone between the southwest interior region to the south and the central interior region to the north. The generalized climatic regions are outlined in Figure 3. The change to the central interior region is quite distinguishable through vegetational changes north of the Cottonwood river. The central interior region is characterized by having generally humid conditions (the result of reduced temperatures and somewhat increased precipitation in comparison with the southwest interior). Here, winters are cold and the summers are cool and short. Four to five months have mean temperatures below $32^{o}F$.

Tables I and II summarize temperature and precipitation data for these two regions.

Physiography and Topography

Both study areas possess a great diversity of landforms and topography. In the discussion that follows only the major physiographic subdivisions as outlined by Holland are described.[1]

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[1]Stuart S. Holland, Landforms of British Columbia, A Physiographic Outline, British Columbia Department of Mines and Petroleum Resources, Bulletin No. 48 (Victoria B. C.: Queen's Printer, 1964), p. 44.

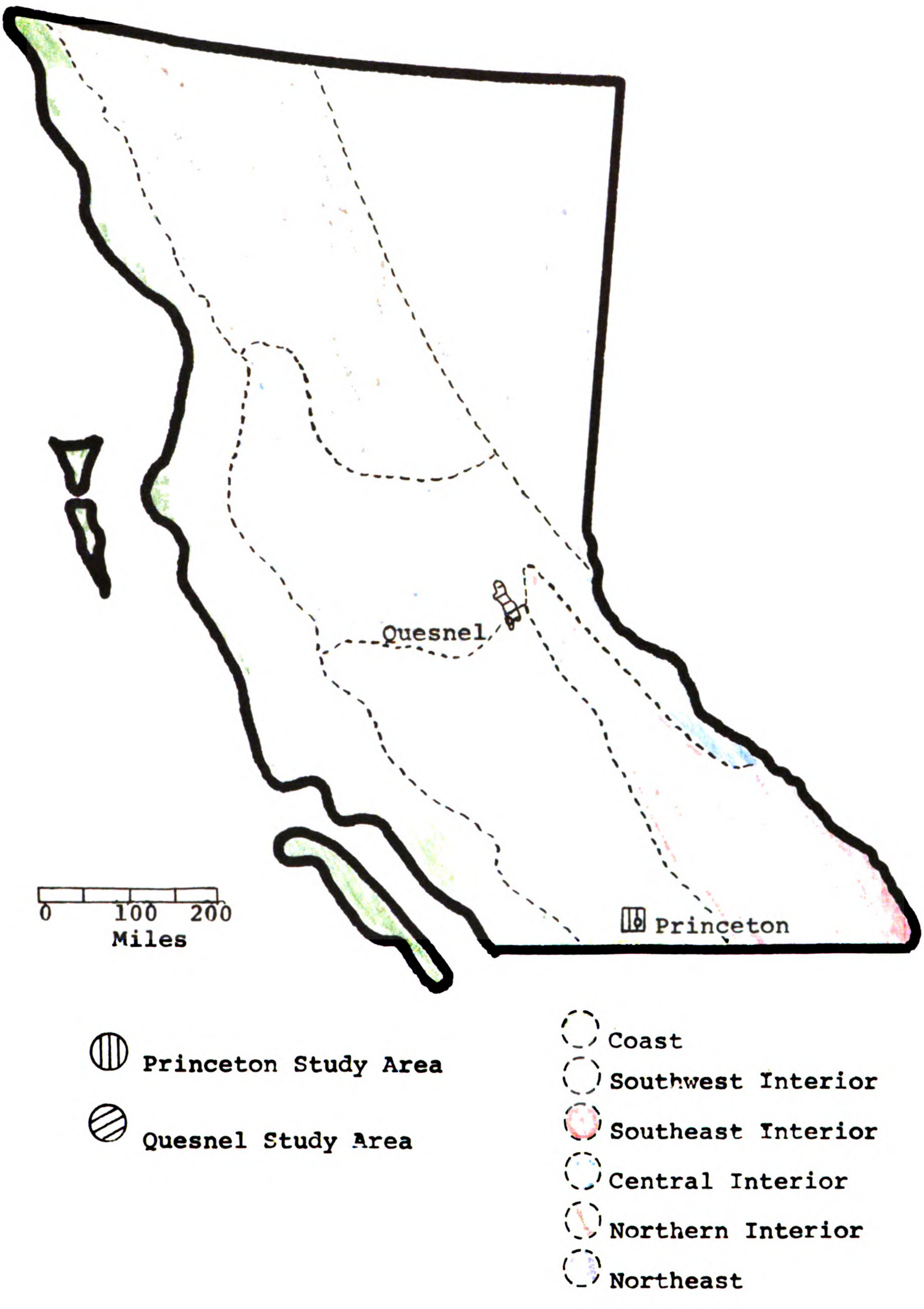

Figure 3. Generalized Climatic Regions in British Columbia

Table I. Generalized Temperature Data for Princeton and Quesnel Study Areas. The S. W. Interior Plateau and the Central Interior Climatic Regions.*

Region	Mean Monthly		Number of Months		Annual range	Average Number of Days frost free
	Jan.	July	> 50°F	< 32°F		
S. W. Interior Plateau	10-20	55-60	3-4	4-5	40-50	50-120
Central Interior	10-15	55-60	304	405	40-50	50-100

Table II. Generalized Precipitation Data for Princeton and Quesnel Study Areas. The S. W. Interior Plateau and the Central Interior Climatic Regions.*

Region	Mean Annual	Season of		Percent of total precipitation which falls as snow
		Maximum	Minimum	
S. W. Interior	15-25"	Winter (south) Spring (north)	Spring (south) Spring (north)	30-50
Central Interior	15-20"	Summer	Spring	25-30

*Source: J. D. Chapman et al., editors, British Columbia Atlas of Resources, British Columbia Natural Resources Conference, (Vancouver B. C.: Smith Lithograph Company, 1956), p. 21.

Princeton area.--This area lies in the southern portion of the Thompson Plateau, and includes the eastern portion of the Hozameen Range and the northern portion of the Okanagan Range.[1] There is a complete transition between the plateau area and the adjoining mountain ranges because the rise of the plateau surface towards the mountains is gradual with progressively higher summit levels and greater dissection of the plateau surface. The Thompson Plateau is a gently rolling upland of low relief, with prominences of more restricted rock rising above it to 6,768 feet at Lookout Mountain, and 5,702 feet at Wilbert Hills. Glaciation has produced many drumlins and drumlin-like forms oriented southeastly and southerly. Between drumlins, in old meltwater channels, and along the river and creek valleys, stratified sands, and gravel have been deposited.

Quesnel area.--The Quesnel area contains portions of both the Fraser Basin and the Fraser Plateau.[2] The Fraser Basin is an irregularly shaped area of low relief surrounding the main river valleys. Its surface lies for the most part below 3,000 feet and is covered with lacustrine clays and silts and glacial-fluvio and alluvial deposits.

The Fraser Plateau is generally a flat to gently rolling country, with prominences of more resistant rock.

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[1] Ibid., p. 44.

[2] Ibid., p. 67 and pp. 69-71.

The glacial till and glacial-fluvio outwash deposits, which cover the plateau surface, are evident by the occurrence of drumlins, and drumlin-like forms and by meltwater channels and stream deposits.

Forest Vegetation

In the discussion on forest vegetation, the forest regions as described by Rowe have been elaborated on.[1]

Princeton area.--The plateau area is classified as the Ponderosa Pine and Douglas Fir Section (M.I.) of the Montane Forest Region.[2] The area of concern in this study (the higher elevations of the plateau) is covered with a mixture of Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*), the latter forming a relatively permanent type over large areas because of the frequency of fires. Engelmann spruce (*Picea engelmanni*) mixes with Douglas fir and lodgepole pine on cool, north-facing slopes.[3]

Quesnel area.--The study area contains part of two Forest Regions. The Central Douglas Fir Section (M.2) in the south, and the Northern Aspen Section (M.3) in the north.[4]

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[1]J. Stanley Rowe, *Forest Regions of Canada*, Canada Department of Northern Affairs and National Resources, Forestry Branch, Bulletin No. 123 (Ottawa, Ont.: Queens's Printer,1959).

[2]*Ibid.*, pp. 37-38.

[3]Canada, Department of Forestry, *Native Trees of Canada*, Bulletin No. 61 (Sixth edition; Ottawa, Ont.: Queen's Printer, 1961).

[4]Rowe, *op. cit.*, p. 38.

Douglas fir is common in the southern portion of the study area but thins out northward. Only scattered stands occur north of the Cottonwood river. Lodgepole pine occurs on most of the soils encountered. Exceptions are the very poorly drained soils. Black spruce (Picea mariana) occur to a limited extent (in depressional areas) on very poorly drained soils. Engelmann spruce and white spruce (Picea glauca) are common throughout the north and eastern parts of the area, with the best stands occurring in the Fraser Plateau, east of the Fraser and Quesnel rivers.

Soils

Soil surveys have been conducted in both study areas. The kinds and extent of soils occurring in the Princeton study area are described in detail in soil survey reports by Green and Lord.[1] Similar information for the Quesnel study area can be found in the soil survey reports by Farstad and Laird; and by Mackintosh, Sneddon, and Farstad.[2]

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[1]Alix J. Green and Terry M. Lord, "Soil Survey of the Princeton Map Area, British Columbia," Canada Department of Agriculture, Research Station, Vancouver B. C. (In preparation); and Terry M. Lord and Alix J. Green, "Soil Survey of the Tulameen Map Area, British Columbia," Canada Department of Agriculture, Research Station, Vancouver B. C. (In preparation).

[2]L. Farstad and D. G. Laird, Soil Survey of the Quesnel, Nechako, Francois Lake and Bulkley-Terrace Areas in the Central Interior of British Columbia, Report No. 4, of the British Columbia Soil Survey, (Victoria B. C.: Queen's Printer, 1954); and E. E. Mackintosh, J. I. Sneddon, and L. Farstad, "Soil Survey of the Quesnel Area in British Columbia," Canada Department of Agriculture, Soil Survey Report No. 10, of the British Columbia Soil Survey (In preparation).

Generalized profile descriptions of the soils studied can be found in Appendix I.

The basic unit in the soil classification system used in these surveys is the soil series. A soil series consists of soils that are developed on similar parent material and under similar environmental conditions, particularly drainage and vegetation. Any significant variation in one or more of the soil forming factors results in dissimilarities of profile features and the soil is classified as a different series. In some cases, individual soil series occupied large continuous areas but more commonly, they occur as soil associations. Continuously eroding lacustrine deposits adjacent to streams, are delineated as eroded land types and rock land areas represent rock land types.

While series was the basic unit used in the field classification of soils, other categories were used to group soils into broader classes. In the classification system adopted by the National Soil Survey Committee, there are six levels at which soils may be separated or grouped together.[1] These are: order, great groups, subgroup, family, series and type. In the three upper categories of order, great groups and subgroups divisions are based on major differences

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[1]National Soil Survey of Canada, Report on the Sixth Meeting of the National Soil Survey Committee of Canada, (Laval University, Que.: [n.p.], October, 1965).

in morphological features exhibited in the soil profile. In the lower three categories of family, series and type, divisions within any one subgroup are based on soil variations resulting from differences in composition, texture of the parent materials, drainage, and difference in thickness and degree of development of soil horizons.

In the mapping of soils, the soil association was commonly used, particularly in upland areas, where soil capabilities for agriculture were rated as low, and where further refinements for forestry purposes did not warrant the expenditure of additional time and effort which would otherwise be required to separate these mapping units at the series level. The drainage association is a group of soils, consisting of different series, developed under various drainage conditions on similar parent material. Each soil series in the drainage sequence occupies a different position in the landscape and differs in profile characteristics due to the local influence of drainage and vegetation.

Methods Employed

Determination of Soil Capability for Forestry

The first step was examination of the areas using aerial photographs and a stereoscope in an attempt to pick out suitable forest stands for measurement. Stands were selected and marked on the airphotos on the basis of their apparent uniform age and composition growing on uniform materials and in a specific topographic position. An attempt was also made to get a sequence of plots growing either on different materials or in a different topographic location within specified areas.

The second step was the location and examination of the plot in the field. In general, the stands selected for measurement were even-aged, close to rotation age (80-100 years), thrifty, fully stocked and were predominantly of one species. One-fifth acre plots within the stands were marked for measurement if the plot could be located in a uniform area and if the trees were growing in a soil, representative of the major soil series identified during the soil survey. Observed features of soil profile, soil depth, soil drainage, and landform were recorded.

Plot measurement was the third step. One-fifth acre square or rectangular plots were laid out, the shape selected being dependent upon the uniformity of the area and the stand conditions. For example, a rectangular 2 chain by 1 chain plot was frequently used on rapidly drained ridges which were less than 2 chains wide but were more than 2 chains long. Square plots were employed wherever uniformity of soils and stands were greater than 2 square chains. On each plot, all trees were tallied in one-inch diameter classes. Five sample trees of the calculated average plot diameter were measured for height and age. Volume of the plot, on the basis of these sample trees and, using the British Columbia Forest Service standard cubic-foot volume tables was determined.[1] Mean Annual Increment (M.A.I.) was then derived by dividing the total volume of the plot converted to a per acre basis by the average stand age. The M.A.I. was then adjusted by the use of site index curves to a rotation age of 100.[2] M.A.I.'s were then grouped into the 7 class forest capability system outlined by McCormack.[3]

Selection of Soils

In this study, two soil catenas have been selected, one from each area to show the general forest-soil relationships found. A catena being defined as a sequence of contrasting soil series developed from similar parent materials, but differing in slope and drainage.

In the Princeton study area, a catena containing four soil series developed on a sandy loam till has been chosen. This catena occurred over extensive areas and in a number of locations. However, the data included in this study refers to the plateau area only, in an attempt to keep the climate and forest vegetation variables as constant as possible.

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[1]British Columbia, Forest Service, Standard Cubic-Foot Volume Tables: Interior Species, Forest Surveys and Inventory Division, Vol. II (Victoria B. C.: Queen's Printer, 1962).

[2]Forest capability classes and their limitations to forest growth are shown in Appendix II.

[3]R. J. McCormack, Land Capability for Forestry: Outline and Guidelines for Mapping, Prepared for Canada Land Inventory of ARDA, Rural Development Branch, (Ottawa, Ont.: Queen's Printer, 1967), pp. 4-6.

A soil catena on fine-textured glacial lacustrine deposits was chosen in the Quesnel area. Observations are limited to the three main soil series found to reoccur on these lacustrine deposits, under similar climate and forest vegetation conditions.

The two different catenas were chosen to see what apparent forest-soil relationships did exist and to observe if any factors appeared to have an overriding influence upon forest productivity. In both cases, the same species were selected and measured on each soil series present. Observations as to soil development, soil drainage and topographic position was observed and recorded.

Forestry Interpretations

Wherever possible, a single forest capability rating was applied to each soil series. However, two or more classes were assigned to some soils whose productivity ranged over more than one capability class because of minor variations in soil properties.

Observed limiting factors were assigned to each soil to indicate the nature of the limitations to forest growth. Major limitations on the studied soils were soil moisture deficiency or excess and soil permeability or effective depth of rooting zone.

Tree species were rated in three categories--suitable, not suitable, and limited suitability for each soil series according to the characreristics of each soil, the silvics of each tree species, and their observed occurrence and growth. Only those tree species of present commercial value occurring or expected to occur on each soil series were considered.

CHAPTER IV

OBSERVATIONS, INTERPRETATIONS AND CONCLUSIONS

Observations

In both catenas studied, the imperfectly drained soil members were found to be the best suited for the growth of lodgepole pine and white and engelmann spruce.[1] Trees growing on these soils are able to utilize seepage water and nutrients moving down slope from adjacent upland soils. Because of their topographic position, these soils are not subject to extremes in temperature or evapotranspiration. The limitations to forest growth are not easily identified on the medium textured till, while rooting depth restrictions due to the soil structure appear to be the limitation on the fine textured lacustrine deposits. The topographic positions of the imperfectly drained soils studied were similar. They occurred on the lower sections of long straight slopes and on shorter slopes with a concave curvature (Figure 4). The drainage sequence of the soils studied in the Princeton and the Quesnel study areas are shown diagrammetrically in Figures 5 and 6.

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[1]Soil drainage classes are defined in Appendix III.

Figure 4. The imperfectly drained Pefferle soil series on the lower section of a long straight slope.

The moderately well drained and well drained catena members, generally had a lower forest capability than the imperfectly drained soil series. This is due to a moisture deficiency that exists in these soils. On the glacial lacustrine deposits, soil structure also restricted rooting depth. In regards to growth and establishment, lodgepole pine appeared to be best suited to these soils. Upper and middle slopes with a straight to slightly convex topographic position were the predominant places where these soils were found. However, moderately well to well drained soils also occurred near the tops of knolls where their limited areal

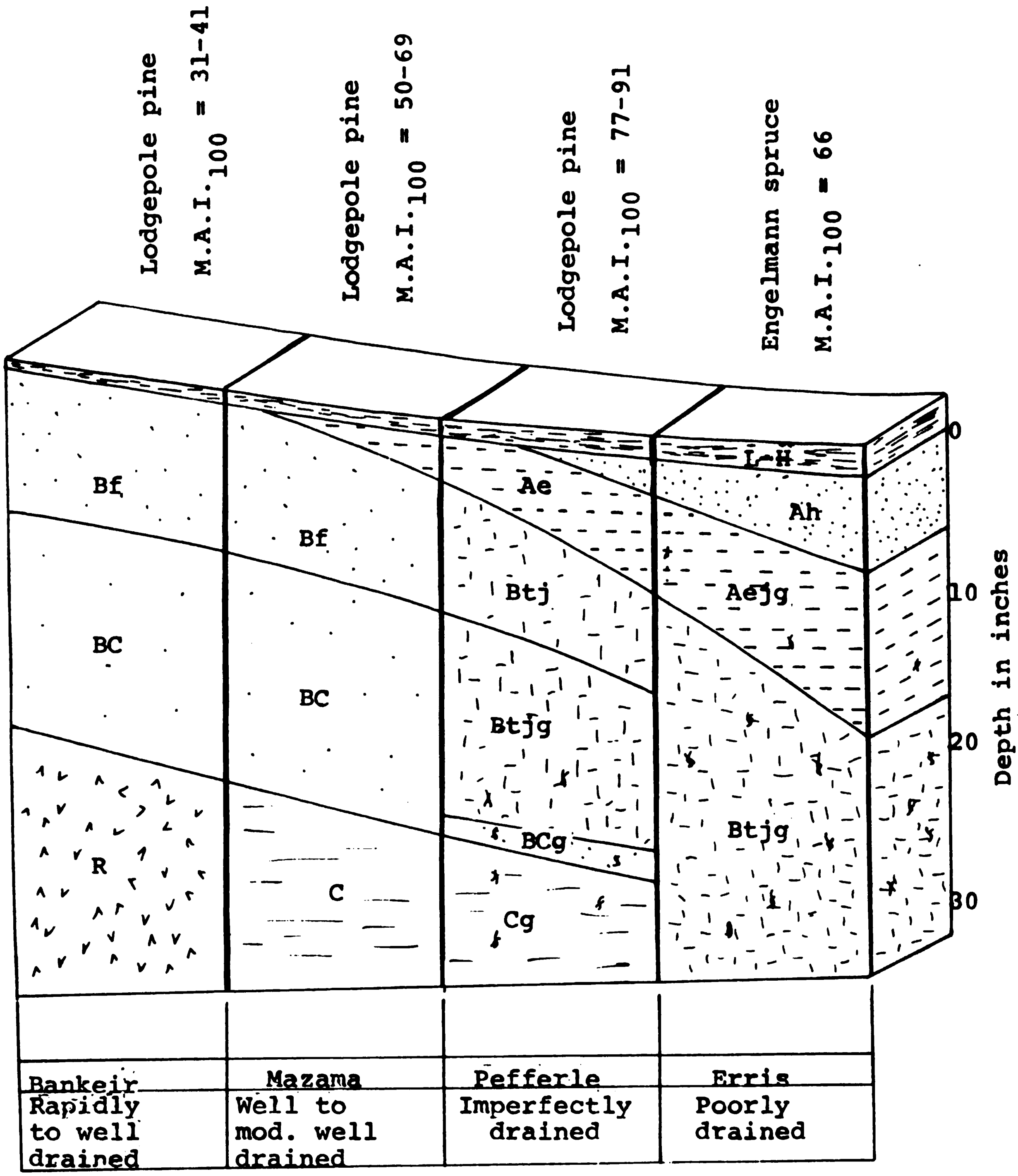

Figure 5. Drainage Sequence of Soil Series in the Princeton Study Area

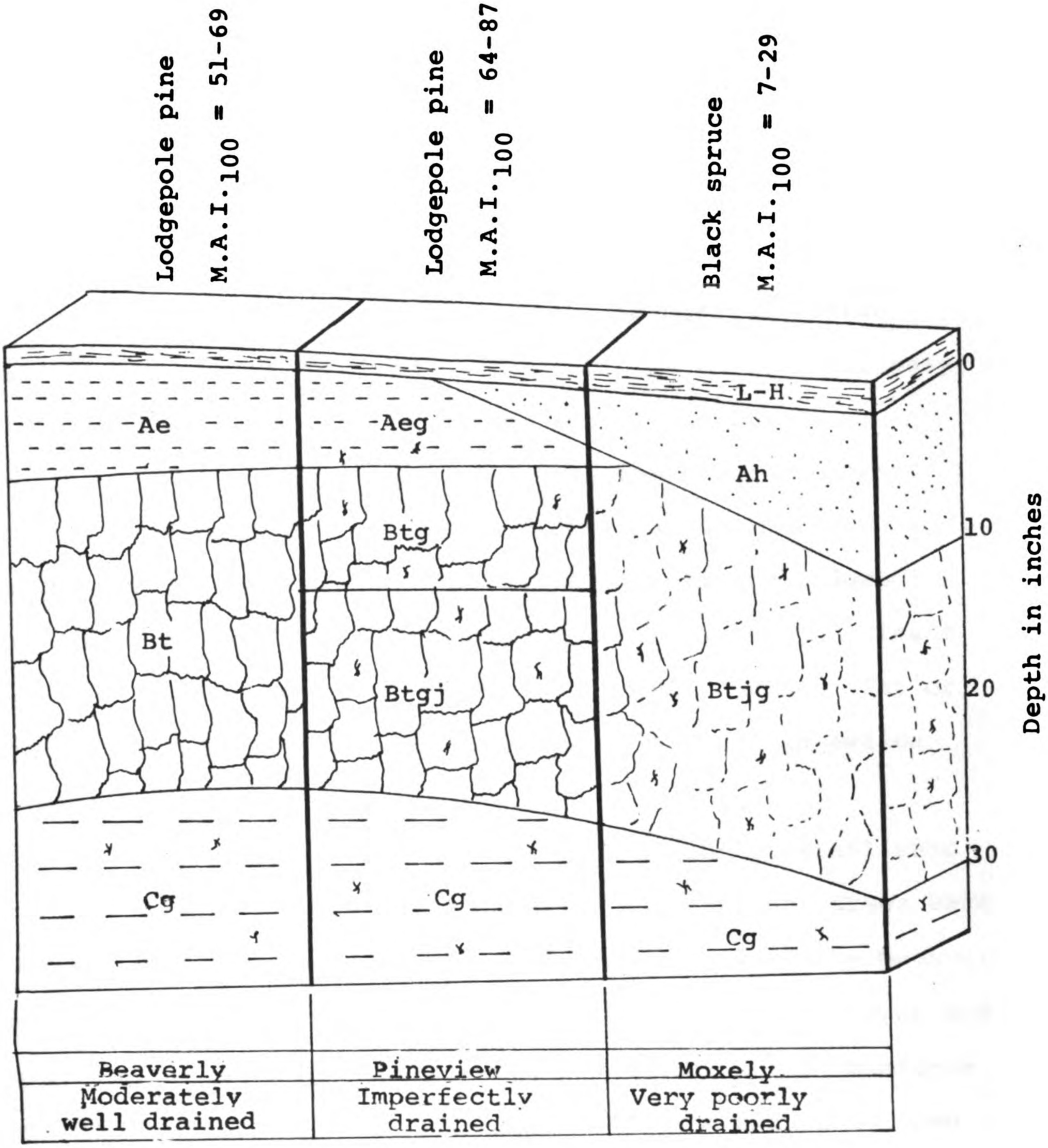

Figure 6. Drainage Sequence of Soil Series in the Quesnel Study Area

extent was too small to allow seepage water to collect in the rooting zone (Figure 7). In the Princeton area, the rapidly to well drained soil series was closely associated with exposed bedrock (Figure 8).

At best, these soils have a capability rating of class 5 for lodgepole pine. Few stands of established Douglas fir were found. Their convex or upper slope position often associated with ridges and rock outcrop made for their easy identification, both on airphotos and in the field.

On the poorly drained soils in the Princeton area, excess soil moisture was the only observable limitation to forest growth and species suitability. Solitary lodgepole pine occurred occasionally within the otherwise predominant engelmann spruce stands. This soil series occupied flat or concave low-lying areas and was commonly found in swales associated with stream channels.

Extensive flat-lying areas with a poorly established surface drainage pattern and enclosed depressional areas were typical of the very poorly drained soil series in the Quesnel area. The high water table severely limits forest growth and species suitability. Forest vegetation varied from mixtures of black spruce, engelmann spruce, and white spruce to open areas.[1]

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[1]In the Quesnel area, no distinction has been made between engelmann and white spruce and their intergrades.

Figure 7. The well drained Mazama soil series occurring near the top of a knoll.

Figure 8. Rapidly drained Bankeir soil series closely associated with exposed bedrock.

The relationship between the two studied soil catenas and some forestry observations are summarized in Tables III and IV.

Interpretations

Comparable land classification methods and studies have been described by Christian and Lacate.[1] Both systems divide the land surface into land units, on the basis of the major observable features, topography, surfacial geological deposits, drainage patterns and vegetation. Land units as defined by Lacate "are the relatively small, homogeneous segments of the land surface which have a characteristic topographic form and internal geologic structure and with which are associated distinctive types of soils and vegetation."[2]

Reports by Lacate and others indicate a significant relationship between forest capability and the delineated land units.[3]

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[1]C. S. Christian, "The Concept of Land Units and Land Systems," Proceedings of the Ninth Pacific Science Congress, Vol. XX (Bangkok, Thailand: Organizing Committee, 1957), pp. 74-81; and D. S. Lacate, Forest Land Classification for the University of British Columbia Research Forest, Department of Forestry, Publication No. 1107 (Ottawa, Ont.: Queen's Printer, 1965).

[2]Ibid., p. 8.

[3]Ibid.; and D. S. Lacate et al., "Forest Land Classification and Interpretations for Management in the Spruce Working Circle, Tree Farm License No. 9, Okanagan Valley, B. C.," B. C. Department of Agriculture, Co-operative Interim Report, (Kelowna, B. C.: July, 1965); and P. N. Sprout, D. S. Lacate, and J. W. C. Arlidge, Forest Land Classification Survey and Interpretations for Management of a Portion of the Niskonlith Provincial Forest, Kamloops District, B. C., Department of Forestry Publication No. 1159 (Ottawa, Ont.: Queen's Printer, 1966).

Table III. Relationship Between a Soil Catena in the Princeton Study Area and Some Forestry Observations

	Soil Series	Classification	Topography	Drainage	Species Sampled	Suitability[1] lP	eS	D	Capability* Class	Limiting Factors[2]
Medium textured glacial till	Bankeir	Orthic Acid Brown Wooded	Convex-ridge & Spurr position	Rapidly to well drained	Lodgepole pine	S-LS	NS	LS	5-7	M,R
	Mazama	Degraded Acid Brown Wooded	Upper & middle slopes straight to convex	Well to mod. well drained	Lodgepole pine	S	LS	LS	4	M
	Pefferle	Gleyed Cutanic Podzo Regosol	Concave & lower slopes	Imperfectly drained	Lodgepole pine	S	S	LS	3	S
	Erris	Orthic Gleysol	Concave to low lying areas	Poorly drained	Engelmann spruce	LS	S	NS	4	W

[1]Suitability and Indicated Tree Species+
S-Suitable — lP-Lodgepole pine
LS-Limited Suitability — eS-Engelmann spruce
NS-Not Suitable — D-Douglas fir

[2]Limiting Factors
M-Moisture deficiency
W-Excess moisture
R-Restriction of rooting zone by bedrock
S-Minor accumulations of adverse factors

+Tree name abbreviations are those used in R. J. McCormack, Land Capability for Forestry: Outline and Guidelines for Mapping, Prepared for Canada Land Inventory of ARDA Rural Development Branch, (Ottawa, Ont.: Queen's Printer, 1967), pp. 78, 80-81.

*Supporting plot data for determining capability class are contained in Appendix IV.

Table IV. Relationship Between a Soil Catena in the Quesnel Study Area and Some Forestry Observations

Fine text. lacustrine

Soil Series	Classification	Topography	Drainage	Species Sampled	Suitability[1] 1P	S	D	Capability* Class	Limiting Factors[2]
Beaverly	Orthic Gray Wooded	Convex to flat knolls	Moderately well drained	Lodgepole pine	S	LS	LS	4	D,M
Pineview	Gleyed Gray Wooded	Concave to lower slopes	Imperfectly drained	Lodgepole pine	S	S	NS	3,4	D
Moxely	Orthic Humic Gleysol	Flat to enclosed depressions	Very poorly drained	Black spruce	NS	LS	NS	6-7	W

[1]Suitability and Indicated Tree Species+
S-Suitable
LS-Limited Suitability
NS-Not Suitable

1P-Lodgepole pine
S-Engelmann spruce
-White spruce
D-Douglas fir

[2]Limiting Factors
M-Moisture deficiency
W-Excess moisture
D-Limited rooting depth and permeability

+Tree name abbreviations are those used in R. J. McCormack, <u>Land Capability for Forestry: Outline and Guidelines for Mapping</u>, Prepared for Canada Land Inventory of ARDA Rural Development Branch, (Ottawa, Ont.: Queen's Printer, 1967), pp. 78, 80-81.

*Supporting plot data for determining capability class are contained in Appendix IV.

Using land units as a basis of delineation, and expanding from the relationship found to exist between topographic position, soil drainages and forest productivity, it is possible to develop generalized guidelines which will assist in identifying and delineating similar segments of the landscape.

The guidelines shown in Tables V and VI represent the most common land units found to occur on the selected glacial till and lacustrine deposits. In addition, some anticipated forest-soil relationships are shown.

It should be noted however, that each area studied will have a distinctive land pattern of its own, and may or may not contain all or some of the major land units listed here. Also, soils will certainly differ as to development, texture, structure, productivity and species suitability.

Additional descriptions of parent materials and soil texture and structure can be found in Appendix V.

Conclusions

Based upon field observations, a number of generalized conclusions about the two drainage sequences in the Princeton and Quesnel study areas can be stated. Some of the conclusions might apply to other soils occurring under similar conditions but in different areas. First, rapidly to well drained soils are best suited for the growing of lodgepole pine. Existing stands studied were either poorly or over-stocked. The over-stocked stands of lodgepole pine have a tendency to stagnate

Table V. Guidelines to Identify the Major Observed Land Units Occurring on Glacial Till and Some Associated Forest-Soil Relationships

Land Unit	Topographic Position	Expected Drainage	Relative Productivity	Expected Limiting Factors
T_1	Convex slopes, ridges, knolls and spurrs	Rapid	Low to very low	Soil moisture deficiency Shallow to bedrock Adverse local climate
T_2	Convex and straight upper slope positions. Downslope from T_1	Well	Medium	Soil moisture deficiency Soil structure
T_3	Middle straight slopes. Upper part of coves, gently sloping areas	Moderately well	Medium to high	Soil structure Soil moisture deficiency Fertility (?)
T_4	Lower straight and concave slopes gently sloping low lying areas. Lower part of coves	Imperfectly	High to medium	Soil structure Fertility (?)
T_5	Lower concave slopes Bottoms of coves, low flat lying areas	Poorly	Medium	Excess soil moisture Soil structure
T_6	Enclosed depressions Bottom of swales extensive flat areas with poor surface drainage	Very poorly	Very low	Excess soil moisture

Table VI. Guidelines to Identify the Major Observed Land Units Occurring on Glacial Lacustrine Deposits and Some Associated Forest-Soil Relationships

Land Unit	Topographic Position	Expected Drainage	Relative Productivity	Expected Limiting Factors
L_1	Convex slopes and tops of knolls, steep escarpments	Rapid to well	Low to very low	Soil moisture deficiency Frequently eroding lands
L_2	Small upper benches gentle slopes, convex to flat lying areas on knolls and upper slopes on knob and kettle topography	Well to moderately well	Medium to high	Soil moisture deficiency Soil structure Fertility (?)
L_3	Concave lower slope positions closely associated with L_2 above and L_4 below	Imperfectly	High to medium	Soil structure Fertility (?)
L_4	Lower concave slopes, low flat lying areas	Poorly	Medium	Excess soil moisture Soil structure
L_5	Flat lying to enclosed depressions, extensive flat areas with poor surface drainage	Very poorly	Very low	Excess soil moisture

on these soils. If artificial regeneration is required, the feasibility of direct seeding versus planting should be investigated. Seedlings resulting from reseeding will not be subject to the planting shock experienced by planting stock, particularly if they are planted in a dry year. Although reseeding makes it difficult to obtain proper spacing, subsequent thinnings could be conducted to obtain a fairly wide spacing which would allow for optimum wood production. These soils, because of their proximity to bed-rock, or because of their topographic position have a low trafficability rating and are susceptible to erosion. Trafficability ratings are based on permanent physical features principal of which are slope, soil drainage, soil texture, and incidence and depth to bedrock. The traffic-ability rating can be used as a guide for assessing ease or difficulty of movement of heavy machinery. Erosion hazards are based upon soil permeability, texture, stoniness and slope of the area. Consideration to these factors should be given in determining road layouts, and building and maintenance costs. In addition, under proper management, open grown stands would contribute little slash on harvesting; considering this and the fact that these soils are often shallow and susceptible to erosion, any future plans for slash burning should be carefully investigated.

Second, the moderately well and imperfectly drained soils have the highest forest productivity and are also suitable for the growth of the widest range of species in the study areas. The determination of the factor or factors limiting forest growth on these soils is most difficult, and is assumed to be due to a minor accumulation of adverse factors. These soils, because of their high productivity and unknown limitations, are the ones which should warrant first priority in future silvicultural and research projects such as thinnings, prunings and fertilization. Because of their inherent productivity, moderately well and imperfectly drained soils also support prolific ground vegetation which competes with the regeneration of tree seedlings. Scarification should reduce this weed competition for the first few years following harvesting. If artificial regeneration must be resorted to, it is suggested that "jumbo size" planting stock (2 + 1 or larger) be used which can compete more effectively with the ground vegetation.

Third, poorly drained and very poorly drained soils were best suited for the growth of spruce in the study areas. The very low rate of growth obtained on very poorly drained soils does not warrant their inclusion in any management plan at present. The greater management problem expected on these soils is regeneration.

Where excess in soil moisture is already a limiting factor to forest growth, the influence one harvesting method has on the position of the water table as compared to other harvesting methods should be thoroughly investigated before a single cutting policy is adopted.

Trafficability is a problem on soils with a high water table, which can be overcome to a certain extent by managing these stands during the winter months when the soils are frozen. The development of all weather roads may be quite costly, but will vary, with the extent of the area to be considered the availability of fill, and the feasibility of drainage.

CHAPTER V

APPLICATION, SUGGESTED PROCEDURE AND EXTENSION OF INFORMATION

Application

The delineation of land units on the basis of their general topographic features and expected soil drainage at best serve only as rough guides as to where and to what extent succeeding field studies should be directed.

Follow-up studies upon which to base forestry decisions should include at a minimum the following observations: (1) Parent materials, including observed variations; or closely associated different kinds of parent materials, (2) Soil classification at the subgroup level and (3) Physical soil properties, most important of which are effective soil depth, texture, structure and drainage.[1] Additional interpretations for management such as erosion hazard, trafficability ratings, seedling mortality and vegetation competition can be carried out concurrently or subsequently.

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[1]Descriptions of soils at the subgroup level are presented by the National Soil Survey of Canada, Report on the Sixth Meeting of the National Soil Survey Committee of Canada, (Laval University, Que.: [n.p.], October, 1965)

Suggested Procedure

Outlined below is a suggested procedure which could be used by a forester planning to initiate a survey on his forested lands.

Selection of an Area

Before selecting an area for study, consideration should be given to available airphoto coverage; existing soil and surficial geology information; access and existing forest cover.

Aerial photographs.--Aerial photographs are a prerequisite to this type of survey. They not only show the access roads, but they aid in the location of specific areas in the field. Furthermore, they are an absolute necessity for mapping the area. The scale chosen will depend upon airphotos available, the detail required and the size of the area expected to be covered.

Airphotos of a scale of 1:15,000 or 1/4 mile to the inch, are excellent for soil mapping, but also have disadvantages. They require intensive airphoto interpretation, and in areas of pronounced relief, considerable distortion can exist. In a reconnaissance survey of this kind, a mapping unit may cover an extensive area, and carry over more than one airphoto. This makes it difficult to maintain continuity as one shifts from photo to photo. If the area to be surveyed is quite large, considerable time is required in the checking, joining and transferring of boundaries. Photos with a 1:15,000 scale are ideal, however for the selecting of suitable forest stands for measurement.

Airphotos of a scale of 1:30,000 or 1/2 mile to the inch, permit easy identification and delineation of the more observable landscape features and are well suited for this kind of survey.

Soils and geological maps.--Existing soil and surficial geology boundaries can be redrawn on the airphotos. Such boundaries will aid the uninitiated in recognizing the soils and their parent materials in the field. Furthermore, those boundaries will serve as ready reference in identifying similar areas in the field and on the airphotos.

Access and existing forest cover.--Good access will reduce field time and will allow for a greater number of field checks. Exposed road cuts are ideal for making observations on the soils. Landform features are usually easier identified on cleared areas which are not masked by forest vegetation. However, on alluvial and flood plain deposits, forest vegetation often serves as a useful guide in the mapping of different drainage patterns. Areas having stands suitable for productivity measurement are obviously more desirable than those that have not.

Initial Survey

Before beginning a survey, a specialist in soils and land classification should be consulted. The specialist can point out mapping techniques which can be employed both in the field and on airphotos. He can also assist in identifying the major landforms, parent materials, and soils, encountered in the field and can point out those features which will serve as useful criteria in mapping.

Before mapping, it is suggested that the major access roads are driven, in order to get an idea of the kind of soils which will be encountered. Frequent stops should be made, particularly when observable changes in topography, parent materials or soils are noted. Observable corresponding breaks in the landscapes at these points should be drawn on the airphotos to aid in future airphoto interpretation. A suggested field card shown in Figure 9 could be used to record all pertinent and observable information noted at this time. Each stop number should be recorded both on the field card and the airphoto. A number of stops being homogenous as to their observed features can then be assigned a symbol which will represent a specific land unit which will encompass all soils and landform features within a defined range.[1]

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[1]The major criteria for separating one land unit from another will usually be: (1) kind of parent material, (2) effective soil depth, (3) soil development, and (4) soil texture and structure.

FIELD CARD

Photograph No.______ By____________

Stop No.______ Date__________

Soil information

Assigned Land Unit__________	Soil description
Soil Classification_________	
Parent Material_____________	
Soil Depth_________________	
Soil Drainage_______________	
Soil Structure______________	
Soil Texture________________	
Topography_________________	
Surface Litter______________	

Forestry interpretations

Estimated Productivity	Low_____	Medium_____	High_______
Actual Productivity ______		Species sampled________	
Limiting Factors to Forest Growth___________			
Erosion Rating	Low_____	Medium_____	High_______
Vegetation Competition	Low_____	Medium_____	High_______
Seedling Mortality	Low_____	Medium_____	High_______
Trafficability Rating	Poor____	Fair_______	Good_______

Additional Comments:______________________________________

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____

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Figure 9. Suggested Field Card.

All future stops falling within the limits of each land unit should be designated on the photos and the field card by the appropriate selected symbol.

Aerial Photograph Interpretation

Using the information collected at the various stops, boundary lines outlining the apparent differences between land units should be drawn. Often two or more land units are too closely interrelated or are too small to be easily separated either on the airphotos or on the ground. In such cases, these land units can be grouped into what Lacate has termed a land association. Land association as defined by Lacate "is an aggregation of geographically associated Land Units."[1] Estimated percentages of each land unit (totalling a 100 per cent) from ground and airphotos observations should be noted in each land association mapped.

In mapping, it is easiest to begin separating those units which are most easily identified. This not only reduces the area left to be interpreted, but gives the interpreter confidence in his work. For example, areas of rock outcrop and swamps could first be mapped out.

Once the area has been mapped, re-checking of the boundaries should be undertaken in the field.

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[1] D. S. Lacate, Forest Land Classification for the University of British Columbia Research Forest, Department of Forestry, Publication No. 1107 (Ottawa, Ont.: Queen's Printer, 1965).

Pre-mapping

Once the interpreter has gained confidence and experience in this procedure, he will be able to extend his mapping to adjacent areas. Field work will entail only checks as to pre-mapped boundaries, percentage estimates of land units within each mapped land association; and the continuity of similar parent materials and soils into the extended area.

Extension of Information

Good forest management today includes the consideration of other land uses as well as that for timber production. Therefore, when forest lands are managed for maximum production, watershed and engineering needs must be taken into account.[1] Some of the information gathered in this kind of survey would apply to the management of other resources as well.

Productivity

Productivity depends on the ability of a soil to supply the necessary tree growth requirements for each species. A knowledge of the species needs and of the importance of various factors affecting growth will require further research and is necessary in obtaining maximum use of the survey data.

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[1]F. Gehrke, "Forest Soil Surveys--Methods, Status, Resulting Information and Use in Management," Symposium of Forest Watershed Management, Sponsored by Society of American Foresters, and Oregon State University, (Corvallis, Ore.: Oregon State University, March, 1963), p. 185.

However, at the present stage of development in British Columbia, the suggested survey procedure outlined will supply data about the nature of the physical and physiographic soil factors on which productivity is greatly dependent and the extent of each kind of soil present.

Unproductive areas, such as swamps and rock outcrops can be easily delineated and their acreages determined. This information, combined with productivity figures for the remaining areas will aid in assigning best land use and establishing management priorities. Soil productivity in terms of forest growth can be determined following a method similar to the one outlined in Chapter III on pages 36-38. Figures 10 and 11 show the comparison between a suitable and a not suitable stand to be selected for measurement.

Forest Management

Information on erodibility and compaction will enable the manager not only to choose logging methods and equipment that will do the least damage to the soil, but also will allow the method most conducive to the establishment and growth of regeneration to be chosen. Soil depth, physical composition, and type of terrain can influence the location of cutting boundaries so as to produce areas similar for future management practices. The nature of the soil can be used in estimating logging costs and breakage can be related to the kind and degree of rockiness. Correlations between volume losses due to insect and decay and seedling mortality

Figure 10. An even-aged well stocked stand suitable for measuring soil productivity.

Figure 11. A multi-storied, uneven-aged stand not-suitable for measuring soil productivity.

due to drought conditions and vegetation competition can easily be determined through follow-up studies using the original survey as a base.

The field card on page 60 has a place for additional information. Interpretations such as erosion hazard and trafficability can be determined from the characteristics associated with each land unit. As an initial rough guide, such interpretations can be rated simply as low, medium or high.

Engineering

The survey will provide information useful in the establishment of possible problem areas where soils with poor drainage, unstable properties, extensive rock outcroppings, and steep slopes may affect road location. This knowledge of position and extent will help the engineer in choosing the best among several alternatives.

The availability of road surface materials can be easily determined from the resulting survey map. Drainage patterns and their related landscape features can be used in determining culvert size and spacing.

Watershed Management

Information about soil-moisture relationships will be required to evaluate water production and quality. Certain physical characteristics of the soil influence its ability to absorb and store water. Soil depth, to a large degree, controls the amount of water that can be temporarily stored and later released to the streams. Texture, structure and organic matter content affect the soils porosity, infiltration capacity, and storage space while the depth and nature of the surface litter aid in estimating erodability.

Some of the data collected during this survey will have future use when correlated with water management studies. At a minimum, the survey will provide a map showing the kinds, extent and locations of parent materials, and their related soil depth, texture and structure. In addition, major drainage channels and seepage slopes may be inferred from the observed drainage patterns and associated land units.

Research

The resulting information from such a survey will provide the research scientist with knowledge about the location and extent of the important soils and the problem soils. Investigations can then be established which will yield results of the widest possible application.

CHAPTER VI

SUMMARY AND FUTURE REQUIREMENTS

Summary

Two soil catenas, one occurring on glacial till, and the other on glacial lacustrine deposits were selected in two different areas of the interior of the Province. A relationship was found to exist between topographic position and resulting soil drainage and forest productivity.

In both study areas, stands having the highest productivity, as determined by their mean annual increment at 100 years of age, occurred on imperfectly drained soils whose topographic position offered protection from extremes in evapotranspiration and exposures. These soils also receive seepage water from adjacent upland soils in quantities that does not impede forest growth.

Based upon these observations and previously devised land classification methods, it is suggested that forest productivity can be determined more effectively and has broader application by the method outlined than by the conventional site index methods. Cleared forest land can be assigned a relative productivity rating while actual productivity rating can be assigned on forested areas as mensurational data becomes available. Such information can then be extrapolated to adjacent cleared, but otherwise similar areas.

Based upon the land classification method devised by Lacate, some guidelines have been proposed which it is hoped will aid the practicing forester in separating his forest land into systematic units which can serve as a base for future management interpretations and plans.[1] In initiating a survey, a specialist in soils and land classification should be consulted to get the survey started on the right track.

A reconnaissance survey is not meant to take the place of more detailed soil surveys. However, such a method, as discussed in this study provides initial information in otherwise unknown areas. It will also facilitate in the location of follow-up detailed soil surveys and research projects in those areas having the greatest interest to forest managers.

The primary purpose of this study was to outline a method which practicing foresters will find not only useful, but will also lead them to take an even greater interest in their soils. It is hoped that consultation with a soils specialist will follow. A co-operative study can have a dual benefit. First, the forester will have an opportunity to study soils and to learn techniques for mapping, which he may

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[1]D. S. Lacate, Forest Land Classification for the University of British Columbia Research Forest, Department of Forestry, Publication No. 1107 (Ottawa, Ont.: Queen's Printer, 1965).

then be able to apply elsewhere unaided. The specialist can learn the difficulties and problems facing the forester and can then devise methods of interpretating soils more tailored to the foresters needs. In sum, it is hoped that such a procedure will have positive consequences, which will be felt at the administrative level.

The findings and procedures discussed in this thesis are not to be considered as a simple solution to a complex problem, but it is hoped that they will stimulate a greater demand for surveys of forest lands.

Future Requirements

The management of forest lands is dependent upon both the administrative framework, and the technical capabilities to execute these decisions. At the technical level, the present state of the arts is quite adequate to provide methods and information to aid in the development of management plans. The literature on forest-soils relationships is voluminous, and several techniques have been devised and used to separate these significant features in the field. So why is it that soils still have such a low priority in forest management plans?

The answer must lie with the level of importance soils have been granted up to the present time. Soils as yet, have not been recognized as the base on which to make decisions. It appears that before soils are elevated to a position of priority they deserve, several difficulties must be overcome.

Lack of Information

The present lack of soils information is apparent in the absence of past and current soil studies, which could serve as a management tool. Soil studies cannot be expected to be conducted in these forested areas until there is a demand for them.

This cycle of waiting for a soil or land survey to prove its worth, which in turn, depends upon a demand for such surveys must be broken. To trust that one part of the cycle will accelerate the other is to take an unacceptable risk that nothing, or too little will happen. A co-operative demonstratable project involving both private and public organizations may be a solution to this dilemma. The University of British Columbia Research Forest is suggested as a suitable place for such a project. The area already has been mapped and classified by Lacate and it would be worthwhile to see some use made of his survey, if nothing else but to make suggestions as to where refinements are necessary for particular purposes.[1] The Research Forest could serve as a valuable place to bring all agencies involved in managing the Province's forest together, to exchange information among the disciplines involved. Previous experiences of soil scientists and foresters working together has resulted in a better understanding of soil and plant relationships.

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[1] *Ibid*.

Furthermore, the Research Forest would be an ideal place to conduct research projects tailored to the numerous unsolved problems that still face the forest industry. Examples of research projects might be: (1) studies on which tree specie or species should be planted on what kinds of soils, in order to obtain optimum seedling survival and future growth, (2) which soils should receive top priority in fertilization projects and other silvicultural treatments, and at what stage of the stand history, and (3) on what kinds of soils is slash burning most detrimental or beneficial and investigations into what alternatives can be used to dispose of slash on those soils where burning has an adverse effect.

Lack of Suitable Research Projects

As mentioned earlier, much of the past research conducted on forest soils has limited value since there were no previous soil surveys to act as a guide. The extent of the studied soils is unknown therefore, and may not be representative of the area in general.

Before future research is conducted, a second look should be given as to the kind of research being conducted. The value of pure research should be carefully weighed in comparison to applied research. At present, the need is greatest for solving the routine problems of soil classification and interpretation, and use and management of forest lands. Without seeking the adequate basic information supplied by a suitable survey, the manager may become completely frustrated by the limited benefits of the data obtained from a costly research project. In the future, considerable preliminary screening should be done to ensure that the important soils and plant species are being tested for yield and performance. It is more important to limit testing to a few key soils whose characteristics and responses are widely different than to test a number of nearly similar soils or soils of minor importance.

Lack of Qualified Personnel

The limited number of trained soil specialists presently employed in the Province is also part of the problem. Because of their absence, projects so necessary for creating a greater interest in soils are not undertaken. Training of personnel qualified in another discipline to be a jack-of-all-trades is not recommended, nor is the tailoring of a simple approach to a complex problem the solution. Success in understanding the importance of soils and having trained personnel to conduct appropriate research can only be obtained by creating a demand for them.

It is hoped that once such a demand exists, it will be reflected in the curricula of the respective universities.

These three main obstacles, (1) lack of information, (2) lack of suitable research projects ready for implementation, and (3) lack of qualified personnel, must be overcome before the Province can be considered ready to plan for a program of more intensive forest management.

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APPENDICES

APPENDIX I

GENERALIZED PROFILE DESCRIPTIONS

Princeton Study Area

Bankeir Series

Bankeir sandy loam is a rapidly to well drained Orthic Acid Brown Wooded soil that has developed on non-calcareous sandy loam till. These soils occupy bedrock ridges, upper valley slopes and crests of rock-cored drumlins. Topography is moderately and strongly sloping on units of rock outcrop and strongly and very steeply sloping on valley steeplands. The slope gradient varies from 15-60 per cent.

The relatively thin mantle of till comprising the sola of Bankeir soils is derived mainly from volcanic rock types, but frequently overlies granitic intrusions. This soil has thin litter horizons (L-F), and brownish colored Bf horizons that grade into sandy loam or loam BC horizons. The BC horizons break into shattered bedrock, usually at a depth of 24 inches or less. A generalized profile of the series if described below:

Horizon	Depth	Description
L	$\frac{3}{4}$ - $\frac{1}{2}$ inches	Fresh grass, leaves, and twigs.
F-H	$\frac{1}{2}$ - 0 inches	Partially decomposed litter with some bleached mineral grains scattered through the lower boundary zone.

Bf1	0 - 4 inches	Pale brown and dark yellowish brown sandy loam; fine granular and weak, fine subangular blocky; very friable, slightly plastic; gradual boundary.
Bf2	4 - 11 inches	Pale brown and dark yellowish brown loam; medium and coarse subangular blocky; firm, plastic, slightly sticky; gradual boundary.
BC	11 - 24 inches	Brown and dark brown to dark yellowish brown sandy loam; medium and coarse subangular blocky; very firm, plastic, slightly sticky; abrupt lower boundary.
R	-24 inches plus	Smooth, slightly weathered andesitic rock.

Mazama Series

Mazama sandy loam is a well drained to moderately well drained Degraded Acid Brown Wooded soil that has developed on non-calcareous sandy loam tills. These soils occupy upper and middle valley slopes and sides of drumlins. Topography is moderately sloping. The slope gradient varies from 6-9 per cent.

The glacial till comprising the sola of Mazama soils is derived mainly from volcanic rock types. This soil has a thin litter horizon (L-F), a thin light colored Ae horizon, a brownish colored Bf horizon that grades into sandy loam BC horizons. The C horizon is a brownish sandy loam. A generalized profile of the series is described below:

Horizon	Depth	Description
L	$\frac{3}{4}$ - $\frac{1}{2}$ inches	Fresh grass, leaves, and twigs.
F-H	$\frac{1}{2}$ - 0 inches	Partially decomposed litter with some bleached mineral grains scattered through the lower boundary zone.

Ae	½ - 1 inch	Pale pink, sandy loam; granular and weak, very friable, abrupt lower boundary.
Bf	1 - 12 inches	Pale brown, and dark yellowish brown, sandy loam to loam; medium subangular blocky, friable, plastic, slightly sticky; gradual boundary.
BC	12 - 26 inches	Brown, and dark brown to dark yellowish brown sandy loam; medium and coarse subangular blocky; very firm, plastic, slightly sticky; gradual boundary.
C	-26 inches plus	Brownish sandy loam.

Pefferle Series

Pefferle series is a imperfectly drained Gleyed Cutanic Podzo Regosol that has developed on non-calcareous sandy loam till. Topography is gently to moderately sloping. The slope gradient varies from 2-9 per cent.

The soil has a thin litter horizon, a light gray Ae horizon, a gleyed Btj horizon and a Cg horizon at a depth of 26 inches. A description of Pefferle series is given below:

Horizon	Depth	Description
L-H	1 - 0 inches	Pine needles and litter partially decomposed.
Ae	0 - 5 inches	Light gray and brown sandy loam, granular, very friable; abrupt boundary.
Btj	8 - 15 inches	Light gray and grayish brown loam with few, fine and faint, brown and yellowish brown mottles; medium subangular blocky; firm; many fine roots; clear boundary.
Btjg	15 - 24 inches	Light gray to grayish brown loam with fine, distinct brown and dark yellowish brown mottles; subangular blocky; gradual boundary.

BCg	24 - 26 inches	Light gray and grayish brown to light olive brown loam with many fine, prominent brown and yellowish brown mottles; medium subangular blocky; gradual boundary.
Cg	-26 inches plus	Light gray and grayish brown sandy loam; fine, distinct olive brown mottles; medium blocky; few roots.

Erris Series

Erris series is a poorly drained orthic Gleysol occurring on gentle to moderately sloping topography. The slope gradient varies from 2-9 per cent.

A description of Erris series is given below:

Horizon	Depth	Description
L-H	2 - 0 inches	Decaying leaves and needles.
Ah	0 - 6 inches	Black mucky loam; coarse granular structure, friable; abundant fine and coarse roots; clear boundary.
Aejg	6 - 17 inches	Variegated colors, loamy sand and gravel, single grain structure; loose, few roots; clear boundary.
Btjg	-17 inches plus	Olive gray loam with medium, prominent mottles of brown to dark brown, medium subangular blocky structure; very few roots.

Quesnel Study Area

Beaverly Series

The Beaverly series are moderately well drained and are classified as Orthic Gray Wooded. These soils, developed on glacial lacustrine deposits, occur on convex slopes and knolls of undulating topography. The slope gradient varies from 6-9 per cent.

This soil has thin litter horizons (L-F), a light brownish colored Ae horizon and a grayish brown Bt horizon that grades into a gleyed Cg horizon at a depth of 27 inches. A generalized description follows:

Horizon	Depth	Description
L-F	1 - 0 inches	Grass and needle litter.
Ae	0 - 7 inches	Light brownish gray, and dark grayish brown, silty clay; moderate, medium, platy structure.
Bt	7 - 27 inches	Grayish brown and very dark grayish brown, clay; coarse prismatic structure; faint mottling along root channels in lower part of horizon.
Cg	-27 inches plus	Light gray to light olive gray clay; yellowish brown mottles; stratified.

Pineview Series

The Pineview series are imperfectly drained and are classified as Gleyed Gray Wooded. These soils, developed on glacial lacustrine deposits, occur on concave and lower slopes of undulating topography. The slope gradient varies from 6-9 per cent.

A generalized description follows:

Horizon	Depth	Description
H	2 - 0 inches	Forest litter.
Aeg	0 - 5 inches	Light gray to light brownish gray, silty clay; moderate medium platy structure; roots abundant.
Btg	5 - 12 inches	Grayish brown to dark yellowish brown, clay; coarse, prismatic structure; roots common.

Btgj	12 - 25 inches	Light gray to brownish gray, clay; coarse prismatic; distinct mottles with small pockets of gray gley; occasional roots; clear boundary.
Cg	-25 inches plus	Light gray to light olive gray, clay; yellowish brown to brown mottles; stratified.

Moxely Series

The Moxely series are very poorly drained and are classified as Orthic Humic Gleysols. These soils occur in enclosed depressions or relatively flat lying areas. The slope gradient varies from 0-5 per cent.

A generalized description follows:

Horizon	Depth	Description
L-H	2 - 0 inches	Decaying leaves and needles.
Ah	0 - 11 inches	Black mucky loam; granular structure, friable; abundant fine and coarse roots.
Btjg	11 - 29 inches	Olive gray, clay; prominent mottles of brown to dark brown; coarse prismatic structure.
Cg	-29 inches plus	Olive gray, clay; yellowish brown to brown mottles; stratified.

APPENDIX II

FOREST CAPABILITY CLASSES, LIMITATIONS AND PRODUCTIVITY

In the classification system outlined by McCormack (1967) pages 4-6, all mineral and organic soils are classified into one of seven classes based upon their inherent ability to grow commercial timber. Class 1 represents the best lands for commercial tree growth, while Class 7 represents the poorest.

Capability class	Limitations to growth of commercial forests	Productivity cubic feet/acre/year
1	No important limitations	111+
2	Slight limitations	91-110
3	Moderate limitations	71- 90
4	Moderately severe limitations	51- 70
5	Severe limitations	31- 50
6	Severe limitations	11- 30
7	Limitations of such a severe nature as to preclude the growth of commercial forests	0- 10

APPENDIX III

SOIL DRAINAGE CLASSES[1]

Soil drainage classes are defined in terms of (1) actual moisture content in excess of field moisture capacity, and (2) the extent of the period during which such excess water is present in the plant-root zone.

It is recognized that permeability, level of ground water and seepage are factors affecting moisture status. However, because these are not easily observed or measured in the field, they cannot be used generally as a criteria of moisture status.

Topographic position and vegetation as well as soil morphology are useful field criteria for assessing soil moisture status.

Rapidly drained.--Soil moisture content seldom exceeds field capacity in any horizon except immediately after water additions.

Soils are free of any evidence of gleying throughout the profile. Rapidly drained soils are commonly soils of coarse texture or soils on steep slopes.

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[1]Source: National Soil Survey Committee, Report on the Sixth Meeting of the National Soil Survey Committee of Canada, (Lavàl University, Que.; [n.p.], October, 1965), pp. 123-24.

Well drained.--Soil moisture content does not normally exceed field capacity in any horizon (except possibly the C) for a significant part of the year.

Soils are usually free of mottling in the upper three feet, but may be mottled below depths of three feet. B horizons, if present, are reddish, brownish, or yellowish.

Moderately well-drained.--Soil moisture in excess of field capacity remains for a small, but significant period of the year.

Soils are commonly mottled in the lower B and C horizons or below a depth of two feet. The Ae horizon, if present, may be faintly mottled in fine-textured soils or in medium-textured soils that have a slowly permeable layer below the solum.

Imperfectly drained.--Soil moisture in excess of field capacity remains in subsurface horizons for moderately long periods during the year.

Soils are commonly mottled in the B and C horizons; the Ae horizon, if present, may or may not be mottled. The matrix generally has a lower chroma than in the well-drained soil or similar parent material.

Poorly drained.--Soil moisture in excess of field capacity remains in all horizons for a large part of the year.

Soils show evidence of strong gleying. Except in high chroma parent materials, the B, if present, and upper C horizons have matrix colors of low chroma. Faint mottling may occur throughout.

Very poorly drained.--Free water remains at or within 12 inches of the surface most of the year.

Soils show evidence of very strong gleying. Subsurface horizons are of low chroma and yellowish to bluish hues. Mottling may be present, but at depth in the profile. Very poorly-drained soils usually have a mucky or peaty surface horizon.

APPENDIX IV

SUPPORTING PLOT DATA FOR DETERMINING CAPABILITY CLASS RATING

Princeton Study Area

Soil Name	Classification	No. of Plots Sampled	Species Sampled	Range in M.A.I.$_{100}$	Capability Class
Bankeir	Orthic Acid Brown Wooded	5	lP	31-41	5
Mazama	Degraded Acid Brown Wooded	7	lP	50-69	4
Pefferle	Gleyed Cutanic Podzo Regosol	4	lP	77-91	3
Erris	Rego Gleysol	1	eS	66	4

Quesnel Study Area

Soil Name	Classification	No. of Plots Sampled	Species Samples	Range in M.A.I.$_{100}$	Capability Class
Beaverly	Orthic Gray Wooded	4	1P	51-69	4
Pineview	Gleyed Gray Wooded	4	1P	64-87	3,4
Moxely	Peaty Gleysol	6	bS	7-29	6-7

APPENDIX V

PARENT MATERIALS

Parent material refers to the initial state of the soil system, and includes the C horizon and other materials above the C from which the soil develops.

A brief description of the main parent materials occurring in British Columbia follows.

Alluvium.--Refers to those materials moved and redeposited by water. It may occur in terraces well above present streams or in the normally flooded bottoms of existing streams. Texture can vary from fine silty materials deposited in quiet waters to coarse deposits, often consisting of large boulders. Stones and rock fragments are rounded and well worked. Sorting is usually evident.

Colluvium.--Is the unsorted or slightly sorted material at the base of slopes, accumulated largely as rock fragments that have fallen down the slope under the influence of gravity. In its extreme form, this material is called talus. Rock fragments are angular in contrast to the rounded, water-worn cobbles and stones in alluvial terraces and glacial outwash.

Glacial till.--Glacial till is generally an unstratified, unconsolidated, heterogeneous mixture of clay, silt, sand and gravels, and sometimes boulders. Unworked till is often very compacted, especially when it is dry. Rock fragments are usually angular in shape.

Glaciofluvial deposits.--These deposits are made up of materials produced by glacier and carried, sorted and deposited by water that originated mainly from the melting of glacial ice. Such deposits can often be found at elevations considerably above present stream channels.

Lacustrine deposits.--These deposits consist of materials that have settled out in the quiet water of lakes. These deposits with a predominate silt and clay texture are usually stone-free and are stratified.

Loess.--These are wind deposits consisting of silts or very fine sands. Such deposits in British Columbia often exist as a thin capping over another parent material.

Marine sediments.--These sediments have been reworked by the sea, and later exposed through surface uplift following the retreat of glaciation. These deposits resemble lacustrine deposits, are fine textured and may or may not contain reminants of marine shells.

SOIL TEXTURE[1]

In the field, soil texture is determined by the feel of moist soil when it is rubbed between the thumb and fingers. Since sand particles feel gritty, silt particles have a smooth velvety feel and clay is both sticky and plastic, an estimate of the relative proportions of the separates may be made. This procedure, of course, will not give the exact percentage of sand, silt, and clay; but, with a little practice on samples of known composition, the relative proportions of the individual separates can be closely estimated. Practice with known samples is the only way to acquire this facility. The ability to determine texture in the field by this method is one of the most valuable practical skills a student of soils can possess.

The outstanding physical characteristics of the main textural grades as determined by the feel of the soil are described below.

Sandy soil.--Sandy soil is loose and single grained. The individual grains can be seen readily or felt. Squeezed in the hand when dry, it will fall apart when pressure is released. Squeezed when moist, it will form a cast, but will crumble when touched.

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[1]Source: U. S. Department of Agriculture, Handbook on Soils, Forest Service, ([n.p.], 1961, plus 1963 and 1966 Amendments), pp. 87-88.

<u>Sandy loam soil</u>.--Sandy loam soil contains much sand, but has enough silt and clay to make it somewhat coherent. Individual sand grains can be easily seen and felt. Squeezed when dry, it will form a cast which will readily fall apart; but if squeezed when moist, a cast can be formed which will bear careful handling without breaking.

<u>Loam soil</u>.--Loam soil is about an equal mixture of the sands and silt with the clay content being between 7 and 27 per cent. A loam is mellow with a somewhat sandy feel, yet fairly smooth and slightly plastic. Squeezed when moist, it will form a cast which can be handled freely without breaking.

<u>Silt loam soil</u>.--Silt loam soil, when dry, may appear cloddy, but lumps are readily broken, and when pulverized, it feels soft and floury. When wet, the soil readily runs together. Either dry or moist, it will form casts which can be handled freely without breaking, but when moistened and extruded between the thumb and fingers, it will not form a ribbon, but will give a broken appearance.

<u>Clay loam soil</u>.--Clay loam soil is fine-textured soil which usually breaks into clods or lumps that are hard when dry. When moist soil is extruded between thumb and fingers, it will form a thin "ribbon" which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded

in the hand, it does not crumble readily, but tends to work into a heavy, compact mass.

Clay soil.--Clay soil is a fine-textured soil that usually forms very hard lumps or clods when dry and is plastic and sticky when wet. When the moist soil is ribboned out between the thumb and the fingers, it will form a long flexible strip. A clay soil leaves a "slick" surface on the thumb and fingers when rubbed together and tends to hold the thumb and fingers together due to the stickiness of the clay.

SOIL STRUCTURE[1]

The sand, silt, and clay particles of soils rarely exist as discrete units or single particles but usually as aggregates of particles. These aggregates are collectively called soil structure. Since this soil characteristic is not easily measured and there are no precise, single-valued expressions for structure, descriptions must be used. There are four basic geometric forms of structure.

Platy.--Platelike or flat with one dimension (the vertical) being much shorter than the other two dimensions.

Prismatic.--Prismlike with the vertical dimension being several times greater than the two horizontal dimensions. Vertices

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[1]Source: U. S. Department of Agriculture, Handbook on Soils, Forest Service, ([n.p.], 1961, plus 1963 and 1966 Amendments), p. 90.

are angular. There are two varieties of prismatic structure: (1) columnar when the top of the prism is rounded and (2) prismatic when the top of the prism is flat.

Blocky.--Cubelike or blocky when the three dimensions are of about the same size. The surface of blocky peds are casts of molds formed by faces of the surrounding structural peds.

There are two varieties of blocky structure: (1) angular blocky--faces flat, most corners are sharply angular and (2) subangular blocky--faces mostly rounded, corners mostly rounded.

Spheroidal.--Rounded or spherelike with all axes equal and having curved surfaces that are not related to the faces of surrounding units. These units are often referred to as granules.

Structureless.--That condition in which there is no definite arrangement of the primary particles. When the particles are coherent they are called massive; when non-coherent, they are called single grain.

The size of the individual structural units is indicated by the terms "very fine," "fine," "medium," "coarse," and "very coarse." The size limitations of these categories vary with the structural type. The grade of the soil structure may be expressed as weak, if the structural units are not very evident in the soil mass; moderate, if they are evident but not distinct; and strong, if very evident in the soil.