Development of a Methodology and Rationale for a Forest Management Site Classification System for Manitoba

Prepared for the

Scientific Authority

Contract No. 01K45-6-0054

Supply and Services Canada

By

R.E. Wells, Ph.D., P.Ag.

ABSTRACT

The major objective of this work was to evaluate the feasibility of incorporating existing Manitoba forest site information into an updated operational forest management site classification and mapping methodology. Several forest site classification schemes devised for use in Manitoba and elsewhere were reviewed as part of an effort to determine the extent to which existing information sources can be applied to predict forest productivity and develop ecologically sound silvicultural prescriptions.

An initial assessment of current site classification information needs was obtained from a questionnaire distributed to senior forestry personnel in government and industry together with follow-up interviews of individuals from both groups. Results from the questionnaire and interviews showed that considerable site information was being obtained from the current provincial forest inventory and a certain amount of soil survey information was also being used where such coverage was available. On the basis of these results, an attempt was made to integrate existing site classification information from forest inventory cruise plots with relevant soil and biophysical survey information for a portion of southeastern Manitoba. The integration was successful but only to the extent of corroborating previous site classification work. Because of lack of detail, scale disparity and inherent limitations of site classification information from the separate sectors, the integration could not be taken to the level needed for current operational use. However, this preliminary integration work did show that existing information could best be utilized, refined and rapidly extended through a mapping approach using aerial photo interpretation.

Review of previous work shows that a hierarchical classification framework is essentially in place in Manitoba and that a relatively modest input is required to upgrade existing information on a sound ecological basis. A multifactor physiographic-soil-vegetation mapping approach is recommended as best suited for developing reliable interpretations based on key characteristics for easier and effective use by operational users.

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REVIEW AND CRITIQUE OF EARLY SITE CLASSIFICATION WORK

A number of site classification systems have been devised and applied in Manitoba over the past fifty to sixty years. All of these systems have had an essentially ecological basis in that they considered, at some level, the mutual relationships between forest vegetation, physiography and soil features. The systems that were designed for regional application provided an initial framework of broad, ecologically-based forest site regions, not only in Manitoba, but also for the forested portion of Canada. They, together with systems that were devised for local operational use, are important because their commonalities provide the basis for improved future work on forest site classification in Manitoba.

Early ecologically-based site classification systems with regional or local application to forestry in Manitoba are reviewed in the two sections immediately following. Early work related to estimation of forest productivity based on site characteristics is reviewed under the heading of Forest Site Productivity. Additional site research references are provided in Appendix 1.

Regional Site Classification

Regional site classification in Manitoba rests largely on the work of two authors. Halliday (1937) in his widely accepted work on forest classification in Canada delineated forest regions based on dominant forest communities comparable to the climatic "climaxes" of Clements (1928). Rowe (1959, 1972) refined Halliday's regions as geographic entities based on broad physiographic divisions. Rowe also subdivided the regions into forest sections based on the consistant presence of particular forest associations. These forest sections provided the most useful regional basis for forest site classification in Manitoba until Zoltai et al. (1967) divided Manitoba into broad ecoclimatic regions as part of the Canada Land Inventory program. Even today, the forest sections are probably referred to more than the first ecoregion divisions.

Ecological Site Classifications

Ecological site classification work applicable to Manitoba conditions was modelled on the Finnish experience (Cajander, 1926; Ilvessalo, 1929) and began with Halliday (1930a) who divided the Pasquia National Forest into four primary site classes. These primary classes were subdivided into broad types on the basis of vegetation composition reflecting major site differences as follows:

1. Grass-herb forests
    - 1.1 Shrub type
        - Contains all pure broadleaf stands; generally on high ground; principal shrubs are hazel, squashberry, juneberry and mountain maple

1.2 Herb-rich type

- Contains mixed woods on well drained slopes and flats; bunchberry; strawberry; dewberry; sarsaparilla

2. Moist-moss forests

2.1 Transition type

- Approaching grass-herb class; moss cover fairly complete; twin flower common; horsetail very common on moist soils

2.2 Hylocomium type

- Complete moss cover; scattered herbs as a consequence of low light conditions; some shrubs in wetter areas; wintergreen (*Pyrola* sp.) common

3. Wet-moss forests

3.1 Hypnum type

- Feathermoss around tree roots; pools of clear water between trees; marsh marigold (*Caltha* sp.) common

3.2 Sphagnum type

- Complete cover of sphagnum; minor herbs

3.3 Ledum muskeg type

- Sphagnum in hillocks; swamp apple common

3.4 Tamarack moor type

- Wet grass and reeds

3.5 Low moor type

- Open muskeg and floating bog; swamp birch common

4. Dry-moss and lichen forest

4.1 Moss-shrub type

- Scattered moss; some shrubs including alder and Labrador tea; rather moist; a transition type surrounding wet-moss class areas

Halliday (1930b) used these primary classes and subtypes as the basis for a rate of growth survey for the forests of the Cretaceous upland (essentially the mixedwood section) of Manitoba and Saskatchewan. Growth and yield data are summarized in terms of nine forest inventory cover sybtypes based, where possible, on the composition of the 61-100 year age class. Less reliance was placed on growth data for subtypes in younger age classes, especially those for jack pine, because of the high probability of fine disturbance being responsible for current stand conditions. Halliday (1930b) also points out that data for the subtypes with intolerant hardwoods can provide only general trends because they include a range of site conditions and stand structures. The some criticism applies to other subtypes, although probably to a lesser extent. However, this work does provide a useful general summary of forest growth and yield in terms of vegetation physiognomy broadly related to site conditions. This work was also very useful as a starting point for work to define forest types in the southern boreal forest (Rowe, 1956a,1956b).

The Hills (1952) physiographic site classification as modified by Rowe (1957) applies over both Manitoba and Saskatchewan and includes southeastern Manitoba. This so-called Hills-Rowe system groups white spruce, black spruce and jack pine forest community types into physiographic site classes: A, B, C, D, etc., on the basis of moisture regime and on pore pattern as reflected by soil texture and structure. An example of the grouping for white spruce is reproduced in Figure 1. The site classes themselves are described in physiographic terms. For example, white spruce site class B is described as including fresh to moist sites on clay loam to clay tills.

Site classes also frequently include several subclasses. For example, site class C, white spruce on moist to very moist sites with a variety of parent materials, includes:

C1 Subluvial sites, i.e. drained depressions of till deposits, shallow valleys with intermittant streams, lower slopes; common undergrowth species are *Cornus stofonifera*, *Ribes* spp., *Mertensia paniculata* and *Mitella nuda*

C2 Alluvial (flood plain) sites, i.e. stream bank levees;

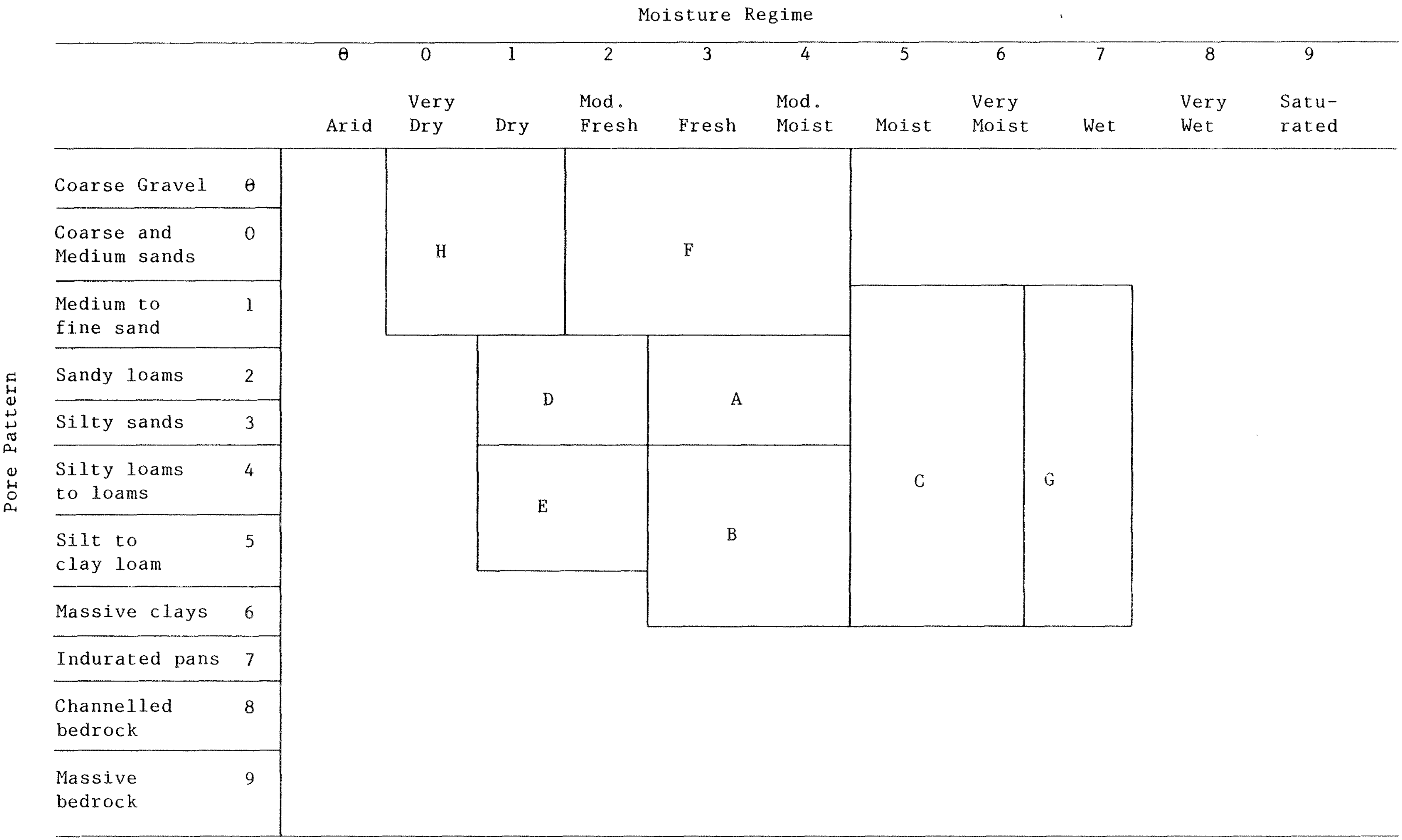

Figure 1. Tentative Grouping Of White Spruce Sites (after Rowe, 1957).

luxuriant undergrowth with tall shrub such as *Acer spicatum*, *Corylus cornuta*, *Prunus* spp., and *Viburnum* spp. very prominent

C3 Seepage slope sites with characteristics of both subluvial and alluvial sites

C4 Non-telluric sites, i.e. low-lying moist to very moist soils with poor internal drainage; grass-covered (*Calamagrostis* type) under open forests; moss-covered (*Hylocomium* type) where white spruce forms a continuous canopy.

A disadvantage of this system is that it is incomplete. Only the structure and general floristic composition is given for forest community types within each of the site classes, and even these are not available for some of the site classes. Successional relationships between forest types are alluded to by Rowe (1957) but, probably because the work is incomplete, they are not shown in any detail.

The Hills-Rowe system is essentially a grouping of physiographically related forest community types in terms of productivity. Productivity ratings for white spruce, black spruce and jack pine are given in terms of site index (average and range) within each physiographic site class. These same forest community types, had they been described in somewhat more detail, could also be recognized in combination with their associated physiographic and soil characteristics as basic site classification units capable of being grouped for a range of purposes.

The Hills-Rowe system has seen fairly wide use in Manitoba. It has been used almost exclusively by Canadian Forestry Service researchers to provide physiographic site descriptions on silvicultural experiment areas. This modified system has also been used to map forest sites and compare their productivity in the Clear Lake area of Riding Mountain National Park (Rowe, 1954). It has not been used to any great extent by Provincial forest agencies. However, because the Hills-Rowe system provides a physiographic framework suited to Manitoba forest site conditions and because it was designed to apply within broader site regions with different climatic regimes, it goes a long way toward providing a unified basis for future site classification work in Manitoba.

Ritchie (1961) examined relationships between landforms, soil types and forest vegetation in work to establish preliminary forest site categories in southeastern Manitoba. This work provides a tentative classification of sites in terms of soil types grouped according to their apparent degree of development of podzolic soil features in relation to soil drainage. The usefulness of this grouping is limited because of the incorrect assumption that the degree of podzolization is mainly related to soil drainage within a given climatic region. However, a reasonably good correlation was found between increased tree productivity and increasing degree of podzol development, expressed as Ae horizon development, with increasing moisture. In addition, useful information about the occurrence of minor vegetation on the various sites is provided. Broad agreement is also shown with contemporary work (Rowe 1957), Mueller-Dombois, 1964, 1965) in that area.

The Mueller-Dombois (1964, 1965) site classification system recognizes fourteen forest habitat types including three subtypes in southeastern Manitoba. These types range from the driest habitats on sand dunes to the wettest habitats on lowmoor bogs. The types are recognized on the basis of landform occurrence, moisture regime, nutrient regime and lesser vegetation.

The Mueller-Dombois system has been of fairly major importance in assigning forest productivity ratings in southeastern Manitoba (Mueller-Dombois, 1964; Bella, 1968). The habitat types have also been related to considerations for potential productivity, choice of species and method for reforestation, and potential for habitat amelioration by drainage.

Mueller-Dombois (1965) has provided keys for identification and mapping of the habitat types. However, the actual mapping done has been very detailed and very limited in extent. The cost of the high amount of ground truthing required for such detailed mapping would prohibit its operational use. A better alternative would involve the use of consistent groups of two to three habitat types found in close association on the landscape for efficient mapping at somewhat smaller scale.

In summary, the Mueller-Dombois system is a detailed, closely-integrated ecological forest site classification. It is a useful system and has seen considerable use for both productivity estimates and silvicultural prescriptions. Its main disadvantage is that it has only relatively local application, in southeastern Manitoba.

Site Productivity Classification

Early site productivity work in Manitoba began with Halliday (1932, 1935). He found in a preliminary study of 17 sample areas in Riding Mountain National Park, a reasonably good agreement between height and volume growth of trembling aspen, white spruce, black spruce, jack pine and four broad forest site groups on a moisture gradient. These four groups, ranging from high to low site values, include: 1) meso-hygrophile or hygrophile forests rich in tall herbs and shrubs and poor in mosses; 2) mesophile forests, a transition class rich in mesophytic herbs and grasses, with some taller herbs and shrubs, and some dwarf shrubs and an irregular covering of mosses; 3) mesophile forests with either an abundance of mosses or fernworts and hydrophytic shrubs, together with low mesophytic herbs and frequently considerable dwarf shrubs; and 4) hydrophile forests with sphagnum or aquatic mosses on peat or muck soils. Considerable variation in soil texture, stone content, content of calcareous material, and pH and total nitrogen values of diagnostic horizons appears within the soils of each group.

The results of modern analysis for soil base exchange characteristics could probably have served to provide a better subdivision of Halliday's site groups but were not available at that time.

Jameson (1963) constructed local volume tables for white spruce and trembling aspen for each combination of physiographic site type (fresh and moist clay-loam) and forest cover type (hardwood and softwood) found on the two predominant soil associations, Waitville and Branville, in Riding Mountain National Park. He found the number of merchantable trees, the rate of height growth and height of dominant trees at index ages and index diameters, and the merchantable and total volume were greater on the fresh Waitville site. However, total number of trees per acre was greater on the moist Granville site. The greater growth in volume and in height of dominant trees on the fresh Waitville site was related to more favorable soil texture, structure and moisture conditions than on the moist Granville site. The dense clay to heavy clay textures and imperfect to poor drainage conditions shown for typical moist Granville soils tend to corroborate these conclusions. Height/age curves plotted from the results of stem analysis of selected dominant white spruce trees on each site showed a similar separation of the two sites but were not directly comparable to height/age curves obtained in the usual manner. The differences were attributed mainly to the use of total age rather than breast-height age for the stem analysis curves and to the presence of sampling errors.

Jameson (1964) also constructed separate empirical yield tables for black spruce on four groups of physiographic sites in four forest sections (Rowe, 1959) in Manitoba and Saskatchewan. The site classification was adapted from Hills (1952) and the site descriptions include soil, landform, topographic and vegetation information. Jameson found in this study that the height/age curves have shapes that vary with sites and are considerably different than the mathematically defined and harmonized curves of normal yield tables. His work showed that the existing general assumption in which forest stands develop in a similar manner but at different levels depending on site index was probably wrong. His work also indicated that better estimates of future productivity of black spruce stands could be obtained if site, age and density of such stands were known. A detailed summary of constance, sociability and cover abundance of selected species is given by site and age class in the appendix to his paper and may be useful to future work for more detailed characterization of black spruce forest types in these regions.

Jameson (1965) further developed the idea of the relationship between height growth and site in a study of jack pine in the mixedwood forest section (Rowe, 1959) of Saskatchewan. The study involved six sites defined by pore pattern and moisture regime, again adapted from Hills (1952), and by cation exchange capacity of the B horizons as a measure of nutrient regime. He concluded that the three interrelated factors of soil moisture regime, soil mutrient regime and soil texture probably have the most influence on height growth of jack pine. Height growth on the four uniformly sandy sites was related to depth to water table. The best height growth occurred on the moist site, where soil moisture was obtained by capillarity from ground water near the surface, and decreased with increasing depth to water table on the very dry site, where soil moisture was supplied only by snow melt and precipitation. Height growth was related to nutrient regime as expressed by cation exchange capacity of soils at the three sites with the same moisture regime. However, nutrient regime alone does not explain the significant slowing of growth at one of these sites after age 40 years. Examination of soil analysis data shows all the soils to have a relatively uniform, high level of base saturation indicating that these soils don't differ greatly in amounts of available nutrients. Closer examination of soil particle-size distributions shows that although the textural designations are dominantly sandy loam, the site that shows reduced growth after 40 years has a significantly smaller proportion of fine sand, very fine sand and silt and therefore possibly also has less favorable moisture holding and moisture delivery characteristics than those of the other two sites. Jameson concluded that the ecological approach used here had the advantage of recognizing significant variations in height and volume growth patterns characteristics of different sites, where the site index approach, by itself, recognized only a family of harmonic curves representing all sites. Also, although there were variations in height growth within site types, they were not so great as to preclude the validity of such types as practical classes for forestry land management.

Rowe (1954) reported on comparisons of height/age data for white spruce on 700 permanent sample plots within the Riding Mountain experimental area. Height/age data were stratified according to a classification which involved grouping of soil associations or parts of soil associations on the basis of ecological similarity expressed in moisture regime and vegetation. Relatively small differences in height growth, generally less than 10 feet, were found for each moisture regime class, (dry, fresh, moist, and wet) when compared either within or between soil associations. Pooling the data from all associations showed that the sites from best to poorest were fresh (2 and 3), moist (4 and 5), dry (0 and 1), and wet (6+), although height differences were again judged to be not sufficiently large to have much significance for ordinary forestry practices. More significance however, was attached to the finding that different growth patterns occurred on some of the soil associations. The sandy soil association was marked by and initial rapid growth and a rather sudden slowing of growth after 50 years, while roughly the reverse situation occurred on the association developed on lacustrine clay. The limited amount of stem analysis data used in this tended to corroborate these results and brought into question the use of conventional site index curves to rate tree development at different growth stages.

The forest land classification developed by Mueller-Dombois (1964) for southeastern Manitoba has been of major importance in assigning productivity ratings in that region. This classification recognizes fourteen forest habitat types, including three subtypes. Each of these is described by landform occurrence, moisture regime, nutrient regime and lesser vegetation, and has been related to site index of jack pine and black spruce. Habitat types were grouped on the basis of site index into four site classes for jack pine and two site classes for black spruce. However, while black spruce site class I differs significantly from II, significant differences are found only between two groups of jack pine site classes, namely classes I and II versus III and IV. However, determination of site index by habitat type may still be important because of differences in stand development. No consideration was given to shape of site index curves and stem analysis techniques were apparently not used in the study.

Mueller-Dombois (1964) also arranged the habitat types and subtypes in order of approximate potential productivity as an aid to plantation development. This information about potential productivity was based on general observations of optimum current productivity.

Bella (1968) constructed yield tables based on 365 permanent sample plot measurements for four commercially important jack pine site types and one subtype described in southeastern Manitoba by Mueller-Dombois (1964). Significant differences were recognized in level and shape among all independent height/age curves drawn for each site on the basis of stem analysis data. The yield tables that were developed for such site types allow the forester to determine the expected course of stand development on each site type and to estimate yields at any age, even before a stand has been established.

A reconnaissance soil survey of approximately 7600 km area in southeastern Manitoba (Smith <u>et al</u>., 1964) was used as a basis to rate the productivity and regeneration of thirteen tree species on 30 soil series, three soil complexes and three miscellaneous land units. Five potential productivity classes and a non-productive or unsuitable class were used for each tree species. The five classes were based on net mean annual increment in merchantable cubic feet of wood volume, ranging from greater than 45 cubic feet per acre per year for Class A to from six to 15 cubic feet per acre per year for Class E. Mean annual increment was determined for moderately well to well stocked stands to a rotation age that varied from 70 years for jack pine to 100 years for black spruce.

The work done by Smith <u>et al</u>. (1964) was a milestone in the use of soil survey survey information to evaluate forest productivity. It still is a valuable contribution but its value is much less than it could be because of the agricultural orientation or bias of the soil survey itself. This is reflected in the fact that where the soils have agricultural value the soil series units are quite narrowly defined and mapped. Where the soils are of little value to agriculture, as is the case with the Sandilands series, the series tend to be either more broadly defined or to be mapped as undefined complexes of soil series with significantly different tree productivity. This is also apparent in the greater numbers of habitat types based on the work of Mueller-Dombois (1964) assigned by Smith et al. (1964) to broadly-defined soil series and soil complexes than to soils rated fair to good for agriculture. Even in cases of agricultural soils with generally two or, at most, three assigned habitat types, no indication is given of which habitat types are dominant or minor components, nor is an estimate given of reliability in terms of what variation is present in mapping units across the surveyed area. Another possibility is that certain soil and topographic factors important to forest growth have not been well described in definitions of soil map units. These shortcomings have made detailed interpretation more difficult and seem to account for the rather low use of the work for forest management in an area of relatively high wood demand and utilization. Similar comments apply with regard to forest productivity work done on the soils of the Lac du Bonnet map area (Zoltai, 1967).

Another reason that little use seems to have been made of this soil survey-based work for forest productivity predictions is that there is a general feeling among foresters that productivity estimates based mainly on well-stocked stands tend to be over-optimistic. This also explains the general non-use of Canadian Land Inventory forest capability ratings (Zoltai et al., 1967) by management and operational foresters in Manitoba. In defence of the CLI inventory, however, it was never intended as an operational site classification too. Its main objective was the production of maps to be published at 1:250,000 scale for use in overall planning at the provincial and national levels and it has served these broader purposes reasonably well.

Forest capability ratings were also applied to units delineated by the biophysical surveys conducted in Manitoba (Mills, 1976). These surveys cover a large portion of the northern part of the province, much of it with a poor cover of forest. However, these surveys do include some areas of commercial forest and, although they are published at a relatively small scale (1:125,000), they should supply a sound ecological basis for any future forest site classification at an operational level, whether for productivity or silvicultural purposes.

REVIEW AND CRITIQUE OF EXISTING SITE CLASSIFICATION

Manitoba Forestry Branch System

Results from the recent forest site classification information needs questionnaire (see section on use of existing information) show that site classification information needs in Manitoba are currently being met to some degree by the provincial forest inventory/site classification program. The site classification that is part of the Manitoba Forest Branch (MFB) inventory is apparently based to some extent on the work of Rowe (1957). It was developed for use with the inventory in the Interlake forest management section and later extended along with the inventory to other areas.

This site classification has a small number of relatively effective site attributes. They include: six moisture regime classes, each of which are associated with particular landform segments; six soil texture classes and one organic class; three soil depth classes, three topographic classes, and nineteen associated indicator plants as show in Table 1 from the Provincial Forest Inventory field instruction manual.

Table 1 also shows that two site classes are used for Jack pine and Tamarack while three classes are used for each of the remaining species. These site class ratings appear in the Type Aggregate designations used to summarize forest inventory data and

Table 1. Manitoba Forest Inventory Site Classification

MOISTURE REGIME	LANDFORM	INDICATOR PLANTS		SUBTYPE AND SITE CLASS					
		Abundant	Scattered	jP	wS	bF	bS	tL	tA
ARID	rock outcrop, higher gravel beach ridges	reindeer moss, creeping savin	bearberry	2	3	--	--	--	3
DRY	higher beach, outwash and moraine ridges	bearberry, creeping savin, reindeer moss, slender mountain rice	common juniper, soapberry	2	3	3	3	--	2
FRESH	lower beach, outwash and moraine ridge, slopes and intermediate terraces	twinflower, buffaloberry, common juniper, rough grained mountain rice	bearberry, bunchberry	1	1	1	1	--	1
MOIST (ground water and vadose water types)	low positions and flaring-out margins on beach and outwash OR till plains, lacustrine flats and higher flood plains	red-ozier dogwood, bunchberry, Ribes sp. naked miterwort, creeping snowberry	buffalo berry, common juniper, rough grained mountain rice, alder	1	1	1	1	1	1
VERY MOIST	depressional positions on beach and outwash and lacustrine deposits	red-ozier dogwood, naked miterwort, bunchberry, Ribes sp., alder	bog cranberry	1	1	1	1	1	1
WET	depressional patches on till and lacustrine material	alder, marsh marigold, bog cranberry		--	--	--	1	1	1
SATURATED	deep organic terrain	sphagnum sp., labrador tea, marsh marigold		--	--	--	2	2	--

NOTE:- Arid sites are generally devoid of tree cover.

Table 2. Type Aggregate, Cover Type and Subtype Example

Type Aggregate

Species Composition	Cover Type & Subtype	Site	Cutting Class	Crown Closure
bS_{10}	13	2	3	4
Although species composition is not part of type aggregate, it must be included to aid compilation.	It is softwood subtype 13 when the basal area of black spruce represents more than 71% of the total softwood basal area.	Poor growth.	Immature	71%+ ground covered by tree crowns.

in the covertype and subtype designations (Table 2) given to each individual stand mapped by the Manitoba Forest Inventory. The site classes themselves are used by the Manitoba Forestry as the basis for summarizing arial distribution of inventory covertypes within forest management units.

This site classification used as part of the provincial forest inventory is rather rudimentary but it does at first appear to supply considerable site information to relate productivity data to a more comprehensive site classification. However, moisture regime classes assigned by inventory field personnel may sometimes be at variance with indicator vegetation, and little reliance can be placed on soil and topographic classes assigned to individual stands apparently because of lack of time and training needed to do a good job of collecting this additional site information. The usefulness of this site information in conjunction with soil and biophysical survey information is evaluated in more detail in a later section of this report.

One of the apparent dissatisfactions with the current MFB site classification cited by users is that the site classes do not have the same meaning in different areas. This is somewhat surprising because recognition of inherent differences in productivity between different regions is built into the system. The trouble is that it is not done in an explicit fashion so that such productivity differences can be understood by the user. At any rate, there seems to be a consensus that the system has been useful but that something better is needed to address current site classification needs.

The fairly recent site prescription work of K. Vogel of the Manitoba Forestry Branch is based on stand and site information provided by the MFB inventory. Vogel used this information to elucidate stand development and successional trends for disturbed and non-disturbed conditions in several forest management areas. He did this by comparing tree species composition and other stand characteristics for different age classes on particular site classes. Management recommendations are given by subtype and site class for much of the forested area of Manitoba. Vogel's detailed site prescriptions may now be somewhat dated but his information on stand development and succession appears to be a valuable contribution and should be utilized in future site classification work.

Another facet of the current site-related work at the Manitoba Forestry Branch involves amalgamation of existing site information using their ARC/INFO geographic information system. The GIS has been used for a pilot study in southeastern Manitoba to overlay forest cover maps on soil maps. Information, such as cutover, fire, insect damage, silvicultural treatment, access, etc., are then summarized in terms of the combined forest cover-soil type units. The weakness of this approach lies mainly with the lack of mapped detail for soil and site characteristics. Simply enlarging the reconnaissance soil maps to the forest inventory maps scale will not supply the needed additional site information. However, a good start has been made in using available GIS facilities as a means to update and manage increased amounts of map and textual information currently available for forest management.

Regional Systems

An ecologically based regionalization has recently become available for Manitoba (Mills et al.,1985) as part of a Canada-wide program sponsored by the Canada Committee on Ecological Land Classification (CCELC, 1986b). This work recognizes ecoclimatic regions as "broad areas characterized by distinctive ecological responses to climate as expressed by vegetation and reflected in soils, fauna and water". These regions are identified and compared on the basis of their vegetation development on normal, well drained sites. They are improved over earlier divisions in that water and fauna are now explicit criteria for their recognition and characterization.

A significant improvement to the above system is provided by the work of Adams (1985) to devise a regional map base for migratory bird habitat inventory. Adams uses three hierarchical mapping levels: ecozones, ecoregions and habitat subregions. His ecozones and ecoregions are essentially the same as those of Mills et al. (1985). However the ecoclimatic region boundaries are refined to coincide with established, broad, soil-geomorphic (physiographic) units (Mills 1980, 1983). These established soil-geomorphic boundaries are the basis for Adam's habitat subregions.

This refinement is significant because it means that the upper hierarchic levels for an ecologically sound forest site classification are now essentially in place. In any event, these regional systems can now be further tested against forest site classification and mapping at operational levels.

REVIEW, ANALYSIS AND CRITIQUE OF RELEVANT SYSTEMS

The relevant classification systems reviewed here are grouped by their area of application. National systems are discussed first while those that apply mainly to individual provinces are reviewed roughly in order of their proximity and importance to the Manitoba situation.

National Systems

Biophysical land classification

Formal guidelines for this system were outlined by Lacate (1969). This system involved combination and integration of physiography, soil and vegetation for classification and mapping at various scales. Initially, the aim was to classify ecologically-significant segments of the land surface, rapidly and at small scale, to satisfy the need for a preliminary overview of forested and associated wildland resources and to provide an ecological basis for land use planning. The criteria used were to be factual and stable for a significant period of time, unaffected by fire, cutover or cultivation and therefore they should include physiography, texture, petrography and depth of surficial materials, type of underlying bedrock, soil moisture regime and regional climate.

Four mapping levels, namely land region (1:1,000,000 to 3,000,000 scale), land district (1:500,000 to 1,000,000) land system (1:125,000 to 250,000) and landtype (1:10,000 to 20,000) are included in this biophysical land classification. The "land region" was to be characterized by a distinctive regional climate as expressed by vegetation. However, because climatic data are usually not available and it is generally not clear as to which climatic data would be significant for various management purposes, Lacate (1969) proposed that major physiographic formations be used as a framework for regional climatic differences. Thus, the system at that time involved mainly a geomorphic approach with a rather arbitrary application of criteria for mapping at different scales. The concept of normal sites with stable vegetation as key regional indicators, used by Hills in Ontario and Krajina in British Columbia, was not explicit at this early stage.

Land regions were to be divided into "land districts" on the basis of a distinctive pattern of relief, geology, geomorphology and associated regional vegetation. These land districts could be considered equivalent to the site districts of Hills (1954, 1960).

Within each land district, areas with a recurring pattern of land forms, soils and vegetation, termed "land systems" similar to the Australian land system (Christian, 1958) were proposed by Lacate (1969) as the main unit for mapping forested land. Land systems strongly resembled Hills landscape units in geomorphic content.

The smallest unit in the Lacate system, called the "landtype", referred to an area of land having a particular parent material with a specific soil series and vegetation succession. The landtype was the basic unit to be used for forest productivity and management interpretations.

Further refinement of this biophysical land classification was accomplished by a program of pilot mapping studies undertaken by the Canadian Forestry Service to adapt the system for use in different parts of Canada. A major key to achieving a truly integrated ecological basis for the system was the recommendation by Jurdant (1969) that the classification and mapping of physiography, soil and vegetation in such biophysical surveys be done concurrently by a team of specialists, not by separate mapping programs to be integrated at a later date.

Recent refinements to Lacate's biophysical land classification include: a revision of terminology and addition of one more detailed category, the land phase or ecosite type (Wiken and Ironside, 1977); addition and integration of wetland ecosystems (Welch, 1977) and wildlife habitat features (Taylor, 1980).

Despite these refinements to the biophysical land classification system to make it an ecological land classification tool, one consistent system has not emerged for uniform application across the country. Instead, local modifications of the system have been developed and applied for particular conditions and purposes in different regions. Terrain conditions in these particular areas have made identification of some of the hierarchical levels difficult or unecessary. For example, the Banff-Jasper biophysical study (Holland and Coen, 1982, 1983) bases its ecoregion divisions on elevational zones and does not require ecodistrict subdivisions. Also, conceptual entry to this modified classification is at the land system or "ecosection" level while the landtype or "ecosite" is the main unit used for mapping at the working scale of 1:50,000. Another difference is the closed or controlled legend format used by this study as compared to open or uncontrolled legends used in other projects, for example the biophysical surveys carried out in Manitoba (Borys and Mills, 1978; Mills, 1976; Veldhuis, 1977). These differences together with the rather general guidelines for application tend to make correlation and use of the Lacate ecological (biophysical) land classification difficult. The Lacate methodology aims at total integration of land form, lithology, relief climate, soils and vegetation (Bailey et. al. 1978). However, to develop such a hierarchy requires a high level of understanding of the interrelations among land elements, as well as an equally high level of agreement among users on specific criteria selected to define units at each hierarchical level (Driscoll et al., 1984).

A major difficulty in using the ecological (biophysical) land classification nationally has been lack of either a generally accepted method of description or a framework for vegetation classification in Canada. These needs are only currently starting to be addressed in the form of a draft proposal by the Canada Committee on Ecological Land Classification Vegetation Working Group for a vegetation classification system for classifying and inventorying vegetation across Canada (CCELC, 1986). The proposed system is modelled on the vegetation classification system being developed for Alaska (Viereck and Dyrness, 1980). The Canadian system is intended to be based purely on vegetation characteristics in order to develop consistent criteria for the various hierarchical levels. The Alaskan system still uses some physiographic and soil features for designating certain classes. The Canadian system (CCELC,1986a) proposes to eliminate these non-vegetation criteria. The main feature of the system is that the criteria in the upper three levels are physiognomic, e.g. Tree, Tree-shrub, Tree-shrub-moss, etc., that reflect vegetation structure rather than species composition. In addition to allowing correlation with detailed local systems already in place, this feature also allows use for rapid vegetation inventory with remote sensing technology.

The ecological (biophysical) land classification system has received a great deal of attention and has been widely applied in Canada for nearly twenty years. Probably its main contribution has been to demonstrate the usefulness of a survey or landscape approach to ecological land classification. The survey approach (Rowe and Sheard, 1981) seeks first to delineate ecologically-significant landscape segments on the basis of current ecological theory stated explicitly as possible. The maps so generated are regarded as theory-generated hypotheses to be tested by sampling and analysis by which the classification is refined through a process of successive approximations. Current availability and almost routine application of numerical and statistical techniques strongly support this approach as a continuing viable alternative for site classification work.

Canadian soil survey system

The Canadian soil survey system is based on the Canadian System of Soil Classification (CSSC, 1978). The classification system which has been developed over the last 60 to 70 years is a taxonomic system with categories based purely on soil properties. The system currently has five levels of generalization or categories. The "Order" is the highest level of generalization. Within this level, soils are grouped according to properties that reflect the nature of the dominant soil-forming processes. Examples include Chernozemic soils with dark colored topsoil as a result of being formed under grassland versus Luvisolic soils with light gray topsoils developed under forested conditions.

The "Great Group" class is a subdivision of the soil order and is based on properties that reflect differences in the strength of the dominant soil-forming process or a major contribution of another process to the dominant one. For example, in the Chernozemic order the great groups are differentiated on the basis of the topsoil color. This property is directly related to the amount of organic matter present, ranging from least in Brown Chernozemic soils formed under dry climatic conditions to most under the Black Chermozemic soils under moist conditions. The Dark Gray Chernozemic soils occur at the grassland-forest transition where breakdown and removal of organic matter and clay from the topsoil become important processes.

There are three more subdivisions below these first two levels. The "Subgroup" defines the central concept of the great group (Orthic) or certain variations from that concept toward other soil orders, for example, a Gleyed Gray Luvisol, where the typical features of a Gray Luvisol are modified by the presence of excessive soil moisture to somewhat resemble soils of the Gleysolic order. The subgroup is identified by a distinct assemblage of soil horizons.

The "Family" is a subdivision of the subgroup which identifies a group of soils that is fairly homogeneous in mineralogy, texture, and soil climate as well as genetic horizons. Because of this relative homogeneity statements can be made about the use and management of the soil families in relation to plant growth, hydrology and engineering characteristics.

The soil "Series" is a subdivision of the family and comprises a group of soil individuals (a polypedon) developed on similar parent material with a distinct assemblage of soil horizons whose features, such as color, texture, structure and thickness, fall within narrowly defined limits. This level is regarded as the most important for considerations of use and management because it refers to real soil entities in the landscape.

Soil resource inventory does not map soil taxonomy. If possible, a soil map unit should contain one class of soil with as few inclusions as possible, so that all of its area can be managed the same way. However, natural soil variability in the landscape generally makes this difficult to achieve. Instead, the goal is to reduce this natural heterogeneity to an acceptable level consistent with the stated purposes of the particular soil survey. These purposes determine the scale, intensity and recommended format of the survey as outlined by the Mapping Systems Working Group (LRRI. 1981). Soil taxonomy, usually the soil series level, is used as an efficient means to name map units and their major components and to communicate information about characteristics important for their use and management. Soil phases - subdivisions of taxonomic units based on external soil characteristics such as stoniness and topography - are used to highlight map unit characteristics important to particular uses.

As pointed out previously, soil surveys are not site classifications in themselves but because soils are classified and mapped within a physiographic framework (surficial materials and landforms) soil surveys provide a good basis for integration of vegetation for ecological site classification and inventory. Detailed characterization of soil properties, many of them important to forest growth and productivity, and their correlation to terrain features greatly aid with their systematic recognition and delineation in a forest site classification and mapping program.

Provincial Systems

Hills physiographic site classification

According to Jones (1969) the conceptual basis of the holistic approach used by Hills (1952, 1960) is to develop a theoretical, more or less arbitrary model of the environment, measure or estimate the necessary variables, and incorporate them in the model. It is actually a classification of the physical environment, and the basic units are physiographic site types. However, vegetation helps to set the physical definitions of the physiographic site types and aids in their field identification. Plant communities on each physiographic site type are described and their successional relationships discussed after the sites have been classified.

Hills recognized three environmental regimes: climate, moisture and nutrients. Each is treated separately but the same environmental elements are often considered in more than one regime. For example, soil colloids are significant to both moisture and nutrient regimes, and topography is included in both climate and moisture regimes.

Scalars for each of these three regimes are intended to be applied within a given macroclimate. Macroclimate is held relatively constant by working within a given geographic region, for example, a Rowe (1959,1972) forest section or a Hills site region. Within such a region, microclimates are classified into ten levels, from warmest to coldest, based on topographic position, air drainage and presence of a water table at or near the soil surface. The other two regimes are also divided into ten intensity classes. Assignment to the moisture scale is based on soil pore pattern as a function of soil texture and structure, and on soil depth, topographic position, and water table. Nutrient regime is based on soil pore pattern, parent material composition, and soil profile development.

The concepts embodied in the Hills system, especially those at the higher levels, have provided a useful basis for later site classification work in Ontario (Jones et al., 1983; Sims,

1985) and elsewhere (Zoltai et al., 1967).

Ontario forest ecosystem classification

Most of the recent site classification work in Ontario has concentrated on the development of relatively simple field-based classifications rather than on the creation of detailed hierarchical schemes. Jones et al., (1983) have integrated land form, soil and vegetation characteristics to develop a field-based forest ecosystem classification for the claybelt area of northeastern Ontario. In this classification, a dichotomous key is used to allocate forest ecosystems to one of fourteen operational groups. The "Operational Group" is defined as "a landscape segment with mature forest which has an identified range of vegetation and soil conditions and probable responses to specific forest management prescriptions". Work leading to development of forest ecosystem classes and the allocation key showed that vegetation in the area was a good indicator of the major soil and site conditions. Low relief and the widespread occurrence of organic blankets and veneers in the area made direct assessment of controlling soil and site factors especially difficult for the forest manager. For these reasons, the key first allocates forest stands to one of twenty-three vegetation types. The second part of the key incorporates important soil and site features to make the final allocation to one of the operational groups. The system (Jones et al.,

1986) also utilizes aerial photo interpretation for mapping and inventory of Operational Groups and, depending upon the scale of inventory and landscape complexity, permits practical delineation of two or more Operational Groups as well as pure, single-class units. These combination units are understood and managed in terms of the kind, proportion and limiting nature of the component operational groups. To date, mapping seems to have been a relatively minor part of this program. The main follow-up effort has been devoted to training forest managers to use the allocation keys and appears to have been relatively successful. Any keys for identification of forest ecosystems under Manitoba conditions should probably be modelled in a similar manner. One major criticism of the system is the apparent lack of explicit forest productivity ratings and ranges for the operational groups. A similar kind of forest ecosystem classification is being extended to the north central region of Ontario (Sims, 1985).

Krajina biogeoclimatic system

The basic concepts embodied in this system have had a rather pervasive influence on forest site classification throughout Western Canada. Biogeoclimatic climatic "zones" in British Columbia were originally characterized in terms of their dominant, most stable vegetation associations found on mesic or normal sites (Krajina, 1965, 1972). Biogeoclimatic subzones were subdivisions of zones characterized by having similar environmental "undertones" either in their soils or vegetation, especially as expressed by their herb and moss layers. Above the biogeoclimatic zone the higher zonal units (biogeoclimatic regions and formations) were identified by having similar environmental "overtones" particularly in their macroclimates, soils, and physiognomy of their tree and shrub vegetation. The system recognized eleven zones, five of which were divided into a dry and wet zone on the basis of precipitation, while an alpine zone was broken down into two altitudinal subzones. The eleven zones were grouped into seven "regions" and these further grouped into five formations according to Koppen's climatic classification. Krajina did not publish any maps of these zones or regions. However, since adoption of the system by the British Columbia Ministry of Forests, mapping at these levels has been extended over most of the Province.

During this process, the biogeoclimatic zone came to be regarded more as a geographic entity having similar patterns of energy flow, biogeochemical cycling, vegetation and soils as the result of a broadly homogeneous macroclimate (Annas and Coupè, 979). The biogeoclimatic zone is generally named after one or more of the shade-tolerant trees which can regenerate on most of the habitats.

Biogeoclimatic subzones are recognized by Annas and Coupè (1979) as subdivisions of a biogeoclimatic zone on the basis of plant associations on mesic sites. These subzones are named by tree species which are shade tolerant and able to regenerate and perpetuate on mesic sites (Klinka, 1977). The biogeoclimatic subzone is now recognized as being essentially synonymous to the ecoclimatic region or ecoregion (Ecoregion Working Group, 1986) and the site region of Hills (1960).

Although maps of biogeoclimatic zones and subzones have been published for several areas of British Columbia, for example Annas and Coupè (1979) and Mitchell et al. (1981a, 1981b), little mapping has been done using the lower category levels of the Krajina system. Instead, as pointed out by Klinka (1977), the methodology has concentrated on application of two integration levels of Krajina's classification: the biogeoclimatic subzones discussed above and the edatopic (edaphic) grid matrix.

The edatopic grid matrix is composed of two major soil gradients: moisture gradient or hygrotope with eight classes, and nutrient gradient,or trophotope, with five classes. The whole grid contains forty squares (edatopes) with each square designated by a combination of the two gradients. More recent versions have as many as fifty-four edatopes.

The methodology involves detailed descriptions of plant associations within biogeoclimatic subzones and their characterization by values of moisture and nutrient regimes so that they can be projected onto the two-dimensional edaphic grid. As a result each edatope on the grid matrix for a given biogeoclimatic subzone corresponds, in whole or in part, to a particular plant association. Management interpretations and prescriptions, such as tree species selection and prescribed burning developed for the plant associations with the subzone (Klinka, 1977; Green et al., 1984), are then conveniently indicated by symbols and patterned overlays on the grid matrix.

Characterization of the plant associations in terms of productivity has apparently not received a great deal of attention although early workers did provide some data on site index (Bell, 1965; Orloci, 1965) and gross volume (Brooke, 1965). However, productivity ratings in terms of site index and mean annual volume increment can be readily incorporated as shown by the recent work of Corns and Annas (1986) in Alberta.

The biogeoclimatic system has been extended to portions of Alberta at the zone and subzone levels (Kojima and Krumlik, 1977; Kojima, 1980) and further work carried out to identify and characterize plant associations (Kojima, 1984). However, there has not been complete adoption of the biogeoclimatic system in Alberta and it has had considerable competition from parallel systems at regional category levels (Strong and Leggat, 1981) from approaches and also at operational levels (Archibald et al., 1984) from approaches with concepts closer to those of the biophysical land classification of Lacate (1969).

A review of the current status and rationale of the biogeoclimatic ecosystem classification (BEC), as it is now called, is given by Pojar et al. (1986). A further shift in terminology of the system is evident in that these authors have broadened the site association category to apply at the biogeoclimatic zone level, while new categories, the site series and the site type, are created for the biogeoclimatic subzone and site levels, respectively. An example of use of the current system for operational mapping and production of forestry interpretative maps is given by Lindeburgh and Trowbridge (1986).

In summary, the strength of the biogeoclimatic system of Krajina lies with its great interpretative capacity deriving from its emphasis on plant associations being closely integrated with environmental factors. Evidence of practical application of the system is not lacking and the major British Columbia forest companies have been using the system for their own purposes for more than a decade. However, its major disadvantage is the lack of an operational mapping methodology by which the system could be more closely controlled and refined. This shortcoming to have arisen mainly from a lack of interest in or an understanding of maps and mapping by the system's major practicioners. It may also be responsible in large part for the considerable difficulty with biogeoclimatic terminology arising from somewhat different definitions and modifications by various workers involved in development of the system.

Saskatchewan ecological site capability classification

Ecological site capability classification (Liu, 1984) is a relatively recent outgrowth of both the present Saskatchewan forest inventory program (Benson, 1979) and is based on criteria drawn from the earlier work of Kabzems et al. (1976). This earlier work provided an ecological grouping of forest communities in the mixedwood section of Saskatchewan. The work was based on the fundamental concept of the ecosystem as a mutually related biotic community situated on particular surficial materials and located within a specific regional climate. Forest community types were defined and grouped into series on the basis of surficial material texture and soil drainage. Because the same forest community types were found to develop on similarly textured materials of different origin, for exaple, clay loam till and clay loam glaciolacustrine, texture rather than origin of surficial materials was recognized as one of two major criteria for identifying the forest ecosystems recognized by this system. These forest ecosystems were also characterized in terms of wood yield and recommendations were made for harvesting and regeneration methods. No much specific information is given about forest succession but the all-pervading influence of fire on succession is recognized. The work of Kabzems et al., (1976) is also valuable because at least some of the site information should be transferrable to the mixedwood forest section of Manitoba and would enhance the compatability of any unified forest site classification system developed for that province.

In the current Saskatchewan system, site capability is defined as "the mean annual increment (MAI) in merchantable volume (cubic meters/hectare/year) which can be expected for a forest area, assuming it is fully stocked by one or more tree species best adapted to the site, at or near rotation age". Forest cover types are placed in a two-dimensional site matrix on the basis of soil texture and soil drainage. Seven standard soil drainage classes (Canada Soil Survey Committee, 1978) and four broad textural classes (Soil Survey Staff, 1951) are used to define the drainage and texture components of each grid cell. Each grid cell corresponds to an individual class or combination of two classes on each co-ordinate. An organic soil class is also recognized. Grid cells are grouped into four site productivity classes on the basis of mean annual increment at rotation age for white spruce, black spruce, jack pine and trembling aspen. The method involves the use of soil maps in conjunction with aerial photographs for initial stratification of soil texture and drainage components in relation to forest covertypes, followed by field work to collect productivity data.

One disadvantage of the method (Liu, 1984) is that it requires a sufficient amount of productivity data before analysis can be carried out and capability classes determined. Moreover, sampling based only on forest covertypes may give insufficient data because samples are not necessarily distributed by capability classes. In that event, more sampling is required for proper analysis.

Another major drawback is that results to date indicate that only intermediate values of texture and drainage on better sites provide the most reliable estimates of site productivity. Productivity predictions for extreme values of texture and drainage are much less consistent. These poor results are presently attributed to confounding effects of inappropriate stocking and species combination on poorer sites. Further refinement in analysis and testing are planned in an effort to solve this problem so that the system can be used operationally.

An important advantage of the system is that sites can be classified by soil and site features in the absence of tree cover. However, the system may not be wholly adaptable to Manitoba conditions. For example, it does not recognize the presence of two-storied soil parent materials on genetic soil horizons with textures significantly different than those of the parent materials. The system also recognizes essentially only moisture regime classes and does not consider differences in nutrient regime which may also be very important under Saskatchewan as well as Manitoba conditions.

New Brunswick forest site classification system

A four-level site classification has been devised for New Brunswick on the basis of climatic regions, geomorphic districts, regolith systems and site types (Van Groenewoud and Ruitenberg, 1982; Van Groenewoud, 1985). In this system, the climatic region is a land area with a distinctive macro-climate established on the basis of multivariate analysis of climatic data. The geomorphic district is an area characterized by the distinct surface expression of a major bedrock formation or group, modified by glaciation and fluvial processes. These two upper levels are comparable to the ecoregion and ecodistrict levels of the biophysical land classification (Lacate, 1969). However, these two levels in the New Brunswick system are not hierarchical and a particular geomorphic district may occur in more than one climatic region.

The third level, regolith system, is also not strictly hierarchical and may lie within more than one geomorphic district (Van Groenewoud, 1985). It is characterized by a) the surface expression and texture of its land forms and b) by its lithologic-mineralogic composition and structure (presence or absence of cleavage and fracture in the rock fragments). Under climatic conditions of relatively high precipitation present over New Brunswick, soil nutrients are quickly removed from the rooting zone by leaching and deep percolation into the ground water. Both lithology and structure of the rock fragments are then very important in determining the rate of plant nutrient production by weathering in this essentially open system.

The forest site type, the lowest level in the system, is based on local criteria including: microdrainage and soil profile characteristics which together influence the variations in soil drainage and plant nutrient production within a particular regolith system; and the important micro-climatic factors of slope aspect and position on slope. Van Groenewoud and Ruitenberg (1982) claim to have avoided the use of vegetation as an internal part of the system because of the disturbed conditions present in much of the New Brunswick forest. However, the reference manual produced by the New Brunswick Forest Site Classification Technical Committee (NBFSCTC, 1985) includes vegetation in keys for identification of site type groups known as "treatment units". The treatment unit is defined as "an operationally-sized portion of the landscape with soil and vegetation characteristics that responds to disturbance or silviculture in a predictable way."

Treatment units are determined on the basis of analysis of landform, soil and vegetation plot data using computer classification and ordination programs, such as TWINSPAN and DECORANA. Once the TU's have been determined for a particular study area which has been stratified as to climate region, geomorphic district, and regolith system, classification keys are built to aid with their field identification and mapping.

The keys are analogous to those used in Ontario (Jones et al., 1983) except that here, primary emphasis is placed on soil and landscape features.

Mapping methodology consists of area stratification to the regolith system level using the climatic regions (Van Groenewoud, 1983) and the available geologic, geomorphic, and soil information. Then the TU's are identified and delineated by a combination of aerial photo interpretation and field site examination. The objective is to delineate individual treatment units with a defined range of variability and response to management treatments, but it is not clear from examples given in the reference manual (NBFSCTC, 1985) what amount of variability actually occurs within delineated units.

The analytical methodology used to develop the New Brunswick system, like that for Ontario (Jones et al., 1983) could also be utilized for site classification work in Manitoba. However, the "regolith system" level of the New Brunswick classification is not recommended for use in Manitoba. As mentioned previously, it applies to an essentially open system of plant nutrient production by mineral weathering and rapid nutrient removal by deep leaching under relatively moist climatic conditions. In contrast, something closer to a closed nutrient cycling system prevails under generally drier Manitoba conditions.

RESULTS OF USER NEEDS QUESTIONNAIRE

The major objective of this questionnaire is to identify current and future needs for site classification information in Manitoba and to document the nature of the needed information. The subobjectives, as defined for questionnaire development, are as follows:

1. To identify for each major user, the management programs which require the availability of site classification information.

2. To identify for each major user, the management decisions which require site classification information and to determine whether their requirements are statuatory or optional.

3. To identify the site classification information which is required for each program or decision in terms of location, scale and content.

At the beginning of August, 1986, the questionnaire was distributed to selected persons professionally involved with management and use of Manitoba forests and judged to have some requirements for site classification information. The affiliations of these individuals includes private companies as well as provincial and local federal forestry agencies. The two main target groups were the provincial forest agency and the major private companies, Abitibi-Price Inc. and Manfor Ltd.

Thirty questionnaires were distributed to the three sectors mentioned above. A total of eighteen completed forms were returned. However, forms completed by individuals from the industrial sector represented several individual users from that sector. As a result, the number of returned forms can be considered well over fifty percent. Conclusions based on these results can therefore be regarded as reasonably representative of all sectors. A copy of the questionnaire is provided in Appendix 2.

Information Users and Management Programs

Table 3 summarizes the management programs and decisions in terms of number of respondents, number of times cited by respondents, and respondent groups. These initial results indicate that site classification information for forest renewal/reforestation programs are of most concern to the broadest range of users. This is also reflected in the greatest variety and larger numbers of citations for associated management decisions requiring site classification information. Site information for stand improvement and forest inventory/productivity programs follow in descending order of importance. After that, site information for harvesting and timber management/utilization programs appears to be of roughly equal concern. The other programs shown in Table 3 have a low

Table 3. Summary of Management Programs and Decisions Using Site Classification Information

Management Program	Number of Respondents	Management Decisions	Number of Times Cited	Respondent Groups
Harvesting	2	-Harvesting system and method	2	Regional Foresters(1)
		-Road Location	1	Industry Foresters(1)
		-Harvesting Plan	1	
Forest Renewal Reforestation	9	-Method of site preparation	6	Regional Foresters(2)
		-Species to be planted	5	Silviculture Foresters(2)
		-Tending treatments	5	Industry Foresters(3)
		-Matching stock type to site	3	Research Foresters(2)
		-Matching stock species to site	2	
		-Evaluation of regeneration	2	
		-Selection of most productive sites	1	
		-Monitoring of F.R. activities	1	
Stand Improvement	4	-Priorization of sites	3	Regional Foresters(2)
		-Projected stand development	1	Silviculture Foresters(1)
		-Treatment required	1	Industry Foresters(1)
		-Location of seed orchards	1	
		-Selection of plus trees	1	
Forest Inventory Productivity	3	-Calculation of Ann. Allowable Cut	2	Survey Foresters(2)
		-Location of temporary sample plots	1	Industry Foresters(1)
		-Location of permanent sample plots	1	
		-Production of volume tables	1	
		-Development of growth and yield models	1	
		-Location of forest land	1	
Timber Management Utilization	2	-Allocation/Licenses	2	Timber Man. Forester(1)
		-Long term planning	1	Regional Foresters(1)
Jackpine Budworm Management	1	-Insecticide application	1	Forest Protection
		-Silviculture treatments	1	
		-Salvage Operation	1	
Spruce Budworm Management	1	-Insecticide application	1	Forest Protection
		-Salvage Operation	1	
Dwarf Mistletoe Management	1	-Sanitation in juvenile stands	1	Forest Protection
		-Post harvest sanitation	1	
		-Premature harvest	1	
		-Host tree removal	1	
Forest Fire Behavior	1	-Fuel type mapping	1	Research Foresters
Economics of Intensive Forest Management	1	-Correlation of site with silviculture treatments	1	Research Foresters

number of respondents but are not inconsequential because they show a broad range in the kinds of associated management decisions that can use some site classification information.

Types of Site Information Required

The responses to question 7 are summarized here because they are a logical follow-up to the preceding summary of responses on management programs and decisions. Unfortunately, the types of site classification information associated with individual management programs cannot be reported because only three respondents completed separate Part II questionnaire sections for each management program cited. Responses to question 7 are, however, summarized by all respondents (Table 4) and by respondent groups (Table 5).

The overall summary of ratings in Table 4 shows ratings given to each type of site information by all respondents expressed as a percentage of the total number of responses. Total responses in each case are shown in the column at the right side of the table. These responses show that a dominant portion (greater than 40 percent) of all respondents rated the following 15 information types as highly useful (classes 4 and 5) for their management programs:

Table 4. Types of Information Required by All Respondents

Type of Information	Not Used	Usefulness(1) Slight 1	2	3	4	High 5	Number of Times Cited
Climate zone/Ecoregion	15	-	8	39	23	15	13
Vegetation:							
- Cover type	-	-	-	18	24	58	17
- Physiognomic group	31	15	-	23	-	31	13
- Association	7	-	-	36	21	36	14
- Dead and Down	-	-	-	-	-	100	1
Surficial Material	6	11	6	6	43	28	18
Landform	6	-	-	25	38	31	16
Topography	6	6	6	29	35	18	17
Slope	6	-	6	41	29	18	17
Moisture regime	6	-	-	-	41	53	17
Depth to Bedrock	6	-	12	24	34	24	17
Soil:							
- Gt. Group, Subgroup	12	6	12	-	41	29	17
- Association	22	18	18	12	12	18	17
- Profile description	18	-	34	18	18	12	17
- Humus form	18	6	18	6	34	18	17
- Texture	6	-	6	18	35	35	17
- Pore pattern	40	18	6	18	6	12	17
- Structure	18	18	-	18	28	18	17
- Drainage	6	-	-	12	35	47	17
- Chemical Properties	34	24	6	18	6	12	17
- Engineering Properties	52	6	18	12	6	6	17
Ratings:							
- Erosion	18	18	18	18	28	-	17
- Forestry use (CLI)	13	7	-	-	20	60	15
- Wildlife use (CLI)	50	7	22	7	7	7	14
- Recreational use	33	-	26	8	-	33	12
- Engineering use	76	8	8	-	8	-	13

(1) Figures reported here are percentages of total number of times cited

	Percent
- Moisture regime	94
- Forest cover type	82
- Soil drainage	82
- Forestry use rating (C.L.I.)	80
- Surficial material	71
- Soil texture	70
- Soil Great Group, Subgroup	70
- Landform	69
- Depth to bedrock	58
- Vegetation Association	57
- Topography	53
- Soil humus form	52
- Slope	47
- Soil structure	46
- Physiognomic group	44

Similarly, a dominant proportion of respondents rated the following four site information types as a moderate to high (classes 3, 4 and 5) requirement for their management programs:

	Percent
- Climate/Ecoregion	77
- Erosion rating	46
- Soil association	42
- Recreation use	41

Of the remaining six information types shown in Table 4, five including soil pore pattern, soil chemical and engineering properties, wildlife and engineering use ratings were dominantly either not used or rated a low to moderate (classes 1, 2 and 3) requirement for various management programs. The remaining information type, dead and down is not considered here because there was only one respondent.

The trend in site information type requirements by respondent groups shown in Table 5 appears generally similar to that shown for all respondents. An important difference, however, is that in many cases, the variation within groups is equal to or greater than that between groups. Some of this variation can be attributed to the lack of separation of information requirements for individual management programs as mentioned before. For example, the one industrial forester who did list separate requirements for different programs rated soil engineering and related properties higher for harvesting than for forest renewal programs. However, distinctions such as this could not be discerned in responses from the two other respondents returning more detailed answers to question 7. The main conclusion here is that there appears to be a sizeable range of opinion within respondent groups as to what types of site information are essential for particular programs.

Table 5. Types of Site Information Required by Each Respondent Group

Type of Information	REG	SIL	IND	SUR	PRO	FIR	TIM
	Respondent Group						
Climate zone/Ecoregion	H	O-H	O-M	O-H	M	H	O
Vegetation:							
- Cover type	H	H	H	H	H	H	H
- Physiognomic group	H	O-H	O-H	O-H	L-M	M	-
- Association	M-H	M-H	O-H	H	M-H	H	-
- Dead and Down	-	-	-	-	-	H	-
Surficial material	H	M-H	H	H	L-H	L	O
Landform	M-H	M-H	H	O-H	M-H	M	O
Topography	M	M-H	H	O-L	M-H	H	L
Slope	M	M-H	M-H	L-M	M-H	H	O
Moisture regime	H	H	H	H	H	H	O
Depth to bedrock	M	H	H	M-H	L-H	-	O
Soil:							
- Gt. Group, Subgroup	H	L-H	H	O	H	L	L
- Association	M-H	O-H	M-H	O-H	L	L	O
- Profile description	L-H	L-H	L-H	O	L-M	L	O
- Humus form	L-H	L-H	L-H	O-H	O-M	H	O
- Texture	M-H	H	H	M-H	M-H	L	O
- Pore pattern	M	O-H	O-H	O	O-L	O	O
- Structure	M-H	O-H	H	O-H	L-M	L	O
- Drainage	H	H	M-H	H	M-H	H	O
- Chemical properties	M	O-H	O-H	O	L	O	O
- Engineering properties	L-M	O-H	O-H	O-L	O	O	O
Ratings:							
- Erosion	L-H	L-H	M-H	O-H	L-H	O	O
- Forestry use	H	H	O-H	O-H	H	H	L
- Wildlife use	-	O-L	O-L	O-H	O	H	L
- Recreational use	-	O-L	O-L	O-H	H	H	L
- Engineering use	-	O-L	O-H	O	O	O	O

1. Respondent Group
   - REG - Regional Foresters
   - SIL - Silviculture Foresters
   - IND - Industrial Foresters
   - SUR - Survey/Inventory
   - PRO - Forest Protection
   - FIR - Fire Research
   - TIM - Timber Management

2. Rating Levels
   - O - Not Used
   - L - Low Usefulness (Class 1,2)
   - M - Moderately Useful (Class 3)
   - H - Highly Useful (Class 4,5)

Scale of Mapped Information

Questions 5 and 6 address the matter of scale preference. The responses to question 5 grouped by all respondents show a marked preference in favor of a scale around 1:20,000. The margin of preference is greater than 2 to 1 over the next larger scale (1:5,000) or the next smaller scale (1:50,000). Other smaller scales were not mentioned. Greater variation is again shown within respondent groups. While industrial, survey, and protection foresters are predominantly in favor of 1:20,000 scale, silvicultural foresters are evenly split between 1:20,000 and 1:5,000 scales. Regional foresters are evenly split between 1:20,000 and 1:50,000 scales. Fire research and timber management foresters favor a 1:50,000 scale.

Responses to question 6 with regard to the usual size of areas involved in management decisions showed the predominant range to include a roughly even split among the first three classes (less than 10 acres, 160 acres or less, and 160 to 640 acres). No clear divisions were evident among most respondent groups although protection and timber management foresters did tend to be involved with areas much larger than 640 acres.

Responses to question 6 with regard to the smallest size of areas involved in management decisions are predominantly in favor of the specific site (less than 10 acres). Timber management, perhaps not surprisingly, was the exception with a minimum size of 1 to 10 townships.

Location of Site Information Requirements

Responses to question 4 regarding location of areas requiring forest site classification information for management decisions in the short term (1 to 5 years) shows a roughly even preference for the following seven forest management sections: Pineland, Interlake, Mountain, Saskatchewan River, Highrock, Nelson River and Lake Winnipeg East. Long term listings were not completed by many respondents but there is some tendency to include site information from all forest sections for longer term decisions among those who did complete this part of question 4.

Information Sources and Format

Respondents are asked in questions 8 and 10 to indicate where they presently obtain their needed site classification information and how useful they found each source for their particular programs. Responses to question 8 showed that forest cover maps are presently the predominant source. This may be so because nothing else with the same amount of detail and coverage is so generally available. Responses also revealed extensive use of special in-house surveys, fuel type mapping and various types of on-site investigations.

Responses to question 10 with regard to specifics of meeting present needs for site information corroborate this extensive use of in-house data collection and mapping to supplement the forest inventory information.

Also revealed was the relatively low usage of soil survey maps and CLI forest capability maps. Margin notes by a few respondents suggest that lack of coverage and insufficient detail are two reasons for low use of soil surveys. Lack of detail and perhaps some question of content appear to be major reasons for low use of CLI maps.

Responses to question 9 involve rating the usefulness of particular formats in providing forest site information. Although there are some exceptions within groups, respondents now feel that the most useful information comes from site specifice data and map displays of original data. There also appears to be a general willingness to consult text descriptions of original map elements. More respondents, however, feel that mapped displays of secondary derived information (eg. CLI) are of no or little use than those who report moderate to high usage. There are again few clear preferences within respondent groups. Silvicultural foresters alone show a uniformly high preference for site specific data. Regional foresters, however, are fairly uniform in having a moderate high regard for map display of original data. Similarly, while most respondents find text descriptions of original map elements useful, only regional and survey foresters find them to be of uniformly high usefulness. Extreme variation is characteristic of preferences within groups for map displays of secondary derived information (eg. CLI).

Summary

The main results of this questionnaire are as follows:

1. High variation was found within respondent groups with regard to kinds of site information required for particular forest management programs and decisions.

2. A 1:20,000 map scale is favoured by most respondents.

3. Silvicultural foresters are uniformly in favour of site specific information.

4. Original data (map and textual) rather than interpreted data is favoured by most respondents.

5. Use of special in-house studies and surveys to obtain needed forest site data is rather common and indicates that existing site information is in many cases not adequate for current needs.

Overall, these results reveal that Manitoba users of site classification information seem prepared to derive this information from maps as well as from more site specific sources. In fact, the consensus in favour of site maps at 1:20,000 scale may indicate that many users would be satisfied to get most of

their site information from maps without regard for considerably higher costs of producing reliable mapped information at relatively large scales. At any rate, the results of the user needs questionnaire strongly suggest that any unified site management classification system proposed for use in Manitoba should involve both a mapping approach and a site specific approach so that different users can identify and deal with their own key problem areas.

6C

PROPOSED SITE CLASSIFICATION SYSTEM FOR MANITOBA

Usefulness of Existing Information

The existing sources of site classification information in Manitoba include the following:

1. Canada-Manitoba Soil Survey Program: Agricultural soil surveys completed under this program cover extensive portions of the forested area of Manitoba. The benefit of such surveys for forest site classification is that they provide detailed information about soil characteristics and, their occurrence across the landscape. In addition, most of these soil surveys provide information about the potential productivity of forested soils in the survey areas, and several also refer to other research information about silvicultural treatments needed for successful forest regeneration for particular soil conditions. General information is usually given about the dominant forest cover associated with particular soil map units and is a good starting point for more detailed integration of soil and vegetation as part of a forest site classification.

   An immediately apparent major disadvantage of these soil surveys is the relatively small scale, generally around 1:125,000, of their mapped information. Soils areas mapped at this scale usually delineate landscape segments with several associated soils which occur in repetitive fashion at particular topographic locations. That is, soil occurrence within these delineated areas has to be understood in terms of topographic location as related to the occurrence of local surficial geological materials, rather than assumed to be of uniform areal distribution. The important implication here is that detailed information about forest cover type-soil, and topography relationships can not be obtained by simply overlaying the covertype map on reconnaissance soil maps enlarged to covertype map scale.

2. Biophysical Survey Program: These surveys provide an extensive, ecologically-based inventory of soil and forest conditions in the northern part of Manitoba. The integration of soil and vegetation characteristics provided by these ecological surveys is superior to that provided by the soil surveys to the south. However, the scale of mapping is again small (1:125,000 to 1:250,000) and the comments above regarding derivation of information from map overlays apply even more. Furthermore, because of the rapid reconnaissance nature of these biophysical surveys and the low priority for follow-up work, much of the vegetation data collected during the surveys has not yet been utilized in a systematic manner to identify and characterize forest site classification units. Such units could serve as a valuable basis for more detailed site classification work in these and possibly also in adjoining areas.

3. Canada Land Inventory (CLI) Program: Forest land capability classification coverage extends over all of the forested area of Manitoba. It provides estimates of potential productivity based on the kind and degree of a series of factors judged to be limiting to forest growth and yield. Complete coverage of the forested area of Manitoba is provided by this inventory. However, the published map scale is again small (1:250,000) and the complex units depicted do not necessarily have a close association with basic surface geomorphological patterns. Such association of CLI units with basic landform features could have added greatly to the usefulness of the CLI inventory. The CLI program was carried out for specific purposes within a specific time frame and did serve these purposes reasonably well. But the relatively short term usefulness of its interpreted information severely limits its value as an aid to present forest site classification work. The CLI forest capability work in Manitoba continues to be helpful because the potential productivity ratings were tied to individual soil series, taxonomic soil units that can more closely integrate environmental factors with biological productivity.

4. Earlier Ecological Site Classifications: The Hills physiographic site classification as modified by Rowe (1954, 1957), and the habitat types of Mueller-Dombois (1964, 1965), provide a basic but rather sketchy framework for further site classification work at an operational level. The Mueller-Dombois system provides abundant biophysical detail but is

restricted to forests in southeastern Manitoba. The Hills-Rowe system applies to all the forested area but because it is still primarily a physiographic site classification, it provides more physiognomic than floristic information on vegetation communities associated with the physiographic site groups. Furthermore, both these classifications have had very minimal application for mapping and, as a result, their use at an operational level is still essentially untested.

5. Provincial Forest Inventory: This inventory carried out by the Manitoba Forestry Branch now covers all of the forested area at a 1:15,840 (four inches per mile) scale. It provides a wealth of information on forest productivity but the associated site classes based on productivity are rather rudimentary and are not presently ordinated within a hierarchical climatic-physiographic framework. However, results of the user questionnaire reveal that this inventory currently serves as the major source of forest site information in Manitoba. Consequently, the present exercise to evaluate existing information for use in a proposed forest site classification is based on site information provided by the forest inventory together with information derived from soil and biophysical surveys. The operating assumption was that sketchy site information provided by the forest inventory could be supplemented by land-based information in order to obtain forest groups with some meaning for productivity and possibly also for silvicultural treatment.

Trial application of existing information

An area was selected to include a range of environmental conditions and availability of existing site information. The area is located in southeastern Manitoba (Figure 2) and includes Forest Management Units 20, 23, 30 and 31. As shown on Figure 2 and the accompanying legend (Table 6) the area represents portions of three ecoregions and their associated subregions as described by Adams (1985).

Next, approximately 500 cruised stands were selected to obtain a representative cross section of forest covertypes in the area. Site data collected by the Manitoba Forestry Branch during the forest inventory was then coded and entered on dBASE in a microcomputer to facilitate rapid sorting. The coded data included: Type aggregate (covertype, site, cutting class and crown closure); tree species composition; regeneration species, regeneration stocking; average site index of stands; and moisture regime. Soil texture and topography information on the stand index cards was not coded because of lack of rigor in application of these designations by the forest inventory teams.

Soil and landform information for individual stands was derived by plotting the location of stands on the available soil survey maps and was also coded for dBASE sorting. The soil and physiographic parameters assigned to each stand were

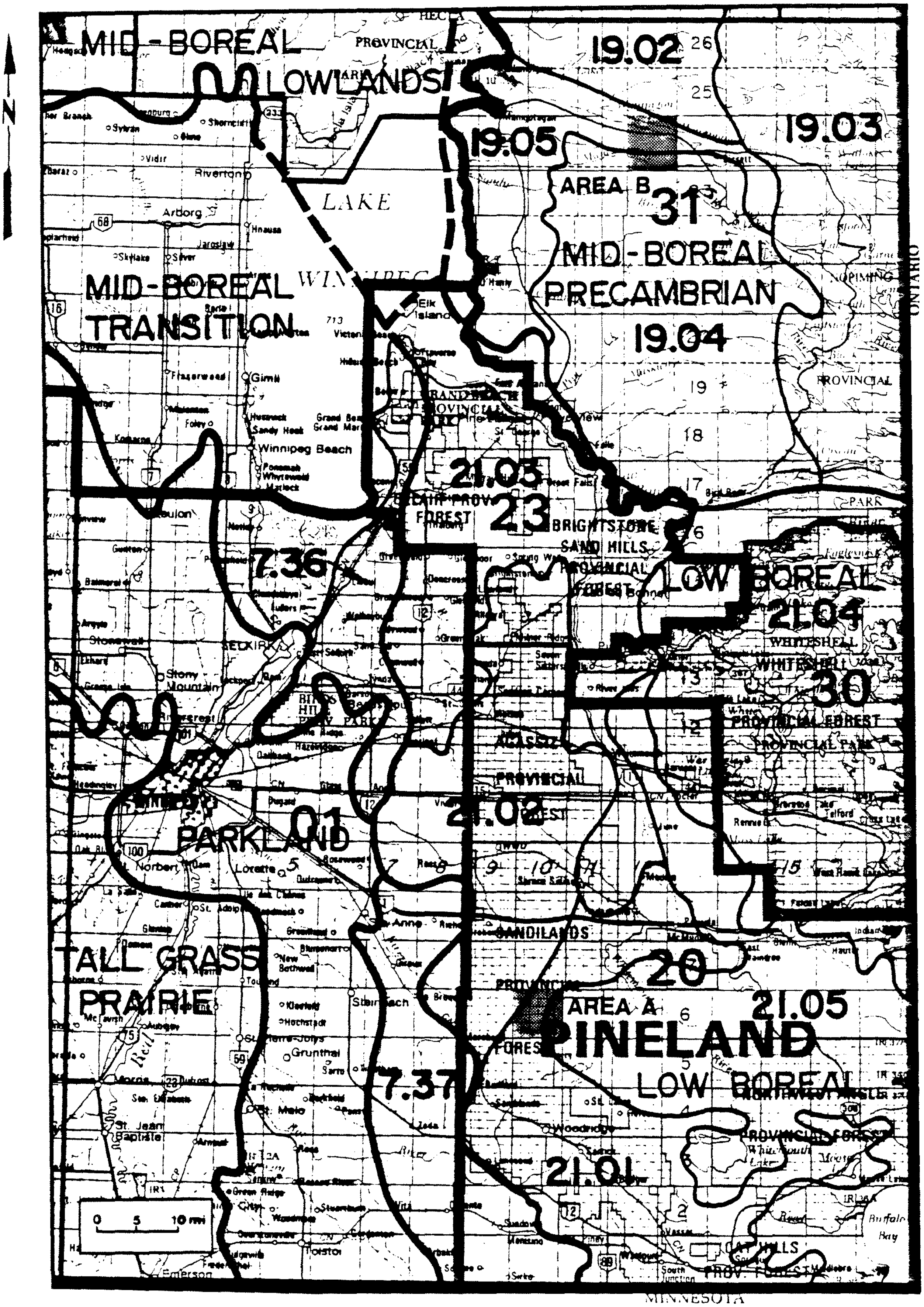

Figure 2. Location of Demonstration Areas.

Ecoregion

Subregion

Table 6. Ecoregion/Subregion Map Legend

Map Symbol	Ecoregion/Subregion	Elevation (ft.)	Genetic Surface Materials Form	Soil Development and Texture Class
7.00	Mid Boreal Transition			
7.36	Pine Ridge Plain	720-900	Fluvial, hummocky, and lacustrine veneer, level lacustrine veneer	Humic and Luvic Gleysols, clay loam
7.37	Caliento Plain	900-1,100	and Horizontal fens	Gray Luvisols, sandy loam, Organics, Black Chernozem, loamy
19.00	Mid Boreal Precambrian			
19.02	Bloodvein River Plain	700-1,050	Rock, hummocky and Bogs, flat	Acid Rock; Gray Luvisols, clay loam; and organic soils
19.03	Mantario Lake Upland	960-1,300	Rock, hummocky, ridged; Moraine veneer/Rock rolling; and Bogs, flat	Acid Rock; Eutric Brunisol, sandy loam; and organic soils
19.04	Manigotagan Lake Plain	900-1,000	Lacustrine veneer/Rock, hummocky; Rock, rolling; and Bogs, flat	Acid Rock; Gray Luvisols, clay loam and organic soils
19.05	Wanipigou River Plain	700-800	Lacustrine, level and Bogs, flat	Gray Luvisols, clay loam and Organic soils
20.00	Low Boreal			
21.01	Bedford Hills	1,050-1,250	Fluvial, hummocky to level; Moraine undulating; (Eolian, hummocky); Lacustrine veneer; Bogs and Fens	Gray Luvisols, loamy to sandy Loam, Eutric and Dystric Brumisols Sandy loam
21.02	Brokenhead River Plain	850-1,100	Lacustrine veneer and Fens, horizontal	Humic and Luvic Gleysols, loamy; Gray Luvisols, sandy loam; and Organics
21.03	Lac Du Bonnet Plain	720-950	Lacustrine, level and Fens, horizontal	Gray Luvisols, clayey; Gleysols, clayey; and Gleysols, loamy
21.04	Whiteshell River Plain	900-1,100	Rock, hummocky; lacustrine veneer/ Rock; (Bogs, flat)	Acid rock, Eutric Brunisols, sandy loam; and Organic soils
21.05	Whitemouth Lake Lowland	1,050-1,150	Bogs and Fens, level; Lacustrine, level; Moraine, undulating	Organic soils

simply an estimate using the available information from soil survey reports and the forest vegetation cover. Because of natural soil variability and the relatively small scale of the soil maps, these estimates are considered to be of only fair to good reliability. The estimates could probably have been refined somewhat by using relevant aerial photographs to locate particular cruise plots more precisely as to topographic position. However, preliminary inspection of some cruise plot locations on the aerial photographs revealed that, because of the operator's lack of detailed familiarity with the region, the amount of refinement gained would not have justified the additional effort, even if sufficient time had been available. In effect, however, the process of obtaining additional site data from the soil surveys is still regarded to be considerably better than simply a mechanical overlay of forest cover maps on soil maps without any understanding of soil-vegetation relationships.

Texture, calcareousness, and soil drainage were used as key characteristics for the dBASE sort. Sort parameters also included soil subgroups, e.g. Orthic Gray Luvisol, as well as subgroup phase, e.g. shallow to bedrock, and the presence or absence of moisture seepage as indicated by high average values of site index (S.I.) at 50 years for particular stands.

The computer sort on the basis of the above parameters groups stands in terms of their land-based site characteristics. Soil-vegetation groups obtained from this computer sort are presented in Table 7. These results show general trends in productivity as indicated by site index ranges. However, there is so much overlapping in site index values that the groups can hardly be considered distinct in terms of height growth. In effect, the groups probably do nothing more than confirm already known trends in productivity ranging from poorest on coarse-textured, shallow soils with rapid drainage and on poorly drained, organic soils to best on well drained to imperfectly drained soils with seepage conditions. Moreover, the lack of systematically collected and sufficiently detailed data for lesser vegetation prevents further integration of vegetation and site characteristics necessary to identify and characterize more narrowly defined site units for operational use.

Similar inconclusive results were obtained when available information on site index by species was used for comparison between dBASE sort groups designated by soil series (Table 8). Data appear to be too variable to show differences between series although some broad trends are again evident in relation to moisture regime variation.

Volume increment, i.e. mean annual increment, was not used for comparison because of the lack of differences shown by the site index data and because of time constraints. Yield tables for the respective regions were not immediately available in order to convert volume increments to a common age, usually rotation age, for valid comparisons. Time

Table 7. Results of dBASE Sort of Coded Stands

Low Boreal Ecoregion

Sandy Fine Parent Material (Fluvial, Lacustrine)

- Medium acid to neutral; Imperfect drainage

Lonesand (GLE.DYB)*	- JP,BS/Tall shrubs/Grass, forbs
(S.I. 15-19)	- TA,WB/Tall shrubs/Forbs

- Weakly calcareous; Rapid drainage

Sandilands (E.DYB)	- JP/Dwarf shrubs/Lichen
(S.I. 12-13)	

- Weakly calcareous; Good drainage

Sandilands (E.DYB)	- JP(TA)/Tall shrubs/Grass, forbs
(S.I. 12-18)	

- Weakly calcareous; Moderate drainage (no seepage)

Sandilands (E.DYB)	- JP,BS,WS/T. shrubs/Feathermoss,grass,forbs
St. Labre (O.GL)	- TA/Tall shrubs/Grass, forbs
Vassar (BR.GL)	
(S.I. 14-17)	

- Weakly calcareous; Moderate drainage (with seepage)

Sandilands (E.DYB)	- JP,BS,RP/Tall shrubs/grass, forbs
(S.I. 16-18)	

- Weakly calcareous; Imperfect drainage (no seepage)

Wampum (GL.GL)	- BF/Tall shrubs/Feathermoss, forbs
Wintergreen (GL.GL)	- TA,BA/Tall shrubs/Feathermoss, forbs
(S.I. 15-17)	

- Weakly calcareous; Imperfect drainage (with seepage)

Wampum (GL.GL)	- TA,BA,AS/Tall shrubs/Grass, forbs
Wintergreen (GL.GL)	- BF,BS/T. Shrubs/Feathermoss, forbs
Caliento (GL.GL)	
(S.I. 16-22)	

* See key to soil subgroups at end of table

Table 7 - continued

Sandy Skeletal (Glaciofluvial)

- Moderately to very stront y calcareous; rapid drainage

Woodridge (O.EB) (S.I. 12-14)	- JP/Dwarf shrubs/Lichens

- Moderately to very strongly calcareous; Good drainage

Woodridge (O.GL) (S.I. 13-17)	- JP,BS,TA/Tall shrubs/Grass, forbs

Mid Boreal Precambrian Ecoregion

Sandy Skeletal (Till)

- Medium acid to neutral; Very shallow; Rapid drainage

Indian Bay (O.DYB) Nora Lake (E.DYB) (S.I. 9-13)	- JP,BS/Arctostaphylos, Cladonia

- Medium acid to neutral; Shallow or deep; Good to moderate drainage

Nora Lake (O.DYB) Telford (E.DYB) (S.I. 15-18)	- JP,BS/Feathermoss, Forbs, (Cladonia)

Coarse Loamy (Till)

- Medium acid to neutral; Very shallow; Rapid drainage

Orthic Dystric Brunisols Eluv. Dystric Brunisols (S.I. 13-15)	- JP/Cladonia

- Medium acid to neutral; Shallow; Good drainage

Orthic Dystric Brunisols Eluv. Dystric Brunisols (S.I. 13-16)	- JP,BS/Feathermoss, Forbs (Cladonia)

- Medium acid to neutral; Deep; Good drainage

Eluviated Dystric Brunisols (S.I. 16-18)	- BS,JP/Feathermoss, Forbs - TA/Tall shrubs/Forbs

Table 7 - continued

Low Boreal Ecoregion

Clayey Parent Material (Lacustrine)

- Very calcareous; Moderate drainage (no seepage)

Lettonia (SZ.GL)	- WS/Tall shrubs/Forbs
(S.I. 13-14)	- BF/Feathermoss, Forbs

- Very calcareous; Moderate drainage (with seepage)

Lettonia (SZ.GL)	- BF/Tall shrubs/Forbs
Arnes (D.GL)	- TA/Tall shrubs
(S.I. 17-21)	

- Very calcareous; Imperfect drainage (no seepage)

Framnes (GL.GL)	- TL/Tall shrubs/Grass feathermoss
Thalberg (GLSZ.GL)	- BS/Tall shrubs/Feathermoss, forbs
(S.I. 13-14)	- AS/Tall shrubs/Feathermoss, grass
	- WS/Tall shrubs/Feathermoss, grass

- Very calcareous; Imperfect drainage (with seepage)

Thalberg (GLSZ.GL)	- WB/Tall shrubs/Feathermoss, grass
(S.I. 15-18)	- AS/Tall shrubs

- Very calcareous; Poor drainage (with seepage)

Tarno (R.HG)	- TA/Tall shrubs
(S.I. 19-20)	- AS/Tall shrubs/Grass, forbs

Table 7 - continued

Mid Boreal Precambrian Ecoregion

Clayey Parent Material (Lacustrine)

- Very calcareous; Good drainage

Lettonia (SZ.GL)	- WS/Tall shrubs/Grass, forbs
(S.I. 17-24)	- TA.BA/Tall shrubs/Forbs
	- BF,Tall shrubs/Grass, forbs
	- JP/Tall shrubs/Forbs

- Very calcareous; Moderate drainage (with or without seepage)

Lettonia (SZ.GL)	- BS/Tall shrubs/Feathermoss, forbs
(S.I. 15-21)	- TA,BA/Tall shrubs/Forbs
	- WS/Tall shrubs/Forbs
	- BF/Tall shrubs/Forbs

- Very calcareous; Imperfect drainage (with or without seepage)

Malloy (GL.GL)	- BS,BF/Forbs
Pine Valley (GLD.GL)	- TL/Tall shrubs/Forbs
Mukatawa (GLSZ.GL)	- TA/Forbs
(S.I. 16-20)	

- Weakly calcareous; Good drainage

Lorteau (O.GL)	- BS/Tall shrubs/Forbs
(S.I. 14-20)	- TA,BA/Tall shrubs/Forbs

- Weakly calcareous; Moderate drainage (with or without seepage)

Lorteau (O.GL)	- WB/Tall shrubs/Forbs
(S.I. 17-20)	- BF/Tall shrubs/Forbs

- Weakly calcareous; Imperfect drainage (with or without seepage)

Gleyed Gray Luvisol	- TA/Tall shrubs/Forbs
Gleyed Dark G. Luvisol	
(S.I. 17-21)	

Table 7 - continued

Low Boreal Ecoregion

Organic Parent Material (Mesic Peat)

- Medium acid to neutral; Shallow

Terric Mesisols (mod)[x] (S.I. 12-14)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum
Terric Mesisols (sp)[x] (S.I. 9-13)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum

- Extremely acid; Deep

Typic Mesisols (mod) (S.I. 13-15)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum
Typic Mesisols (sp) Typic Fibrisols (S.I. 7-13)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum

Mid Boreal Precambrian Ecoregion

Organic Parent Material (Mesic Peat)

- Medium acid to neutral; Shallow

Terric Mesisols (mod) (S.I. 13-15)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum
Terric Mesisols (sp) (S.I. 10-13)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum

- Extremely acid; Deep

Typic Mesisols (mod) Baynham Wanipigow Lake (S.I. 13-15)	- BS, TL, (EC)/Feathermoss, Sphagnum, Ledum
Typic Mesisols (sp) Baynham Typic Fibrisols (S.I. 9-14)	- BS, TL, (GC)/Feathermoss, Sphagnum, Ledum

x - See key to organic subgroup phases at end of this table

Table 7 – continued

* Key to soil subgroups (CSSC, 1978)

Eutric Brunisols (EB)

O.EB	– Orthic Eutric Brunisol

Dystric Brunisols (DYB)

D.DYB	– Orthic Dystric Brunisol
E.DYB	– Eluviated Dystric Brunisol
GL.DYB	– Gleyed Dystric Brunisol
GLE.DYB	– Gleyed Eluviated Dystric Brunisol

Gray Luvisols (GL)

O.GL	– Orthic Gray Luvisol
D.GL	– Dark Gray Luvisol
BR.GL	– Brumsolic Gray Luvisol
SZ.GL	– Solonetzic Gray Luvisol
GL.GL	– Gleyed Gray Luvisol
GLD.GL	– Gleyed Dark Gray Luvisol
GLSZ.GL	– Gleyed Solonetzic Gray Luvisol

Humic Gleysols (HG)

R.HG	– Rego Humic Gleysol

x – Key to subgroup phases, organic soils

mod – modal
sp – sphagnic

Table 8. Current Forest Productivity of Soil Series

Parent Material	Soil Name	Soil Drainage	Moisture Regime	SITE INDEX # Coniferous Species JP	WS	BS	BF	TL	Deciduous Species TA	BA	WB	AS	MM
Loamy, moderately to very strongly calcareous till	Carrick	Good	Fresh	-	-	-	-	-	-	-	10-16(15)	-	-
	Carrick	Good*	Fresh*	-	-	-	-	-	13-19(16)	-	-	-	-
	Carrick	Moderate	Fresh	-	-	-	-	-	14-21(17)	11-15(13)	15-20-(17)	-	-
	Piney	Imperfect	Moist	-	13-15(14)	10-16(13)	10-16(13)	-	13-16(15)	12-15(14)	-	-	-
	Piney	Imperfect*	Moist*	-	-	-	-	-	15-21(18)	10-14(12)	-	-	-
Clayey, moderately to very strongly calcareous lacustrine	Lettonia	Good*	Fresh*	-	10-17(12)	10-12(13)	12-22(16)	-	16-21(19)	-	13-18(15)	-	-
	Thalberg	Imperfect	Moist	-	10-14(12)	11-15(13)	-	-	-	-	-	10-15(13)	-
	Thalberg	Imperfect*	Moist*	-	-	-	14-16(15)	-	15-22(19)	-	16-20(18)	12-18(15)	-
Clayey, moderately to very strongly calcareous lacustrine over silt	Frammes	Imperfect	Moist*	-	-	-	-	-	-	-	-	-	14-19(16)
	Tarno	Poor*	Wet*	-	-	-	-	-	-	20-24(22)	17-20(19)	12-20(17)	-
Sandy skeletal, moderately to very strongly calcareous glaciofluvial and washed till	Woodridge	Rapid	Dry	9-14(12)	-	-	-	-	-	-	-	-	-
	Woodridge	Good	Fresh	12-18(15)	-	-	-	-	12-15(14)	-	-	-	-
	Richer	Good	Fresh	13-20(17)	-	-	-	-	15-23(19)	-	-	-	-
	Sirko	Imperfect	Moist	-	-	-	13-16(14)	-	14-17(15)	-	13-18(16)	-	-
Sandy fine, weakly calcareous, fluvial-lacustrine	Sandilands	Rapid	Dry	9-18(13)	-	-	-	-	-	-	-	-	-
	Sandilands	Good	Fresh	9-20(15)	-	-	-	-	14-24(19)	-	-	-	-
	Sandilands	Moderate	Fresh	9-18(15)	-	-	-	-	13-20(17)	-	-	-	-
	Wintergreen	Imperfect	Moist	-	11-16(14)	-	12-19(15)	-	-	14-17(16)	-	-	-
	Wintergreen	Imperfect*	Moist*	14-22(17)	-	10-15(13)	-	-	13-25(17)	12-19(16)	12-18(15)	-	-
Sandy fine, medium acid to neutral fluvial lacustrine	Lonesand	Imperfect	Moist	12-18(16)	-	9-14(10)	-	-	14-22(16)	-	10-15(13)	-	-
Sandy fine, weakly calcareous over clayey, very calcareous lacustrine or till	Vassar	Good Moderate	Fresh	11-18(16)	-	-	10-15(12)	-	-	-	12-15(13)	-	-
	Caliento	Imperfect	Moist	-	13-16(14)	10-20(14)	15-17(16)	17-24(20)	16-23(19)	13-17(16)	-	12-14(13)	-
	Wampum	Imperfect	Moist	-	13-21(17)	9-11(10)	14-19(16)	-	17-21(19)	-	15-19(17)	-	-
Organic	Terric Mesisols	Very Poor	Saturated	12-13(13)	-	9-15(12)	-	14-15(15)	-	-	-	-	-
	Typic Mesisols	Very Poor	Saturated	-	-	7-11(10)	-	9-15(12)	-	-	-	-	-

\# Range (Mean)
* With Seepage

constraints also precluded incorporation of more plot data needed for possibly better overall comparison of these tentative groups.

Further work for comparison of these rather broad site groups obtained from existing information is therefore judged non-productive. Further improvement in this tentative classification is unlikely because the available site and vegetation data are not sufficiently detailed and have not been collected in a coordinated manner. On the other hand, the overall correctness of this approach is corroborated by general correspondence of results to information from earlier sources (Halliday, 1935, Rowe 1954, Mueller-Dombois, 1964, Zoltai, 1967). However, work to date clearly demonstrates the need for a more systematic and closely coordinated approach to site data collection. In conclusion, satisfactory results for forest site classification in Manitoba will be best achieved by building modern site data collection and analysis procedures into the basic ecological approach of earlier workers (Rowe, 1954, 1956,; Mueller-Dombois 1964, 1965).

Mapping exercise

An aerial photo mapping exercise involving portions of two townships, one in the Low Boreal ecoregion and the other in the Mid-Boreal Precambrian ecoregion, was carried out to see how existing site information could be used for more detailed site mapping. Black and white aerial photographs (1:15,840 scale) with the forest inventory covertype delineations were examined stereoscopically to delineate site areas. Information obtained from existing reconnaissance soil and biophysical surveys was also used to aid delineation of site areas at this larger scale.

The first of these two mapping demonstration areas (Figure 2) is located in the northeast portion of Township 6, Range 10 East. The results of the mapping are shown on the map diagram, overlays and legend in Appendix 3. Some on-site familiarity with this area was gained during a brief field trip prior to photo interpretation.

Results of the mapping in this area demonstrate that with photo interpretation and a minimal amount of ground truthing, more detailed soil and landform information can be provided and much of the soil and site heterogeneity reduced to manageable proportions. These results also demonstrate that more detailed examination and mapping show covertype and soil boundaries that are quite different at small scale actually correspond quite closely at larger scale.

The second mapping demonstration area is located in a portion of Township 24, Range 12 East (Figure 2) within the Mid-Boreal ecoregion. Results (Appendix 4) show that because of obvious landform differences, site unit boundaries in this area correspond even more closely to forest covertype boundaries than in the first area. However, it is still necessary to add boundaries where major soil and physiographic differences are not considered by forest cover typing.

In conclusion, the mapping exercise is valuable because it demonstrates that a framework for collection of more detailed information about ecological site relationships can be quickly and effectively provided by a mapping stratification based on existing information about soils and landforms. At the same time this framework permits rapid extension of new information in the form of a mapping program. However, such a mapping program would need to rely on a site classification based on new more detailed information rather than on that now available. Such new information could best be collected as part of a combined mapping and classification operation. Sampling intensity would have be be higher at the outset in order to establish or verify basic site types and their interrelationships within ecoregions. After that, the intensity could be lowered to a level needed for routine identification as site mapping is extended across regions.

Use of Additional Soil and Vegetation Data

As pointed out in the previous section, existing site information is not adequate to develop a forest site classification to meet current and future operational needs in Manitoba. However, the amount of additional information required is judged to be relatively modest. This is so because an overall hierarchical classification framework is already in place.

This is especially so at the higher category levels. Ecoclimatic regions have been established for Manitoba (Mills et al., 1985) and accepted within a national framework (CCELC, 1986). The physiographic divisions of Manitoba and their associated soils (Mills, 1980; 1983) are now recognized as the next lower hierarchical level, that is as separate subregions each with a particular combination of dominant landform and soil components nested within ecoclimatic regions (Adams, 1985). This means that particular forest site types established for operational purposes can now be evaluated and compared on a regional basis, something that was not possible before.

Units at the lower end of this hierarchical framework are as yet not well defined. The Hills system as modified by Rowe (1957) provides a broad grouping of white spruce, black spruce and jack pine forest community types in terms of soil texture and moisture regime. These site class groups are shown in another study by Rowe (1954) to have different productivity and growth patterns but their floristic composition and successional relationships are not closely specified. Instead, physiographic terms are used to designate the site classes, for example fresh till sites, dry till sites, swamp border sites, etc. However, this system is applicable over a considerable portion of the forested area in Manitoba and seems to best lend itself for use as a first approximation or outline for future forest site classification work in Manitoba. Use of such a physiographically-based system as a first approximation seems justified under widespread conditions of forest disturbance by fire and logging present in Manitoba. The system has provided useful site classes for forest productivity and silvicultural research but it is not complete. Several of the site classes have not yet been studied in detail and new classes may also have be defined. Incorporation of Mueller-Dombois (1964; 1965) site types or their equivalents is suggested as a start toward refining the system for improved use in southeastern Manitoba.

Proposed site classification system

In summary, what is envisioned here is not the development and application of the Hills-Rowe system per se. Instead, the existing information provided by that system would be used as a starting point for an ecological, physiographic-soil-vegetation mapping approach using modern procedures for data collection and analysis. The site classification units identified by this approach could be equivalent to the ecosystem associations of Corns and Annas (1986), or they could be phases of such associations as required for Manitoba conditions. In any event, they would certainly be integral components of site <u>mapping</u> units. These site classification units would be characterized in terms of closely integrated soil, site and vegetation parameters and would be identified within broader classification levels of ecoregions and subregions as outlined by Adams (1985). The final system would not resemble the Hills-Rowe system except that the site types would also be defined within a physiographic-soils framework as required.

With regard to practical use of the system developed by this mapping approach, the operational forester would not necessarily have to work with the site classification units themselves. Instead, map-based, operational interpretations of site units could be developed for general field use and planning operations. More detailed or site specific needs would be served by using simplified keys, similar to those developed in Ontario (Jones et. al., 1983), for field identification of operationally equivalent groups of site units for particular silvicultural purposes.

With regard to productivity evaluation of site units, an initial evaluation could be done using mensurational data collected as part of the combined mapping-classification operation. More detailed evaluation would involve later development of yield tables for particular site units or groups of site units with additional data. A major part of these additional data could probably be obtained by using current forest inventory yield data stratified in terms of ecosystem associations by the proposed ecological site mapping approach.

The development and application of the proposed site classification and mapping approach would be aided by modern computer storage and handling facilities for both textual and mapped information. Experienced gained in this regard by other provinces, especially that of Ontario, Alberta and British Columbia, would be used to tailor the proposed system for use with the ARC/INFO facility used by the Manitoba Forestry Branch. The knowledge and experience of Canada-Manitoba Soil Survey personnel should also be involved to ensure that the system is fully compatible with Manitoba requirements.

Finally, it should be noted that the rationale for development of the proposed system rests on the recognition that modern forestry management deals not only with forests but also closely involves the land base. An ecological mapping-site classification approach using modern methods of data analysis is therefore recommended as the best available method to achieve a unified site classification framework for solving major site-related forestry problems in Manitoba.

Recommended methodology

Development and application of the proposed system of site classification should include a number of steps outlined as follows:

1. Selection of priority areas for pilot studies. As a start, two pilot areas, each at least three to four townships in size, could be selected to represent major kinds of forest conditions in Manitoba. One of these areas should probably be selected where there is a good supply of site related information. The other area could be selected where such information is sketchy or unavailable.

2. Photointerpretation and detailed mapping of the pilot areas, using Manitoba Forestry Branch aerial photography (1:15,840) with covertype boundaries, and also using an initial map legend based on existing information as demonstrated by this study.

3. Detailed field sampling within and possibly also outside pilot areas in order to collect data needed to identify and adequately characterize site units and their variability. Information collected at sample plots would include detailed descriptions of soil, site and vegetation properties, and forest productivity data for site index and mean annual increment comparisons. Soil samples would also be collected for laboratory characterization of soils representative of site units. Ecological field plot forms available from other provinces could be used or modified for Manitoba conditions as required.

4. Computer file input of collected data. Use of dataloggers or microcomputers is recommended for most efficient and cost effective data entry.

5. Computer-aided analysis of collected data, including results of soil laboratory analysis, to characterize site classification units.

6. Revision of site mapping legend as required.

7. Digitize final site maps for input on ARC/INFO.

8. Development of interpretative keys using results from the computer aided analysis. Input from experienced operational forestry personnel should also be used to develop these interpretative keys.

9. Preparation of initial field guide to be used in conjunction with site maps and interpretative keys for technology transfer testing before adopting an operational program. Field guide should be modelled on those prepared for Ontario (Jones et. al., 1986) and Alberta (Corns and Annas, 1986) for convenient use in the field.

10. Field examination of site units in the company of experienced operational foresters at various intervals in order to evaluate the development and use of site classes,

site maps and interpretative keys for operational purposes. This combined input and technical transfer process is regarded as critical to developing a forest site classification that can be used by operational personnel.

The recommendations embodied in this report are derived from the current review of the existing Manitoba forest site classification status and needs. They recognize that existing site information is inadequate for current needs and that more ecologically-based information will have to be collected in a rapid and effective manner. They also recognize that existing site-related information should be utilized to the fullest extent possible and that newer methodologies ought to be incorporated where feasible on the basis of the proven experience of users in other areas with some similarity of forest conditions. They are also aware that interpretative input by the end user is essential for development of a fully satisfactory site management classification system for Manitoba. And finally, it is recognized that such a system has to be compatible for integrated use as one part of a larger, modern geographic information system now being developed for forest management in Manitoba.

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ACKNOWLEDGMENTS

This contract project was conducted for the Manitoba Forestry Branch with joint funding provided for forest site classification research in Manitoba by the 1984 - 1989 Canada-Manitoba Forest Resource Development Agreement. Under the terms of this agreement, the project was administered and co-ordinated by the Canadian Forestry Service from the Northern Forest Centre in Edmonton, Alberta. Project work involved the use of library facilities in Edmonton and Winnipeg, field travel for familiarization with forest site conditions in Manitoba, and consultation with senior forestry personnel from both government levels, from industry and from universities.

The author wishes to acknowledge the contributions made by the following persons and their agencies to the successful completion of this report.

Manitoba Forestry Branch

R.H. Lamont, G. Becker and N. Tuinhoff of the Forest Inventory Section for their full help and co-operation throughout the project.

L. Yarn and G. Ardron of the Silviculture Section for helpful input and criticism.

W. Rugg, A. Savaria, D. Lamb, G. Peterson and S. Kaczanowski, Regional Foresters, for informed consultation and questionnaire input which greatly aided in understanding of forest site classification needs in their respective areas.

K. Vogel, Regional Forester, for extremely helpful consultation and field guidance in the Southern Region.

Industrial Sector

T.H. Peacock, Divisional Forester, Abitibi-Price Inc., and W.E. Jonas, Divisional Manager, Manfor Ltd. for extremely helpful questionnaire input and consultation from the forest industry aspect.

Canadian Forestry Service

Dr. I.G. Corns, Research Scientist, Northern Forest Research Centre, (and Scientific Authority for this contract) for helpful comments and constructive criticism throughout the project.

R. Waldron, Program Manager, Northern Forest Centre, Edmonton, for helpful suggestions, and for guidance in locating additional information on early site classification work in Manitoba.

W.J. Ball and J. Dyck, Winnipeg Office, for keen interest and helpful background information.

D. Robinson, Librarian, Northern Forest Centre, Edmonton, for help in locating copies of major unpublished manuscripts in the library archives.

Universities

Dr. J.S. Rowe, Professor Emeritus, Department of Botany, University of Saskatchewan, Saskatoon, for very helpful consultation and insight on forest site classification problems in Manitoba.

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Appendix 1

Annotated Bibliography

of

Forest Site Research in Manitoba

ANNOTATED BIBLIOGRAPHY OF FOREST SITE RESEARCH IN MANITOBA

This annotated bibliography includes both published and unpublished references and reports relating to forest site classifications and soil survey, forest site productivity, and silvicultural management in Manitoba. Most of these references have been gleaned from the library files and archives of the Canadian Forestry Service, Northern Forestry Centre, Edmonton, Alberta. Copies of major research contributions, both published and unpublished have been made for the client, the Manitoba Forestry Branch. A few site productivity classification references from other Prairie Provinces have been included where they are judged to be relevant to Manitoba conditions.

Forest Site Classification - Systems

Adams, G.D. 1985. A regional map base for a migratory bird habitat inventory, Prairie Provinces. A report to accompany maps, Revised copy October 25, 1985. Habitat Conservation, Canadian Wildlife Service Saskatoon.

- Three hierarchical mapping levels are proposed to satisfy national and regional planning needs and to collate regional and localized habitat information. These include management zones or ecozones, ecoregions, and habitat subregions. A significant improvement of this system is that it uses the broad soil-landscape or geomorphological (physiographic) units as subdivisions of the recently established ecoclimatic regions. (Mills et al. 1985) and thereby permits a more reliable integration of vegetation with soils and landforms at operational levels useful for forest site classification and mapping.

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- Good source of references for the surficial geology in Manitoba.

Halliday, W.E.D. 1935. Report on vegetation and site studies, Clear Lake, Riding Mountain National Park, Manitoba. Canada Dept. Interior, For. Service. Res. Note 42.

- One of the earliest example of work to elucidate relationships between understory vegetation, parent material and growth of

aspen, white spruce, black spruce and jack pine in the Riding Mountain area of Manitoba.

Hills, G.A. 1952. The classification and evaluation of site for forestry. Ontario, Dept. Lands and Forests, Div. of Res., Res. Rep. 24. 41 pp.

Hills, G.A. 1953. The use of site in forest management. Forestry Chronicle 29:128-136.

Hills, G.A. 1960. Regional site research. Forestry Chronicle 36:401-423.

Hills, G.A. and G. Pierpoint. 1960. Forest site evaluation in Ontario. Ontario Dep. Lands and Forests Res. Rep. 42, 64 pp.

- The Hills' system provides a holistic or integrated classification of the physical environment in terms of basic units called physiographic site-types. However, vegetation is used to help set the physical definitions of the physiographic site-types, and also aids in field identification. The conceptual basis for the Hills system involves development of a theoretical but more or less arbitrary model of the environment, measurement or estimation of the necessary environmental variables, and incorporation of them in the model. Hills' system has been widely used by Canadian Forestry Service personnel in Manitoba for classification of sites used in forest research projects but has seen little or no use at the provincial level.

Jameson, J.S. and J.H. Cayford. 1964. Forestry. In: Soil Survey of the South-Eastern Map Sheet Area Manitoba Soil Survey. Soils Report No. 14, pp 94-104.

- Soils of the area are mapped and described in a detailed reconnaissance inventory at a scale of two miles to the inch (1:126,720). A portion of the report provides information about soil features important to forestry. Estimated productivity and silvicultural practices for forest reproduction are presented for each of the soil map units, and the soils are grouped into forest land-use capability classes, subclasses and units.

Mills, G.F. 1976. Biophysical land classification of northern Manitoba. P.201-219. In: J. Thie & G. Ironside (ed.) Proc. 1st

Meeting Can. Comm. on Ecological (Biophysical) land. Class. May 25-28, 1976, Petawawa, Ont.

- A systematic biophysical land classification of northern Manitoba was started in 1974 and completed a field inventory of some 85,500 sq. km (33,000 sq. miles) in a two year period. This inventory classifies and maps terrain in terms of landforms, surface deposits, vegetation, soils, drainage permafrost, associated aquatic systems and climate. The inventory is designed to provide an ecologically sound basis for land use decisions concerning forestry, agriculture, recreation, wildlife, community development and hydrology. Methodology for data collection compilation and presentation is described. An example is given illustrating the hierarchical nature of the system and the integrated approach to data presentation. Some anticipated uses and limitations of the data, together with estimated costs of the inventory, are presented.

Mills, G.F., L.A. Hopkins and R.E. Smith. 1977. Organic soils of the Roseau River watershed in Manitoba Inventory and assessment for agriculture. Canada Dept. of Agriculture Monograph No. 17.

- Organic soils of the area are classified and mapped at a scale of one inch to one mile (1:63,360). Organic soil units are designated by soil series and series phase and are characterized in terms of kind of organic parent material, underlying mineral substrate, dominant organic landform and dominant vegetation cover. This detailed characterization of the organic soils and their landforms should provide a more useful basis for ecological integration of forest cover with organic soils and landforms in the area.

Mills, G.F., H. Veldhuis, J.M. Stewart, D. Wotton and W. Koonz. 1985. Ecoclimatic regions of Manitoba. Unpublished manuscript. Prepared by the Manitoba Ecoclimatic Region Working Group. 25p.

- Divides Manitoba into ecoprovinces, ecoclimatic regions and subregions and describes these in terms of their dominant climate, vegetation, soils, wildlife and land use. Represents a recent consensus on ecoclimatic divisions for the Province.

Mueller-Dombois, D. 1962. The forest habitat types in southeastern Manitoba and their application to forest management. Preliminary draft. Project MS-213 Unpublished manuscript.

- Provides a detailed description of forest habitat types recognized for southeastern Manitoba. Copy provided to client.

Mueller-Dombois, D. 1964. The forest habitat types in southeastern Manitoba and their application to forest management. Canadian J. Bot. 42(10):1417-1444.

- Fourteen forest habitat types, including three subtypes, are described in a forest land classification for southeastern Manitoba. These are based on silviculturally significant differences of soil moisture and nutrient regime interpreted in terms of vegetation, soil and landform features. The types are designed to include the regional environment ranging from the driest habitats on sand dunes to the wettest on organic terrain and from the nutrient-poor sites on siliceous sands to the richest on alluvial deposits. The purpose of the classification is to provide a basic framework for silvicultural practices in the areas. Aspects of application for current forest management include productivity and choice of species for planting, regeneration, and habitat amelioration by drainage.

Mueller-Dombois, D. 1965. Eco-geographic criteria for mapping forest habitats in southeastern Manitoba. For. Chron. 41:188-206

- Summarizes ecological relations of the habitat types both in tabular and profile diagram showing the habitat types as a generalized ecological series. Aerial photo and field mapping keys are provided as aids for identification and deliniation of habitat types in field mapping operations.

Ritchie, J.C. 1959. The vegetation of northern Manitoba III. Studies in the subarctic. Arctic Institute of North America, Technical Paper No. 3.

- Study area located at Seal River in the far northeastern part of the province. The plant communities are described according to slope positions on various landform types including boulder till, esker, peat deposits, lake shorelines, and riverine deposits. Successional trends are discussed within this framework. The predominant landform type, low hills and ridges of boulder till, have black spruce lichen forest while lichen forests dominated by white spruce are confined to eskers and alluvial deposits.

Ritchie, J.C. 1961. Soil and minor vegetation of pine forests of southeast Manitoba. Forest Research Division, Technical Note No. 96. 21p.

- Examines relationships between landforms, soil types and forest vegetation in an attempt to establish preliminary categories of forest site and gain some understanding of forest succession. Describes the range of soils on which pine stands are found in the southeast, provides information on minor vegetation and some preliminary data on the performance of trees in relation to site. Provides a tentative grouping of sites in terms of soil profile types grouped according to their apparent degree of development of podzolic soil features in relation to soil drainage. The usefulness of this grouping is limited somewhat because the author assumes, incorrectly, that the degree of podzolization is mainly related to soil drainage in a given climatic region. However, a reasonably good correlation was found between increasing degree of podzol development (with increasing moisture) and increasing tree productivity. Useful information is provided on the occurrence of minor vegetation on the various sites. Broad agreement is shown with the later work of Mueller-Dombois.

Rowe, J.S. 1954. Forest sites in the Riding Mountain experimental area. Unpub. Progress Report, Project MS-168. Dept. Northern Affairs and National Resources, Forestry Branch: Forest Research Division, Winnipeg, Manitoba. 39p.

- Reports on progress of forest land classification and mapping work in the Clear Lake area. Also discusses results of site productivity measurements for site categories found in the area.

Rowe, J.S. 1956. Uses of undergrowth plant species in forestry. Ecology 37:461-473.

- Outlines a simple scheme, based on physiognomy of the undergrowth and on moistness of the site, for describing stands in the southern boreal forests of Manitoba and Saskatchewan. As an aid to stand description, a table is presented showing the positions of about 200 common species relative to one another so far as their heights and moisture preferences are concerned. Some of the common forest communities in this region are briefly described using the moisture-physiognomy scheme. The possibility of using the groupings of species in the five moisture series, as shown on the vegetation table, for the moistness of site is examined, and a method of working out a Vegetation Moisture Index is proposed. This index is compared with moisture estimates derived from the study of soils and topography and a good correspondence is shown. Suggests that the method used in working out an index of moistness from the plant species present on a particular site could also be used to derive indices of soil fertility and ecoclimate for use in stand description and in forestry research.

Rowe, J.S. 1957. Forest site classification. Canada Dept. Nor. Affairs and Nat. Resources, For. Br. Res. Div. Project MS-173. Unpubl. MS.

- Classification system of Hills is modified for application in Manitoba and Saskatchewan. Site classes are described in terms of moisture regime and pore pattern for white spruce, jack pine and black spruc. Copy provided to client.

Rowe, J.S. 1959. Forest regions of Canada. Canada Dept. Northern Affairs and National Resources. Bulletin 123.

- Subdivided forest regions delineated by Halliday (1937) into forest sections.

Rowe, J.S. 1972. Forest regions of Canada. Department of the Environment. Canadian Forestry Service. Publ. No. 1300.

Rowe, J.S. and P.J.B. Duffy. 1959. White spruce in the southern Boreal forests of Alberta, Saskatchewan and Manitoba. Canada, Dept. Nor. Affairs and Nat. Res., For. Br., Unpubl. MS.

- Copy not located.

Tarnocai, C. 1975. Interim Soil Survey Report of the Cormorant Lake Area. Canada Soil Survey 73p and Map.

- Soils are mapped at a scale of 1:125,000 for the same area covered by Cormorant Lake pilot biophysical classification study (Zoltai et al. 1969). Deliniated areas generally consist of estimated decile combinations of soil series components. Detailed descriptions and laboratory analytical results are provided for representative profile samples of soil series.

Veldhuis, H. 1977. Land and site classification in Manitoba and Saskatchewan. Proceedings, Ecological Classification of Forest Land in Canada and Northwestern U.S.A. September 30-October 2, 1977, pp 209-236.

- Emphasizes the value of soil surveys as a basis for ecological land and site classification in Manitoba and points out that the additional data gathered on site components during the Manitoba forest inventory is considered by Manitoba foresters to be useful for site classification. Reviews the progress of ecological (biophysical) land classification in both provinces and reveals that the foresters concerned consider that the scale and detail of information provided by these inventories are insufficient for their purposes.

Zoltai, S.C. 1967 Forestry. In: Soils of the Lac du Bonnet Area. Manitoba Soil Survey. Soils Report No. 15, pp. 102-111.

- The soils of the area are characterized as soil series and their distribution either as series or complexes of series is shown on a map at a scale of two miles to the inch (1:126,720). A key to the soils is provided along with a generalized soil map. The soils are grouped into agricultural and forest land-use capability classes, subclasses and units, and the kind and degree of limitations affecting land-use for specific recreational needs are described.

Zoltai, S.C. 1971. Southern limit of permafrost features in peat landforms, Manitoba and Saskatchewan. Geol. Assoc. Can. Special Pap. 9, 305-310.

- Provides useful information about the distribution and expression of permafrost features in organic terrain in northern sections of the province.

Zoltai, S.C. 1973. Vegetation, surficial deposits and permafrost relationships in the Hudson Bay Lowlands In Proc. Symp. on the Physical Environment of the Hudson Bay Lowland. Mar. 30-31, Guelph, Ont., pp. 17-34

- Provides information about surficial materials, soils and vegetation in this region.

Zoltai, S.C., E.T. Oswald and C. Tarnocai. 1969. Land classification for land evaluation: Cormorant Lake Pilot Project. Canada Dept. Fish. and For., For. Br. Inf. Rep. MS-X-20 31 p.

- Landscape units and land systems are mapped at a scale of two miles per inch (1:126,720) on a photomosaic base for an area of approximately 5,400 square miles, located between latitude 54 degrees and 55 degrees N, and 100 degrees and 102 degrees W. The hierarchical land classification system outlined by Lacate (1969) is used with some adaptations to local conditions. Land systems are described in terms of the landform, soil and vegetation characteristics of their component land types and a profile diagram showing the generalized occurrence of these components is provided for each land system. Forest capability ratings are also given for each land type component. A good basis is thereby given for later detailed forest site classification and mapping as required.

Zoltai, S.C., J.P. Senyk, P. Gimbarzevsky, and A. Kabzems. 1967. Manitoba and Saskatchewan. In:R.J. McCormack, Land capability classification for forestry. Canada Dept. Forestry andRuralDevelopment, Canada Land Inventory. Report 4.

- Reviews of the CLI system as it is applied in Manitoba and Saskatchewan. Presents a map of ecologically significant site regions for the two provinces and summarizes the forest sites that occur within each capability class in each of the regions. Presents a tabular summary of forest capability classes of various sites (dry, fresh, moist, wet) on different materials (clay, loam, sandyloam, sand, peat and rock) in the different regions.

Zoltai, S.C. and N.B. Schultz. 1971. Forestry. In: Soils of the Grahamdale Area. Manitoba Soil Survey. Soils Report No. 16, pp. 84-93.

- Presents estimated productivity and required silvicultural reproduction practices by forest tree species for the soils of the area and a grouping of soil series into forest land-use classes, subclasses and units, is also provided.

Forest Site Classification - Productivity

Bella, I.E. 1967. Development of Jack pine and Scots pine in the Spruce Woods Forest Reserve, Manitoba. Canada Dept. Forestry and Rural Development. For. Br. Dept. Pub. No. 1171.

- Growth of jack pine and Scots pine plantations were compared 48 years after planting. Scots pine has maintained a significantly greater diameter and basal area increment than jack pine and has produced greater volumes per acre. Many trees of both species showed poor form. All trees have retained dead branches, but they were heavier on Scots pine. Scots pine has reproduced more readily than jack pine.

Bella, I. 1968. Jack pine yield tables for southeastern Manitoba. Dept. Fisheries and Forestry. Forestry Branch. Publ. No. 1207.

- Jack pine yield tables based on 365 permanent sample plot measurements are presented for the major jack pine site types in southeastern Manitoba. Total volume yield curves are constructed by fitting a modifived version of a logarithmic growth function to the data. Merchantable volumes are obtained by using ratios. Sites are described in terms of landform features, soil characteristics and vegetation using the Mueller-Dombois classification system.

Cayford, J.H. 1963. A description of mature jack pine forests growing on different sites in the B18a (Mixedwood) Forest Section, Manitoba and Saskatchewan. Canada Dept. of Forestry, For. Res. Br. Unpubl. MS.

- Copy not located.

Cayford, J.H., Z.Chrosciewicz and H.P. Sims. 1967. A review of silvicultural research in jack pine. Canada Dept. Forestry and Rural Development, Forestry Branch, Departmental Publication No. 1173.

- In a preliminary study in the Rainy River Section (L.12) of the Great Lakes-St. Lawrence Forest Region six soil profile types were recognized and preliminary productivity ratings determined. The best jack pine stands occurred on sandy gley podzols where site index at 50 years was 50, and average volume per acre at 70 years was 50 cords. Poorest stands occurred on dry, melanized and weakly podzolized sands where site index at 50 years was 43 to 45, and average volume per acre at 70 years was 30 cords. Jack pine stands on grey-wooded soils and polzols of fresh moisture status were intermediate in productivity (Ritchie, 1961).

In a more detailed study in the same section, fire forest habitat types, which commonly supported jack pine stands, were recognized. The most productive habitat type was the oligotrophic moist type on beta-gley podzols, which had a site index at 50 years of 54. The least productive type was the oligotrophic very dry type on aeolian regosols, which had a site index of 40. The oligotrophic dry type on minimal podzols, the oligotrophic fresh site type on low beta- and gamma-gley podzols, and the mesotrophic fresh type on bisequa podzols and bisequa and bisequa and orthic grey-wooded soils were intermediate in productivity (Mueller-Dombois, 1964).

For the Boreal Forest Region in Manitoba and Saskatchewan, six sites, based on groupings of soil moisture regime and permeability, have been recognized as commonly supporting jack pine (Jameson 1961, 1964). A statistical analysis of the height-age regression for each site indicated that regressions differed from one another either in slope or in level, and justified the recognition of the six sites. Site indexes at 50 years were 58 on fresh sandy loam to loam soils, 53 on moist stands, 52 on clay-loam soils, 50 on fresh sands, and 34 on dry sands (Jameson, 1964).

Duffy, P.J.B. 1962. The use of soil survey reports in the appraisal of forest land productivity in Alberta. For. Chron. Vol. 38, No. 2 pp 208-211.

- Merchantable forest stands were sampled on four soil series mapped in the Rocky Mountain House area of Alberta. It was found that variation in growth within a soil may be so large that prediction of forest yield is difficult, in which case a finer breakdown is needed. One series, for example, could be subdivided into phases based on criteria, surface texture, which affects available moisture in the soil. Other factors being tested included, slope angle, slope length, position on slope and depth of solum. The results of the study may suggest certain regrouping of soil series by topographic classes for better prediction of growth and yield.

Duffy, D.J.B. 1965. A forest land classification for the Mixedwood Section of Alberta. Dept. of Forestry Publication No. 1128.

- A field survey was devoted to the description and classification of soils and forest productivity in the accessible portion of the Mixedwood Forest (white spruce-trembling aspen) of Alberta. The basis for the classification is the distinction between different parent materials divided according to moisture status and the attendant differences in forest growth. Using white spruce maximum dominant height 80 years as a site index, parent materials are ranked in a forest land productivity classification. Prime sites for spruce are on moderately well-drained to poorly drained soils; less productive sites occur on well drained to poorly drained soils and the poorest merchantable stands are on very poorly drained and on rapidly drained soils. Some uses of the classification in forest management are discussed.

Jameson, J.S. 1963. Comparison of tree growth on two sites in the Riding Mountain forest experimental area. Canada Dept. For. Publ. 1019.

- Plot and tree measurements were made in uneven-aged white spruce-trembling aspen stands of common fire origin on the two predominant sites of the Riding Mountain Forest Experimental Area to compare stand and tree growth. The number of merchantable trees, the rate of height growth and the height of dominant trees at index ages and index diameters, and the merchantable and total volume were greater on the fresh Waitville site. Total number of trees per acre was greater on the moist Granville site. The greater growth in volume and in height of dominant trees on the fresh site was attributed to more favourable soil texture, structure and moisture conditions than on the moist site.

Jameson, J.S. 1964. Preliminary yield tables for black spruce Manitoba-Saskatchewan. Canada Dept. For. Publ. 1064.

- Yield tables, prepared from 167 single-examination plots, are presented for four physiographically defined sites. The sites are described as to soil parent material, soil profile development, lesser vegetation and height of dominant trees. The paper describes a modified intercept-percent method of preparing yield tables, and shows that intercept-percent varies with stand age as well as with site. The tables provide number of trees, basal area, average diameter and volume in cubic feet for the merchantable portion of a stand by ten-year age classes. Merchantable volume at 100 years is 2,200 cubic feet on site A, 1,923 cubic feet on site B, 1,523 cubic feet on site F and 1,289 cubic feet on site D.

Jameson, J.S. 1965. Relation of jack pine height growth to site in the mixedwood forest section of Saskatchewan. P. 299-326. In: Forest-soil relationships in North America. Second North American Forest Soils Conference. 1963. Oregon State Univ. Press, Corvallis, Oregon.

- Height-growth curves, based on stem analysis data are given for dominant jack pine for six ecologically defined sites. Jack pine habitats were initially described by soil pore pattern and soil moisture regime. Soil pore pattern was determined from soil texture and structure. Soil moisture regime was determined from soil profile development, position on slope and position of the ground water table as indicated by depth and intensity of mottling. For jack pine cover types, the recognized combinations of pore pattern and moisture regime were grouped, and use was made of recurring patterns of tree and lesser vegetation observed in the area to establish the six jack pine sites. Concluded that three interrelated factors - soil moisture regime, soil nutrient regime, and soil texture - probably have the greatest influence on height growth.

Jarvis, J.M., G.A. Steneker, R.M. Waldron and J.C. Lees. 1966. Review of silvicultural research-white spruce and trembling aspen cover type-Mixed Wood Forest Section, Boreal Forest Region, Alberta-Saskatchewan-Manitoba. Canada, Dept. For. and Rural Dev., For. Br., Dept. Publ. No. 1156.

- All studies were based on a physiographic framework comprising soil moisture regime, soil origin and soil texture. Sites in Alberta were grouped into four significant productivity classes. Dominant height of white spruce at 80 years of age varies from about 95 feet on the best sites to under 50 feet on the poorest. Results of studies carried out in Manitoba and Saskatchewan (MS-69, MS-168, MS-173 and MS-183) compare favourably with those of the study in Alberta. Although heights appear somewhat shorter and volumes a little less in Manitoba and Saskatchewan than in Alberta, differences between sites show similar trends.

Johnson, H.J. 1955. Growth and yield of black spruce, Sandilands Forest Reserve. Canada, Dept. Nor. Affairs and Nat. Res. For. Br. Unpubl. MS.

- Copy not located.

Johnson, H.J. 1957. Empirical yield tables for aspen on the Riding, Duck and Porcupine Mountains Manitoba. Canada Dept. Nor. Affairs and Nat. Res., For. Br. S & M 57-8.

- Empirical yield tables were prepared for aspen in pure even-aged stands in the Mixedwood Section of Manitoba. Data from 162 one-fifth and one-tenth acre plots were used in the analysis. Mensurational techniques used in the preparation of the tables follow those described by Chapman and Meyer (1949) for normal yield tables.

Pike, R.R. 1955. Yield of white spruce and balsam fir in an undisturbed stand, Duck Mountain, Manitoba. Canada Dept. Northern Affairs and Nat. Res., For. Br., For. Res. Div., Tech. Note 11.

Waldron, R.M. 1962. The effects of certain climatic factors on the terminal growth of white spruce at the Riding Mountain Experimental Area in Manitoba. MSc thesis, Univ. of Toronto.

Wilson, G.M. 1952. Problems predicting growth of jack pine in Manitoba and Saskatchewan. Canada Dept. Res. and Dev., For. Br. Unpubl. MS.

- Copy not located.

Silvicultural Management - Regeneration

Bruce, N.G. and H.P. Sims. 1970. Site preparation essential to obtaining best results from jack pine cones. Pulp and Paper Mag. of Canada, Volume 71, July 17, 1970.

Cayford, J.H. 1955. Silvicultural techniques for securing jack pine regeneration, Sandilands Forest Reserve. Canada, Dept. Nor. Affairs and Nat. Res. For. Br., Unpubl. MS.

- Copy not located.

Cayford, J.H. 1958. Scarifying for jack pine regeneration in Manitoba. Canada Dept. Nor. Affairs and Nat. Res. For. Br., Tech. Note No. 66.

Cayford, J.H. 1959. Seeding jack pine on the Sandilands Forest Reserve, Manitoba, 1925-55. Canada Dept. Northern Affairs and Nat. Resources For. Br. Tech. Note 79.

Cayford, J.H. 1961. Broadcast seeding jack pine at weekly intervals. Canada Dept. of Forestry, For. Res. Br. Tech. Note 106.

Cayford, J.H. 1963a. Planting spruce and pine Interlake Area, Manitoba. Canada Dept. of Forestry, Progress Report 63-MS-6.

Cayford, J.H. 1963b. Reproduction and residual stand development following cutting in red pine-jack pine stands in Manitoba. Canada Dept. of Forestry, For. Res. Br. Publ. No. 1010.

- Logging damage, including skidding and burning of slash piles, reduced advanced growth. Stocking with both red pine and jack pine regeneration varied with residual basal area. Approximately 30 square feet per acre appeared optimum for early establishment of jack pine and between 50 and 90 square feet for red pine. Regeneration was most commonly present on patches of mineral soil and on areas where litter thickness was reduced during logging. Unfavourable seedbeds included accumulations of slash, feather mosses and herbaceous, grass and shrub litter.

Cayford, J.H. 1963c. Some factors influencing jack pine regeneration after fire in southeastern Manitoba. Canada Dept. Forestry Publ. 1016.

- Site was one of the most important factors affecting survival and early growth of jack pine. Initial stocking was excellent and mortality was low on moderately fresh and moist sites. Initial stocking was generally adequate on dry sites, however, high mortality resulted in understocking. Early height growth was best on moist sites and poorest on dry sites.

Cayford, J.H. 1965. Planting spruce and pine in the Interlake area, Manitoba. Project MS-190, Progress Report 65-MS-20.

- Copy provided to client. Has a section on site classification by J.S. Jameson.

Cayford, J.H. and R.C. Dobbs. 1967. Germination and early survival of jack pine on three sites in southeastern Manitoba. Canada Dept. For. and Rural Dev. Bi-Monthly Research Notes 23.

Cayford, J.H. and R.A. Haig. 1964. Survival and growth of 1949-1962 red pine plantations in southeastern Manitoba. Canada Dept. of Forestry, For. Res. Br. Publ. No. 1093.

- Survival and growth were generally better on fresh than on dry sites. Rainfall during the first planting season was the most important single factor affecting plantation success. Results of spring planting were slightly superior to those of fall planting. Hand planting in ploughed furrows was more successful than machine planting or hand planting in scalps or where no site preparation was done. White grubs and deer appeared to be the only damaging biotic agents, and the damage caused was seldom extensive.

Cayford, J.H. and H.P. Sims. 1962. A study of jack pine seedfall on the Sandilands Forest Reserve, Manitoba. Canada Dept. Forestry For. Res. Br., Unpubl. MS. 62-2.

- Copy not located.

Haig, R.A. 1959a. Results of an experimental seeding in 1920 of white spruce and jack pine in western Manitoba. For. Chron. 35(1):5-12.

Haig, R.A. 1959b. Reforestation by planting, 1918-1930, Riding and Duck Mountains, Manitoba and Saskatchewan. Canada For. Br. Mimeo 59-3.

Haig, R.A. and J.H. Cayford. 1960. Factors affecting survival and growth of red pine plantations in southeastern Manitoba. Canada Dept. Northern Affairs and National Resources. Tech. Note 93.

- Between 1927 and 1958 over one million red pine were planted in the Sandilands forest reserve. On the basis of 400 trees per acre in 1958 representing satisfactory restocking, 26 percent of the planting was successful, and excluding portions destroyed by fire in 1949, 42 percent was successful. Drought was considered the chief cause of failure. A partial overstory of jack pine increased survival but reduced height growth. Young jack pine of about the same age as the planted trees outgrew them by a considerable margin but did not appear to have suppressed their height growth. The presence of a calcareous gravel layer close to the surface reduced survival and growth in some plantations.

Jameson, J.S. 1953. Regeneration of Jack pine cut-over areas, Sandilands Forest Reserve. Canada Dept. Nor. Affairs and Nat. Res., For. Br., Unpub. MS.

- Copy not located.

Jameson, J.S. 1956. Planting conifers in the Spruce Woods Forest Reserve, Manitoba, 1904-1929. Canada Dept. Northern Affairs and National Resources, For. Br., Tech. Note 28.

Jameson, J.S. 1961. Observations on factors influencing jack pine reproduction in Saskatchewan. Canada Dept. Forestry, For Res. Div., Tech. Note 97.

- Sites influenced revegetation chiefly through the lesser vegetation they supported. On the more productive sites competition tended to prevent seedling survival. On sites of intermediate productivity, stocking was sometimes obtained without a treatment to improve seedbed and reduce competition. On the poor sites competition ceased to be an important factor while protection heat and drought became more of a necessity. Results of study probably apply to zone B18a in Manitoba. Copy provided to client.

Jarvis, J.M. 1966. Seeding white spruce, black spruce and jack pine on burned seed beds in Manitoba. Dept. of Forestry Publ. No. 1166.

- The study was carried out in two areas at Riding Mountain and at Pine Falls. Germination and stocking of white spruce, black spruce and jack pine were studied on three seedbed types created by fire on upland sites in Manitoba. Germination stocking were higher for jack pine than for either white spruce or black spruce. Seedbed type had no effect on germination but did influence stocking after two growing seasons. In general, stocking was highest on mineral soil, intermediate on humus and lowest on partially decomposed duff. This study indicated that for successful regeneration of the above three species, fire has to be severe enough to expose mineral soil.

Jarvis, J.M., and J.H. Cayford. 1961. Regeneration following various methods of cutting black spruce in Manitoba. For. Chron. 37:339-349.

- Results five years after cutting indicated that cutover areas at the Sandilands were understocked with regeneration while stocking at the Duck Mountain was a failure. No correlations were evident between regeneration stocking and cutting method. Regeneration of black spruce was associated with type of seedbed. Favourable seedbeds included sphagnum moss, litter and slash. Black spruce seedlings occurred more frequently on the wetter sites because of a greater abundance of favourable seedbeds. Very wet sites were well stocked; wet sites were moderately stocked; and on very moist to moderately fresh sites stocking was a failure.

Jarvis, J.M. and J.H. Cayford. 1967. Effect of partial cutting and seedbed treatment on growth and regeneration in black spruce stands in Manitoba. Pulp and Paper Magazine of Canada, Woodland Rev., August.

Johnson, H.J. 1955. The effect of various slash disposal methods on the regeneration of cut-over jack pine stands. Canada Dept. Northern Affairs and Nat. Res. For. Br. Tech. Note 23.

- All methods of slash disposal studied in the Sandilands Forest Reserve resulted in unsatisfactory regeneration.

Johnson, H.J. 1956. Factors influencing black spruce reproduction on cut-over, burned-over and undisturbed stands. Canada Dept. Nor. Affairs and Nat. Res., For. Br., S & M 56-3.

- Some of the factors (Nelson River area) affecting black spruce reproduction were density, composition and age of the stand, condition of the forest floor, competition, site, climate, disease and animal depredations. All of these factors were important and most could, singly or in conjunction with others, limit the amount of reproduction on an area. It was, therefore, difficult to rate their relative importance as the importance of each varied from stand to stand.

Kolabinski, V. 1965. The affect of scalping and cultivating prior to planting on the survival and growth of white spruce, mesic clay loams, Riding Mountain. Canada Dept. Forestry, For. Res. Br., Internal Report MS-4.

- Mesic, grey-wooded loamy soils were used in the experiment.

Results not reported.

Kolabinski, V.S. 1967. Regenerating cut-over X2B and V2 sites by planting and seeding on scalped strips Manitoba Paper Company Limits. Canada Dept. For. and Rural Dev., For. Br. Int. Rep. MS-53.

- X2B sites (Manitoba Paper Company classification) are sites that occupy lower and mid slope positions and support merchantable stands containing various mixtures of black spruce, white spruce, jack pine and trembling aspen; the soil is a till often containing many large stones and boulders; texture varies from a sandy loam to clay loam; soil depth varies but the minimum is about two feet; moisture condition varies from fresh to moist; advance growth of softwoods is relatively scarce.

V2 sites (Manitoba Paper Company classification) are sites that occupy mid and upper slope positions on low rock ridges and support merchantable stands of black spruce and jack pine; soil origin and texture are similar to those on X2B sites; soil depth averages two feet; moisture conditions vary from dry to moist; softwood advance growth is lacking.

Kolabinski V.S. and J.M. Jarvis. 1970. Clearcutting alternate strips and scarifying in white spruce-aspen stands to induce white spruce regeneration, Manitoba and Saskatchewan. Can. Dept. Fish For. Int. Rep. MS-115.

- Results from these trials demonstrate that mechanical site preparation in partially cut mixedwood stands on mesic sites in the Mixedwood Forest Section will provide favourable conditions for white spruce regeneration. The catch of seedlings in any given year will depend upon the seed source available and on the amount of seed produced the previous year.

Pike, R.T. 1956. Cutting methods for management of white spruce, Riding Mountain Forest Experimental Area. Canada, Dept. Nor. Affairs and Nat. Res., For. Br., Unpubl. MS.

- Copy not located.

Roller, K.J. 1971. Provenance trials with white spruce of different seed sources in central Manitoba. Proc. 13th Meeting of the Tree Breeding Committee on Forest Tree Breeding in Canada. Prince George, B.C. April. pp 97-100.

- Results after 15 growing seasons from seed strongly suggest that seed source is an important factor in performance of planted white spruce. The varying response to precipitation and temperature could be the result of selection produced by differences in ecological factors at the different seed sources. Results of the trial indicate that white spruce seeds obtained from Saskatchewan and Manitoba, especially from Sandilands are more suitable for planting at Riding Mountain than seeds from eastern provinces.

Rowe, J.S. 1955. Factors influencing white spruce reproduction in Manitoba and Saskatchewan. Canada, Dept. Nor. Affairs and Nat. Res., For. Br. Tech. Note No. 3.

- An excellent early ecological study on white spruce reproduction. Copy provided to client.

Rowe, J.S. 1958. The influence of litter and humus on white spruce regeneration in cut-over stands, Riding Mountain. Canada Dept. Nor. Affairs and Nat. Res., For. Br., Unpubl. MS.

- Copy not located.

Sims, H.P. 1964. Root development of jack pine seedlings on burned-over dry sites in southeastern Manitoba. Canada Dept. Forestry, For. Res. Br., Publn. 1061.

Sims, H.P. 1970. Germination and survival of jack pine on three prepared cut-over sites. Canada Dept. Fish. and For., Can. For. Serv. Publ. 1283.

- Germination was significantly greater on a fresh and moderately fresh site than on a dry site. Heat in combination with drought was the main cause of mortality on the dry and moderately fresh sites. Animal damage was a potential hazard on the moderately fresh site.

Sims, H.P. 1977. Survival and growth of jack pine on prepared seedbeds. In: Jack pine in southeastern Manitoba. Environ. Canada, Can. For. Serv. Inf. Rep. NOR-X-508.

- This study indicated that on the moderately fresh and dry sites all seedbeds except the ridge will provide adequate survival of planted stock up to three years. However, most cut-over pine sites in southeastern Manitoba eventually became overgrown with fairly dense lesser vegetation, particularly shrubs, grasses and large perennials. On the fresh and dry sites, height growth or size of planted stock to three years did not vary significantly between

seedbeds.

Sims, H.P. and G.D. Campbell. 1970. Red pine seedfall in a southeastern Manitoba stand. Canada Dept. Fish. and For., Can. For.Serv. Publ. 1267.

Tucker, R.E., J.M. Jarvis and R.M. Waldron. 1968. Early survival and growth of white spruce plantations, Riding Mountain National Park, Manitoba. Canada, Dept. For. and Rural Dev., For. Br.,Publ. 1239.

- Early results from a number of plantations at the Riding Mountain Forest Experimental Area showed that transplant survival was better on fresh to moist sites that had been scalped or disked before planting than on wetter sites or on untreated ground. Height growth showed no relation to site but was better on areas disked before planting than on areas treated by other methods. Summer-planted transplants survived and grew as well as transplants planted in the spring or fall. Elk trampling caused much mortality; frost, especially in low-lying areas, reduced height growth.

Waldron, R.M. 1964. Cutting methods for management of white spruce, Riding Mountain Forest Experimental Area. Dept. of Forestry of Canada, For. Res. Br., Mimeo 64-MS-13.

Waldron, R.M. 1965. Cone production and seed fall in a mature white spruce stand. For. Chron. 41(3):314-329.

- Between 1954 and 1963 cone production of individual trees and seedfall were measured in a mature white spruce stand at the Riding Mountain Forest Experimental Area in Manitoba. Results showed that dominant and co-dominant trees produced heavier cone crops and produced them more frequently than intermediates; intermediates produced heavier and more frequent cone crops than suppressed trees. The stand is situated on a moderately well-drained, Gray Luvisol with a clay loam texture. Minor vegetation consists of a light herbaceous cover with scattered weakly developed colonies of beaked hazelnut (<u>Corylus cornuta</u> Marsh.).

Waldron, R.M. 1966. Factors affecting natural white spruce regeneration on prepared seedbeds at the Riding Mountain Forest Experimental Area, Manitoba. Canada Dept. Forestry and Rural Dev., For. Br. Dept. Publ. No. 1169.

- Periodic and annual examinations of over 4,000 regeneration quadrats showed that in addition to seedbed material, climate, litter fall, vegetative competition, cone crop, crown cover and moisture regime had significant effects on germination and early survival. Data were not available to show what effects all of these factors had on early growth of white spruce seedlings. Results clearly indicated that shelterwood cutting of mature white spruce-trembling aspen stands on fresh to moist clay loam soils, together with preparation of mineral soil seedbeds using a bulldozer and straight blade, will provide conditions ideally suited for the establishment of white spruce regeneration. Specific silvicultural treatments are given for regenerating mixedwood stands.

Walker, N.R. and H.P.Sims. 1984. Jack pine seed dispersal from slash and seedling performance on prepared seedbed. Canadian Forestry Service, Information Report NOR-X-259.

Silvicultural Management - Stand Tending

Bella, I.E. and J.P. DeFranceschi. 1974a. Analysis of jack pine thinning experiments, Manitoba and Saskatchewan. Environ. Can., Can. For. Service, Publ. 1338.

Bella, I.E. and J.P. DeFranceschi. 1974b. Commercial thinning improves growth of jack pine. Env. Canada, Can. For. Serv. Inf. Rep. NOR-X-112.

Cayford, J.H. 1964. Results of a 1921 jack pine thinning in western Manitoba. Canada Dept. of Forestry, For. Res. Br., Publ. No. 1077.

Johnson, H.J. 1955. Thinning jack pine Duck Mountain Forest Reserve. Canada Dept. Northern Affairs and Nat. Resources, For. Br., Unpubl. MS.

- Copy not located.

Steneker, G.A. 1962. Thinning in stands of mixed black spruce, white spruce and jack pine, Duck Mountain Forest Reserve. Unpublished MS.

- Copy not located.

Steneker, G.A. 1974. Thinning of trembling aspen (Populus tremuloides Michaux) in Manitoba. Environ. Can.; Can. For. Serv.; North. For. Res. Cent.; Edmonton, Alberta. Info Rept. NOR-X-122.

Steneker, G.A. and J.M. Jarvis. 1966. Thinning in trembling aspen stands, Manitoba and Saskatchewan. Dept. of Forestry Publication No. 1140.

- There was a marked difference of growth rate between sites; response to thinning treatments on the best site followed a trend similar to those on other sites. Data suggests that thinning should be initiated before the age of 20 years to be most beneficial to further stand development.

Waldron, R.M. and J.H. Cayford. 1961. Thinning in a two-storied stand of jack pine and black spruce in western Manitoba. Canada Dept. Forestry, Forest Research Branch, Mimeo 61-13.

Silvicultural Management - Vegetative Competition

Cayford, J.H. 1957. Influence of aspen overstory on white spruce growth in Saskatchewan. Canada, Dept. Nor. Affairs and Nat. Res. For. Br. Tech. Note No. 58.

- Apparently an excellent early study for zone B18a. Copy not located.

Cayford, J.H. and R.M. Waldron. 1963. Regeneration trials with jack pine on clay soils in Manitoba. For. Chron. 39:398-400.

- Results indicated failure for all treatments applied. Failure attributed to browsing and vegetative competition.

Hennessy, G.R. 1966. Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba. Canada Dept. For. and Rural Dev., For. Br. Internal Report MS-39.

Sims, H.P. and D. Mueller-Dombois, 1968. Effect of grass competition and depth to water table on height growth of coniferous tree seedlings Ecology 49:597-603.

- Greenhouse study to elucidate characteristics of grass competition in relation to root and shoot growth pattern of seedlings. Note that in southeastern Manitoba grass and shrub competition is mainly a factor after disturbance on mesotrophic fresh sites - mostly grasses immediately after fire, and grasses and shrubs (dominantly Corylus cornuta) after logging without fire. This does not occur on similarly disturbed oligotrophic fresh sites.

Steneker, G.A. 1967. Growth of white spruce following release from trembling aspen. Canada, Dept. Forestry, For. Res. Br. Publ. No. 1083.

Steneker, G.A. and J.M. Jarvis. 1963. A preliminary study to assess competition in a white spruce - trembling aspen stand. Forestry Chronicle 39:334-336.

Waldron, R.M. 1959. Hazel foliage treatment to reduce suppression of white spruce reproduction Canada Dept. Nor. Affairs and Nat. Res., For. Br. Tech. Note No. 75.

Waldron, R.M. 1965. Converting aspen stands to white spruce by planting and seeding on scalped strips, Manitoba. Canada Dept. Forestry, For. Res. Br., Internal Report MS-1.

- Twenty areas were established in aspen stands located througnout Manitoba. These stands varied in size from 3 to 160 acres, in age from 15 to 100 years and were located on very dry to very moist (moisture regimes 0 to 6) fine gravel, sandy-loam, clay-loam and clay textured soils. Scalped strips were prepared in each stand using a bulldozer and straight blade. Planting and seeding of white spruce strips was carried out either in the autumn or in the spring. Results not reported.

Silvicultural Management - Fire

Adams, J.L. 1964. Fires and forest fire danger rating in southeastern Manitoba. Canada Dept. Forestry, For. Res. Br., 64-MS-11.

Adams, J.L. 1966. Prescribed burning techniques for site preparation in cutover jack pine in southeastern Manitoba. Pulp and Paper Magazine of Canada, Woodl. Rev. Dec., 574-584.

Chrosciewicz, Z. 1976. Burning for black spruce regeneration on a lowland cutover site in southeastern Manitoba. Can. J. For. Res. 6:179-186.

Chrosciewicz, Z. 1978. Silvicultural uses of fire in mid-western Canada. Pp. 37-46 In: Fire Ecology in resource management: Workshop Proceedings. Environ. Can., Can. For. Serv. Inf. Rep. NOR-X-210.

Sims, H.P. 1973. Some ecological effects of prescribed burning on cutover jack pine sites, southeastern Manitoba. Diss. Abstr. B. Sciences and Engineering 34:4147-4148. Abstr. Ph. D. Thesis, Duke University, North Carolina, U.S.A.

Sims, H.P. and N.G. Bruce. 1969. Recovery of vegetation and its effects on the survival of planted jack pine seedlings after a light burn on a mixed pine-hardwood cutover. Pulp and Paper Magazine of Canada. 21:79-81.

Tucker, R.E. and J.M. Jarvis. 1967. Prescribed burning in white spruce-trembling aspen stand in Manitoba. Pulp and Paper Magazine of Canada, Woodl. Rev. July 333-335.

Williams, D.E. 1955. Fire hazard resulting from jack pine slash. Canada, Dept. Northern Affairs and Nat. Resources, For. Br. Tech. Note No. 22.

Williams, D.E. 1960. Prescribed burning for seedbed preparation in jack pine types. Pulp and Paper Mag., Canada, Woodlands Rev., April p. 38, 40, 42.

Appendix 2

Information Needs Questionnaire

QUESTIONNAIRE

Forest Management Site Classification and Mapping System for Manitoba

Objectives

This questionnaire was prepared to help determine, for all major users of forest management site classification information in Manitoba, the following:

a) Why they need site classification information?

b) Where they need site classification information?

c) What information they need? (ie. basic requirements) and

d) How they obtain this information?

Your answers will help greatly in the co-operative development of a forest management site classification to meet operational forestry needs in Manitoba.

Questions

PART I

1. Please indicate the name and affiliation of the organization responding to this questionnaire.

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2. Please list the management programs carried out by your organization which require the use of forest site classification information.

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3. Please complete Table 1. below. In it you are asked to indicate:

a) The management programs already listed in question 2.
b) The management decisions made in each of these programs which require site classification information.
c) Whether each listed decision fulfills a statutory requirement (i.e. the information is required by law) or is it for operational use only.
d) The relative importance of site classification information in arriving at each management decision.

Table 1.

Management Program	Management Decision(s)	Requirement		Relative Importance				
		Statute	Optional	Low 1	2	3	4	High 5
Eg. Review of application for extension of timber limits.	-Forest Land capability	X						X
	-Accessibility		X		X			

Part II includes questions 4 to 10. Please complete a separate Part II response for each management program identified in Question 2. and Table 1.

4. Please use the accompanying map (Map 1) to indicate the forest sections and forest-management units where you will require forest site classification information in order to make the management decisions which constitute this management program:
   a) in the immediate short term (1 - 5 years)

   ____

   ____

   ____

   b) over the longer term (5- 20 years)

   ____

   ____

   ____

5. For this management program, what scale of mapped forest land classification information will you need to arrive at the management decisions listed in Table 1 ?

Range of (and usual) Publication Scale		Preferred Scale
a) 1:14,000 or larger	(1:5,000)	[ ]
b) 1:5,000 to 1:40,000	(1:20,000)	[ ]
c) 1:30,000 to 1:130,000	(1:50,000)	[ ]
d) 1:50,000 to 1:300,000	(1:100,000)	[ ]
e) 1:100,000 or smaller	(1:250,000)	[ ]

6. Which of the options listed below best describes the usual size and the smallest size of the areas about which the management decisions of the program apply ?

	Usual Size	Smallest Size
a) Specific Site (less than 10 acres)	[ ]	[ ]
b) 1/4 mi^2 or less	[ ]	[ ]
c) 1/4 to 1 mi^2	[ ]	[ ]
d) 1 to 9 mi^2 (1/4 township)	[ ]	[ ]
e) 1/4 to 1 township	[ ]	[ ]
f) 1 to 10 townships (watershed)	[ ]	[ ]
g) 10 to 40 townships (county)	[ ]	[ ]
h) 20 to 120 townships (forest MU)	[ ]	[ ]
i) Greater that 120 townships	[ ]	[ ]

7. Listed below are some types of information frequently found on, or extractable from, forest site classification maps. Please indicate how important each type of information is in helping you make the management decisions applicable to this program.

		Useful				
	Not Used	Slightly				Highly
		1	2	3	4	5
Climate Zone/Ecoregion	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Vegetation Description						
- Cover Type	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Physiognomic group	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Association	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Others(specify)______	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- ________________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Surficial Geologic Material	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Landform Classification	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Topographic Classification	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Slope	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Moisture Regime	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Classification (Great Group,Subgroup)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Association	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Profile Description	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Humus Form	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Texture	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Pore Pattern	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Structure	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Drainage	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Depth to Bedrock	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Soil Chemical Properties	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Engineering Properties	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Erosion Rating	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Forestry Use Rating (specify)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Wildlife Use Rating (specify)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Recreat. Use Rating (specify)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Engineering Use Rate(specify)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Others (specify)________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
________________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
________________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

8. Please indicate the major sources of forest site classification which you presently use and the degree to which each satisfies your present needs.

	Not Used	Least 1	2	3	4	Most 5
Forest Habitat Type Maps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Ecological (biophysical) Land Classification Maps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Forest Cover Maps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Surficial Geology Maps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Source ______________						
Soil Survey Maps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Special In-House Surveys	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Specify ______________						
Forest Site Classification Key	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Specify ______________						
CLI Forest Capability Class'n	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Others (specify) __________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
____________________________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

PART II (continued)

9. For this management program, how useful are each of the various levels of display of forest-site classification information listed below in answering at your management decisions ?

	Not Used	Least 1	2	3	4	Most 5
a) Site Specific Data (i.e. point source site classification, vegetation classification, soil classification, laboratory analysis data, etc.)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
b) Map Display of Original Data (i.e. basic site classification map consisting of generalized units defined in terms of climate, parent geological material, landform, drainage, soil, vegetation etc.	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
c) Text Discriptions of Original Map Elements (i.e. typical report describing general characteristics of map area and specific characteristics of each unique map unit)	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
d) Map Displays of Secondary Derived Data (i.e. interpretative maps, rating maps, etc.) Please indicate types frequently used (eg. CLI) ________________ ________________ ________________ ________________	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

10. How do you meet present needs of your management program requiring forest site classification information ?

a) In-house data collection/mapping ______________________

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b) Internally funded, privately contracted data collection/mapping ______________________

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____

c) Privately funded, privately collected data mapping (i.e. industry produced maps and information for regulatory submissions) ______________________

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d) Production from other government agencies (please specify)

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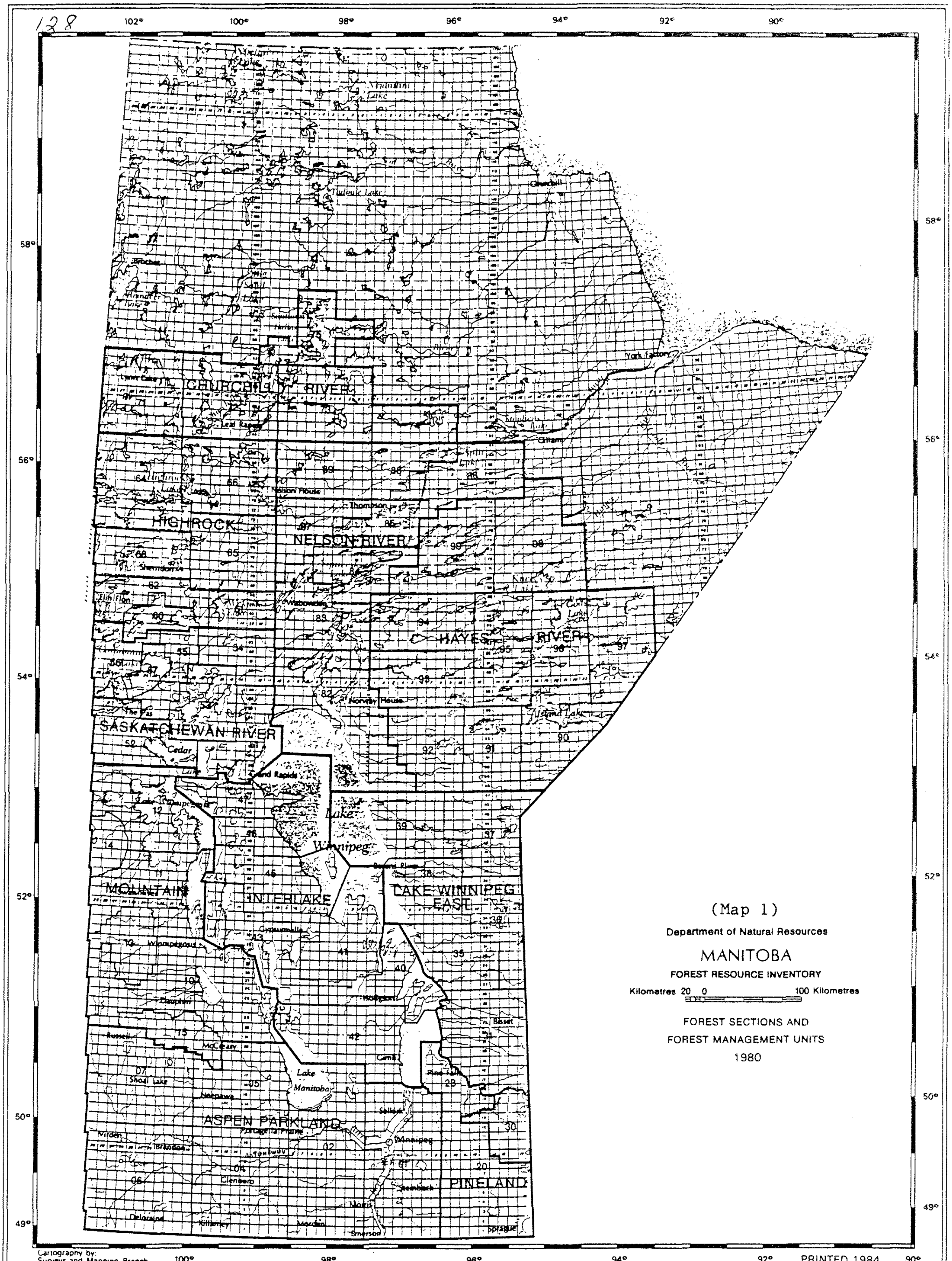

(Map 1)
Department of Natural Resources
MANITOBA
FOREST RESOURCE INVENTORY
Kilometres 20 0 100 Kilometres
FOREST SECTIONS AND
FOREST MANAGEMENT UNITS
1980
CHURCHILL RIVER
HIGHROCK
NELSON RIVER
HAYES RIVER
SASKATCHEWAN RIVER
MOUNTAIN
INTERLAKE
LAKE WINNIPEG EAST
ASPEN PARKLAND
PINELAND
Churchill
York Factory
Lynn Lake
Thompson
Flin Flon
The Pas
Norway House
Grand Rapids
Lake Winnipeg
Lake Manitoba
Winnipegosis
Dauphin
Russell
Neepawa
Portage la Prairie
Brandon
Virden
Winnipeg
Selkirk
Steinbach
Morris
Emerson
Morden
Killarney
Deloraine
Sprague
Cartography by:
Surveys and Mapping Branch,
Manitoba-1980
PRINTED 1984

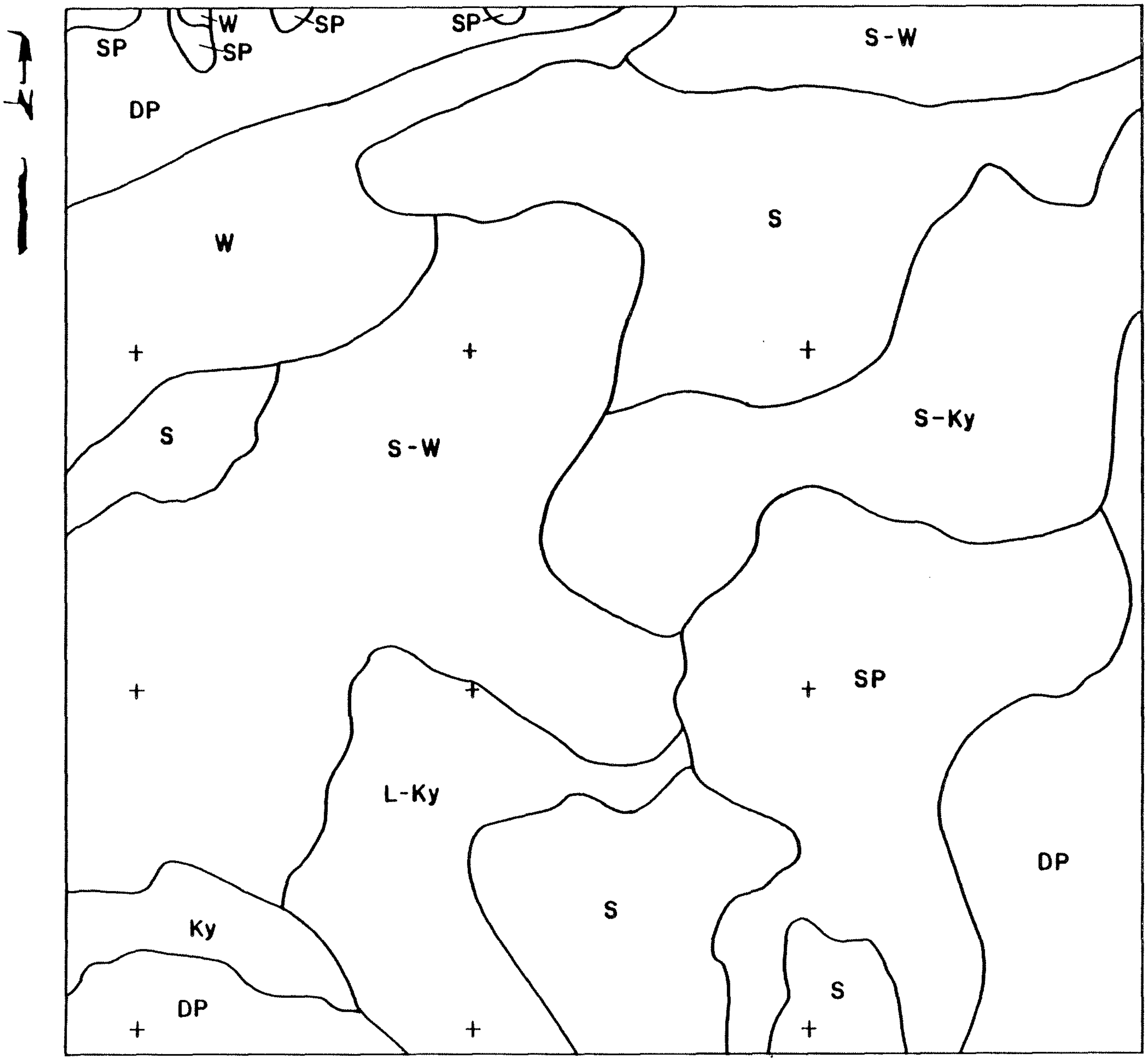
Appendix 3

Map Demonstration Area A

AREA A
SITE MAP LEGEND
TOWNSHIP 6 RANGE 10 EAST

Symbol	Name	Soil Subgroup	Drainage	Vegetation
AV	Alluvium	Gleyed Cumulic Regosols, Mucky Gleysols	Imperfect* Poor*	AS,E,MM,BA/Tall Shrubs/Fern (evm)
BO	Open Bog	Typic Mesisols, Fibrisols	Very poor	Sphagnum/Dwarf Shrubs/BS,TL,EC((10%)
DP1	Deep Peat	Typic Mesisols, modal	Very poor*	BS,TL,(EC)/Feathermoss-Sphagnum-Ledum (S)
DP2	Deep Peat	Typic Mesisols, sphagnic	Very poor	Stunted BS,TL/Feathermoss-Sphagnum-Ledum (S)
KRLS/3	Kerry- Lonesand	Peaty Gleysols, Gleyed Eluv. Dystric. Brun.	Poor* Imperfect	Alder, Willow/Dwarf Birch/Sedges (ew) JP,BS,WS/Forbs & Grasses/Tall Shrubs (om)
KRSI/3	Kerry- Sirko	Peaty Gleysols, Gleyed Gray Luvisol	Poor* Imperfect*	Alder, Willow/Dwarf/Birch/Sedges (ew) BS,BF,WS,TA/Forbs & Grasses/Tall Shrubs (mm,mvm)
KRSP/2	Kerry- Shallow Peat	Peaty Gleysols Terric Mesisols	Poor* Very poor*	Alder, Willow/Dwarf Birch/Sedges (ew) BS,TL/Feathermoss-Sphagnum-Ledum (FS)
LSKR/3	Lonesand- Kerry	Gleyed Eluv. Dystric Brunisol, Pty. Gleysols	Imperfect, Poor*	JP,BS,WS/Forbs & Grasses/Tall Shrubs (om) Alder, Willow/Dwarf Birch/Sedges (ew)
SDI/3	Sandilands	Eluviated Dystric Brunisol	Good to Moderate	JP,BS/Tall Shrubs/Grasses & Forbs (of)
SDLS/3	Sandilands- Lonesand	Eluv. Dystric Brun. Gleyed Eluv. DyB.	Good Imperfect	JP,BS/Tall Shrubs/Grasses & Forbs (of) JP,BS,WS/Forbs & Grasses/Tall Shrubs (om)
SDWO/3	Sandilands- Woodridge	Eluv. Dystric Brun. Orthic Gray Luvisol	Good to Moderate	JP,BS/Tall Shrubs/Grasses & Forbs (of) JP,BS,WS,BF/Tall Shrubs/Grasses & Forbs (mf)
SP1	Shallow Peat	Terric Mesisols	Very poor*	BS,TL/Feathermoss, Sphagnum, Ledum (FS)
SP2	Shallow Peat	Terric Mesisols	Very poor*	BS,EC/Feathermoss, Sphagnum, Ledum (FS)
SPKR	Shallow Peat- Kerry	Terric Mesisols, Peaty Gleysols	Very poor*, Poor*	BS,TL/Feathermoss, Sphagnum, Ledum (FS) Alder, Willow/Dwarf Birch/Sedges
WOG/3	Woodridge	Orthic Gray Luvisol	Good to Moderate	JP,BS,WS/Tall Shrubs/Grasses, Forbs (mf,mf)
WOG/4	Woodridge	Orthic Eutric Brunisol	Rapid	JP/Arctostaphylos/Cladonia (d)
WOKR/4	Woodridge- Kerry	Orthic Eutric Brunisol, Peaty Gleysols	Rapid, Poor*	JP/Arctostaphylos/Cladonia (d) Alder, Willow/Dwarf Birch/Sedges (ew)

* With Seepage



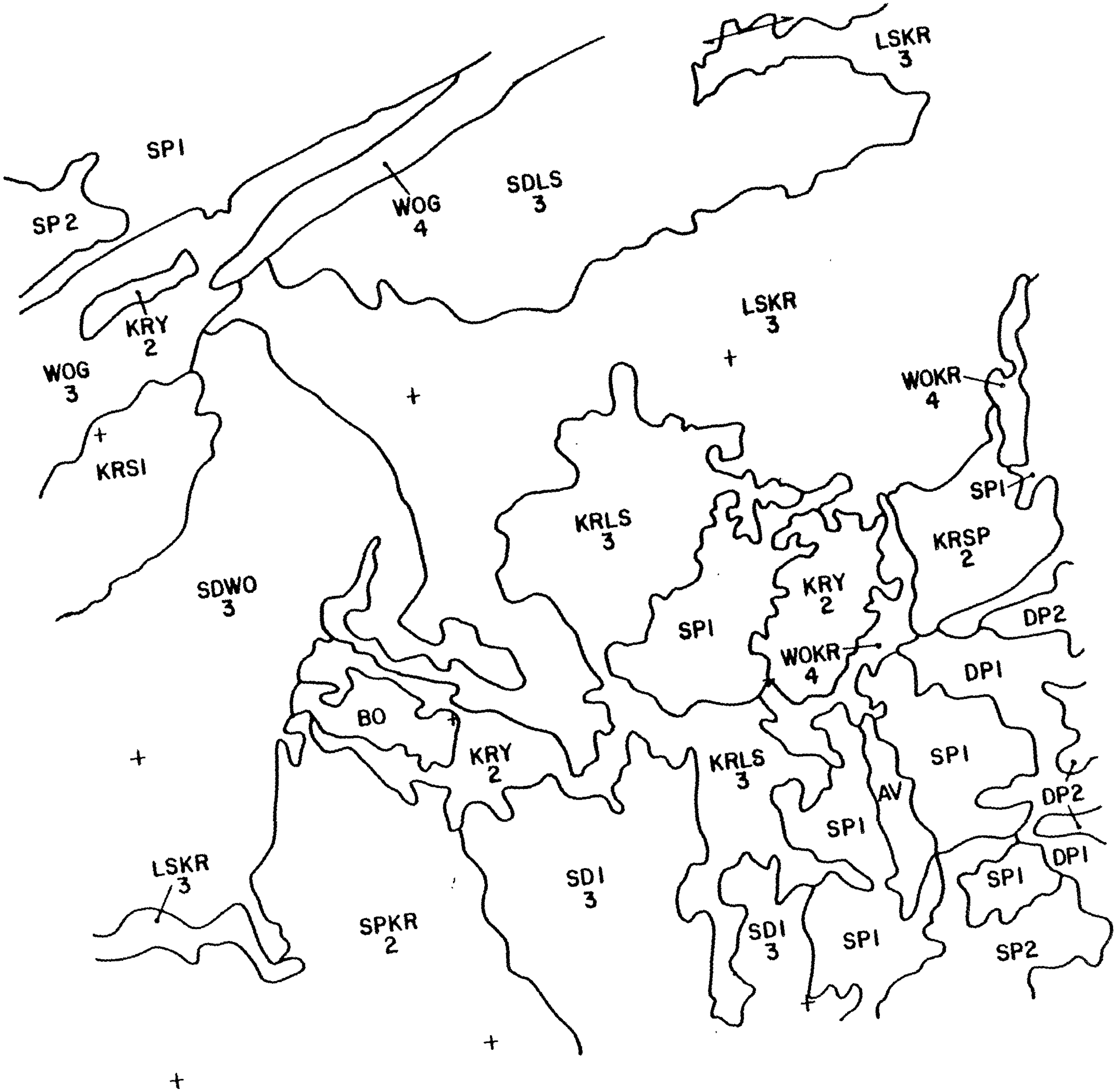
SOILS MAP
Tp. 6 R. 10 E

0 — 1 km
0 — ½ mi

LEGEND

DP	Deep' Feat
L-Ky	Lonesand - Kerry
S	Sandilands
S-Ky	Sandilands - Kerry
SP	Shallow Peat
SW	Sandilands - Woodridge
W	Woodridge

FOREST SITE MAP



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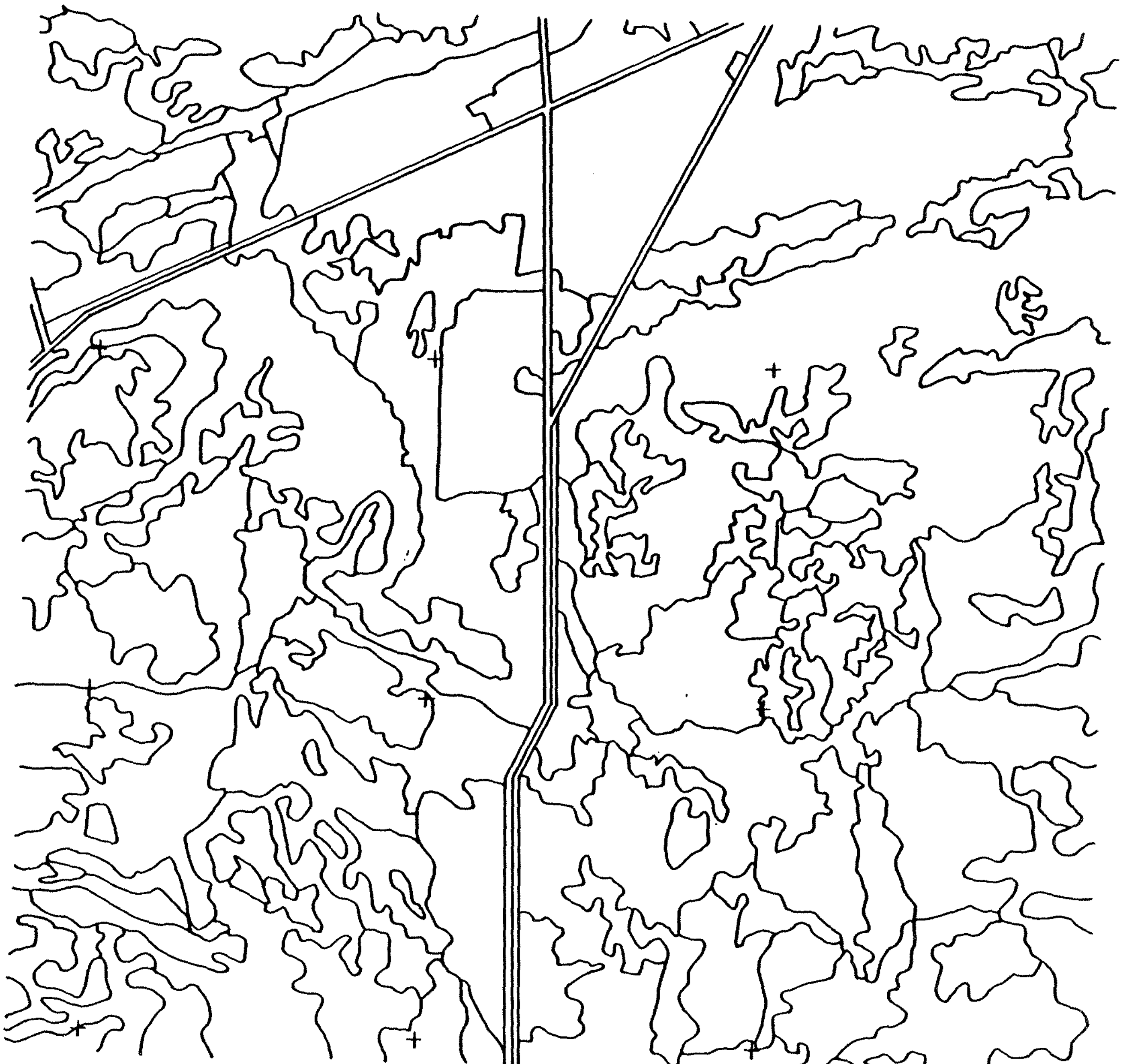


FOREST COVER
TYPE MAP

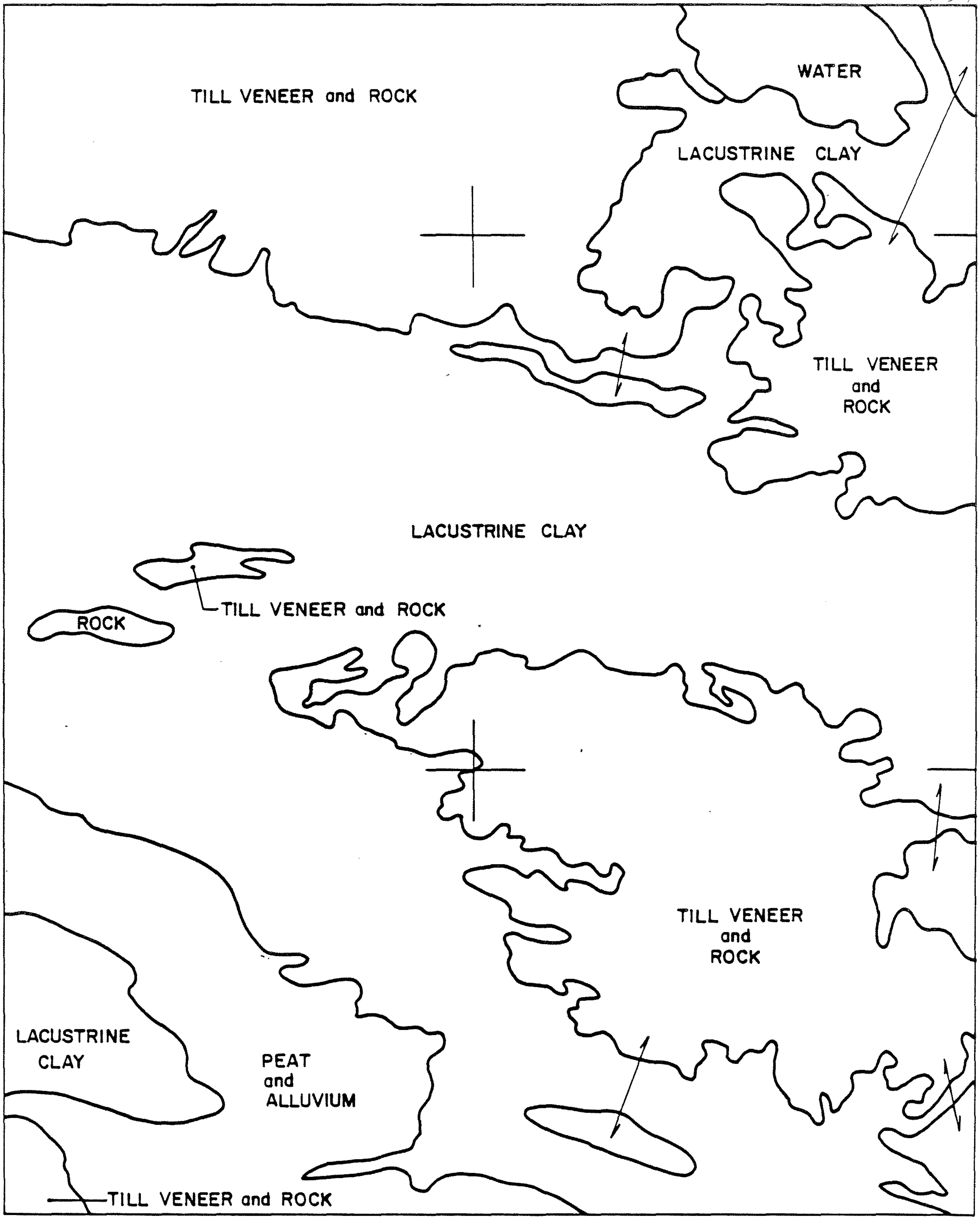
Appendix 4

Map Demonstration Area B

AREA B
SITE MAP LEGEND
TOWNSHIP 24 RANGE 12 EAST

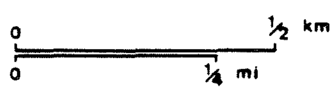
Symbol	Name	Soil Subgroup	Drainage	Vegetation
AV	Alluvium	Gleyed Cumulic Regosols, Mucky Gleysols	Imperfect* to Poor*	Willow, Alder/Sedges
BO	Open Bog	Typic Mesisols, Fibrisols	Very poor	Sphagnum/Dwarf Shrubs/BS,TL (<10%)
DP1	Deep Peat	Typic Mesisols, modal	Very poor*	BS,TL/Feathermoss, Sphagnum, Ledum
IBY1/4	Indian Bay	Eluviated Dystric Brunisols (sh.) Rock (<20%)	Good Rapid	JP,BS,TA/Feathermoss/Arctostaphylos JP/Lichen
IBY1R/5	Indian Bay	Eluviated Dystric Brunisols (sh.) Rock (20-40%)	Good Rapid	JP,BS,TA/Feathermoss/Arctostaphylos JP/Lichen
LTI1/3	Lettonia	Solonetzic Gray Luvisol	Moderate	WS,BF,BS,(TA)/Tall Shrubs/Feathermoss, Forbs
M	Marsh	(Standing Water)	(Inundated)	Marsh (Beaver Flood)
R	Rock	Non-soil	Rapid to excessive	JP/Lichen
SP1	Shallow Peat	Terric Mesisols	Very poor	BS,TL/Feathermoss, Sphagnum, Ledum

* With seepage

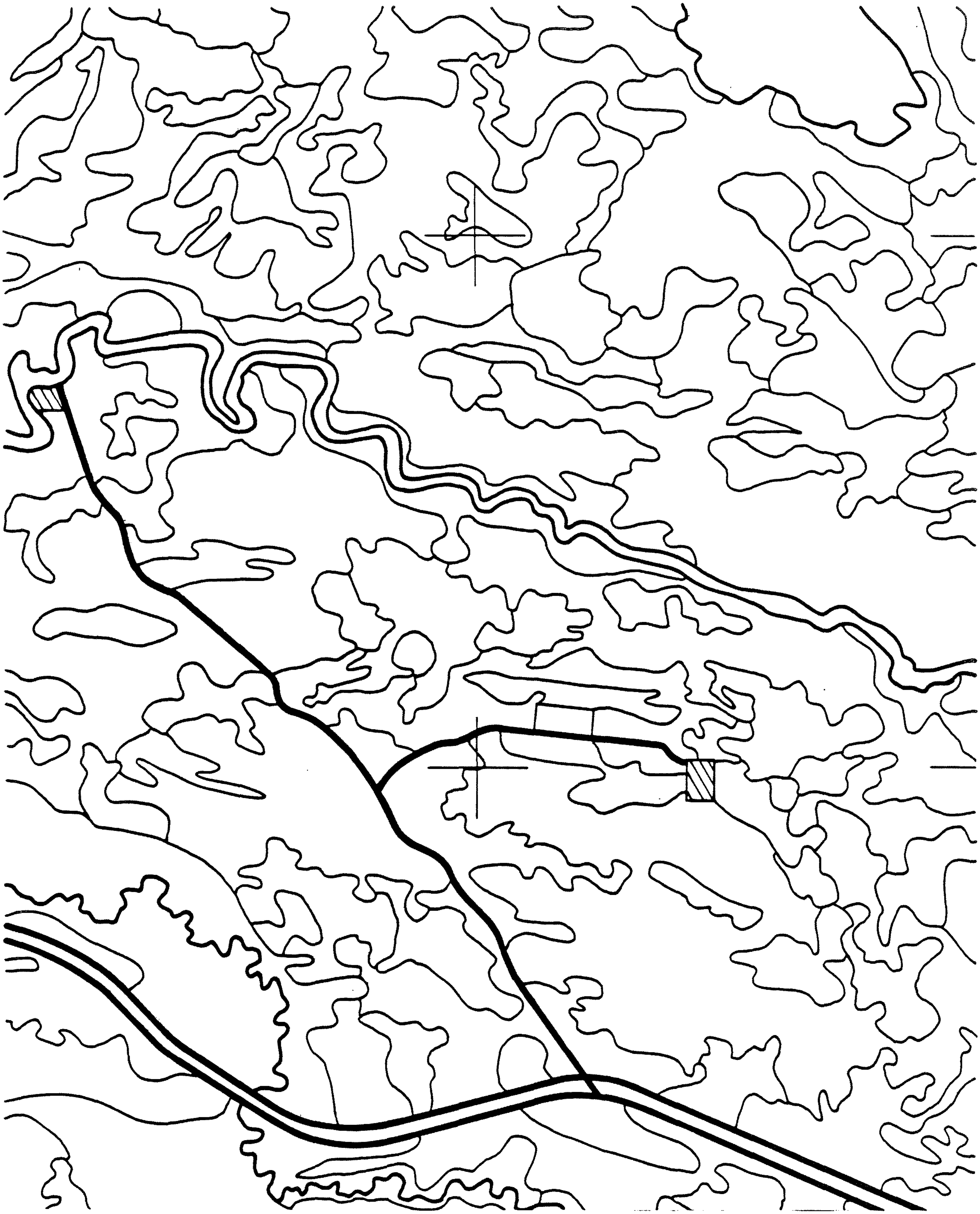


SURFICIAL MATERIALS MAP

Tp. 24 R. 12 E



· FOREST SITE MAP



· FOREST COVER TYPE MAP