ncasi technical bulletin

NATIONAL COUNCIL OF THE PAPER INDUSTRY FOR AIR AND STREAM IMPROVEMENT, INC., 260 MADISON AVENUE, NEW YORK, N.Y. 10016

FORESTED WETLANDS CLASSIFICATION AND MAPPING:
A LITERATURE REVIEW

TECHNICAL BULLETIN NO. 606

MARCH 1991

NATIONAL COUNCIL OF THE PAPER INDUSTRY FOR AIR AND STREAM IMPROVEMENT, INC.
260 MADISON AVE. NEW YORK, N.Y. 10016 (212) 532-9000 FAX: (212) 779-2849

March 21, 1991

Dr. Isaiah Gellman
President
(212) 532-9000

Technical Bulletin No. 606

FORESTED WETLANDS CLASSIFICATION AND MAPPING: A LITERATURE REVIEW

The National Council's Forest Wetlands Program was begun in April 1989 to address information needs related to silviculture in forest wetlands and its environmental effects. Forest wetlands are extremely important sources of timber and have high sustainable productivity given proper management. The National Wetlands Policy Forum (The Conservation Foundation 1988) recognized forest management as a "compatible use" of wetlands that can provide economic returns to landowners while preserving other wetland functions and values. The Forum recommended that private landowners be encouraged to utilize sound silvicultural practices in wetlands, and that timber companies pursue research to enhance both environmental protection and economic returns.

In light of these recommendations, the National Council is working to provide the information needed to develop and/or improve silvicultural Best Management Practices that are economically feasible and minimize adverse environmental impacts. The overall objective of the NCASI Forest Wetlands Program is to determine how landowners can manage wetlands for timber production while protecting other wetland functions such as streamflow regulation, water purification, and food chain/ wildlife habitat support. Results have been, and will be, useful in responding to legislative and regulatory proposals that would severely restrict forest management activities in wetlands.

Questions of wetland definition and classification are receiving priority attention in the NCASI Forest Wetlands Program. This results from our industry's expressed technical concerns over the 1989 *Federal Manual for Identifying and Delineating Jurisdictional Wetlands*. The Manual has greatly increased the extent of federal regulatory jurisdiction under Section 404 of the Clean Water Act. NCASI has conducted an extensive technical review of the Manual and concluded that many areas classified as jurisdictional wetlands bear no visible or functional resemblance to swamps, bogs, marshes, or other recognized wetland types. NCASI has recommended an alternative approach in which wetlands identification and delineation would be explicitly linked to a wetland classification system. The approach would consider differences among wetland types in hydrology, appearance, landscape position, and other factors that must be recognized in order to delineate accurate wetland boundaries.

This technical bulletin complements our analysis of the federal delineation manual by providing a thorough review of the scientific literature on wetlands classification and mapping. It includes (a) a review of wetland definitions, (b) a discussion of land classification concepts and principles as applied to wetlands, and (c) descriptions of classification systems applicable to forest wetlands in the United States and Canada. The information provided will be useful in the development and testing of wetland delineation methods and forestry Best Management Practices.

This review was prepared by Dr. Stephen F. Mader while he was a doctoral candidate at North Carolina State University's College of Forest Resources. Dr. Mader's current position is Environmental Scientist with CH2M Hill in Portland, Oregon.

Your comments and questions on this technical bulletin are solicited and should be directed to Dr. Alan Lucier, NCASI Program Director for Forest Environmental Studies, at this office; (212) 532-9251.

Very truly yours,

Dr. Isaiah Gellman
President

TABLE OF CONTENTS

FORESTED WETLANDS CLASSIFICATION AND MAPPING: A LITERATURE REVIEW

TECHNICAL BULLETIN NO. 606
MARCH 1991

ABSTRACT: Classification and mapping of forest wetlands facilitates communication, understanding, and management of a resource steeped in social, economic, and environmental concern. A broad spectrum of classification systems exists; this review attempts to portray their advantages, disadvantages, and inter-relationships. Included is a review of classification theory for resource management and the historical development of national wetland inventories and wetland classification schemes.

Diagnostic criteria for wetland classification vary widely and are a function of the intended application of the classification and the variability of the forested wetlands resource. Chemical, hydrologic, vegetative, soil, physiographic, ecosystem/ecological, and management criteria commonly distinguish wetland classes.

Approaches to forested wetlands classification are single-factor or multifactor, hierarchical or unstructured, and physiographic or parametric. Multifactor approaches are favored since they have the potential to integrate ecological properties. Hierarchical classifications enable finer, low-level associations among diagnostic characteristics to be absorbed into broader, high-level relationships. Physiographic classifications are commonly small-scale and based on natural units of the earth's surface. Parametric approaches are objective, measurement-derived classifications for detailed applications. Hierarchical physiographic classifications may contain a parametric approach at lower, refined levels. Regional approaches to forested wetlands classification (based on unique diagnostic characteristics of the local resource or accepted convention) can be retained at the lowest hierarchical levels. New approaches to classification should be cognizant of existing systems.

KEYWORDS: Forested wetlands, land classification, natural resource mapping.

RELATED NCASI PUBLICATIONS:

(1) *Best Management Practices for Forest Wetlands: Concerns, Assessment, Regulation and Research.* NCASI Technical Bulletin No. 583 (February 1990).

(2) *Managing Oregon's Riparian Zone for Timber, Fish and Wildlife.* NCASI Technical Bulletin No. 514 (February 1987).

FORESTED WETLANDS CLASSIFICATION AND MAPPING: A LITERATURE REVIEW

Dr. Stephen F. Mader

I INTRODUCTION

A. Problem Analysis

Forested wetlands occur in many different regions, geological formations, and landscape positions. They vary tremendously with respect to soils, hydrology, productivity, species composition, and wildlife habitat. Management practices appropriate for one type of wetland may be inappropriate in another. A practical system of forest wetland classification is needed to guide decisions and actions that affect timber production and other wetland functions (Boyce and Cost 1974).

There is no single correct way to classify forested wetlands. Different criteria and objectives have naturally led to the development of different classifications. Unfortunately, the various classifications have developed without benefit of well defined terminology and taxonomic concepts. Each geographic area poses unique challenges to classification (Bailey *et al.* 1978) and it is not unusual to find several systems in use within a scientific discipline or land management agency. A plethora of terminology to identify wetland features or traits has precipitated confusion; very few terms have consistent usage nationwide (Heinselman 1963, Hofstetter 1983). A common classification language, including terminology and definitions, is urgently needed (Bailey *et al.* 1978).

New needs tend to generate new classifications, but consensus, approval, and acceptance are hardfought and rare, as demonstrated by the partially successful national ecological land classification (Driscoll *et al.* 1984). Once devised, a classification must be marketed to convince potential users of its merit and value and to promote familiarity. The popular *Classification of Wetlands and Deepwater Habitats of the United States* was so successfully "sold" by scientists and planners that previously unfamiliar terms, such as palustrine and estuarine wetlands, have been propelled into regular scientific usage.

B. Scope and Objective

This review targets land resource classification systems that include or suggest a framework for classifying forested wetlands. Many different systems are covered. Only a few specifically address forested wetlands, but all have components that may be applied in new or modified systems for forested wetlands. Special treatment is given to those systems that facilitate prescription of management practices. Local ecological or floristic descriptions without express application outside the respective study area are excluded. Reference sources include agency publications, scientific journals, proceedings, and compendiums.

The objective of the review is to lay the groundwork for better understanding of forested wetland types, recognition of the distinguishing criteria upon which the classification schemes are based, and establishment of basic and applied research priorities. Approaches to forested wetlands classification are reviewed in the context of classification theory. Overviews of wetlands classification development in the United States and Canada are provided, and the relevance of other classification models or ideas is discussed. Specifically, national land classification systems are included since they fit forested wetlands into an ecological or ecosystem framework. Such broad forest classifications demonstrate that common terminology can be shared across regional boundaries.

An examination of available wetland classification schemes suggests many criteria (e.g., vegetation, physiography, hydrologic energy, landscape position) upon which to base distinctions among forested wetlands. For example, terrain classification addresses the productivity and operability of forest sites and offers an approach to improving management decisions in forested wetlands. Important classifications that were developed to address nontimber values of forests or wetlands are also acknowledged along with their potential contribution to forested wetlands management. Finally, a status report on national wetland mapping and inventory projects closes the review.

Terminology used in this review follows Cowardin and others (1979) and Gore (1983), unless otherwise stated.

II WHAT IS A WETLAND?

The definition of wetlands depends on the objectives and field of interest of the user. Many disciplines of study have their own wetlands definitions (Mitsch and Gosselink 1986). Several definitions of "wetland" have been formulated at the federal level to define "wetland" for various laws, regulations, and programs. The following ones, compiled by the Federal Interagency Committee for Wetland Delineation (1989), are most influential.

A. Section 404 of the Clean Water Act

The U.S. Environmental Protection Agency (EPA) and Army Corps of Engineers (COE) adopted a regulatory definition of wetland for administering Section 404 of the federal Clean Water Act. The definition emphasizes hydrology, vegetation, and saturated soils. Wetlands are:

> "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence

> of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."

B. Food Security Act of 1985 and Emergency Wetlands Resources Act of 1986

The U.S. Soil Conservation Service (SCS) has a wetland definition for identifying wetlands on agricultural land. Specifically, this definition is used to assess eligibility of farmers for U.S. Department of Agriculture program benefits under the "Swampbuster" provision of the Food Security Act of 1985. Wetlands are defined by SCS as:

> "areas that have a predominance of hydric soils and that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, except in Alaska identified as having a high potential for agricultural development and a predominance of permafrost soils."

This definition is similar to the EPA and COE definition in that it specifies hydrology, hydrophytic vegetation, and hydric soils. Areas are considered to have a predominance of hydric soils if they fit the SCS hydric soils criteria (USDA Soil Conservation Service 1987). The Emergency Wetlands Resources Act of 1986 includes a similar definition, but without the exception for Alaska.

C. The National Wetlands Inventory

The U.S. Fish and Wildlife Service (FWS) developed the *Classification of Wetlands and Deepwater Habitats of the United States*, which is the basis for reporting the National Wetlands Inventory (Cowardin *et al.* 1979). The classification contains this definition of wetlands:

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Like other wetland definitions, the FWS definition emphasizes three key attributes: (1) hydrology (the degree of flooding or soil saturation), (2) wetland vegetation (hydrophytes), and (3) hydric soils. Unlike the prior two wetland definitions, FWSdesignated wetlands can be either vegetated or nonvegetated, recognizing that some types of wetlands lack vegetation. However, completely drained hydric soils that are no longer capable of supporting hydrophytes due to a change in water regime are not considered wetland since wetland hydrologic conditions no longer exist (Tiner 1989).

Soil scientists were still developing the concept of hydric soils when the FWS classification was completed. Since the mid-1980s, the concept of hydric soils has further evolved (Tiner 1989). For example, recently inundated soils (formerly nonhydric soils) are now by definition classified as hydric soils (U.S. Soil Conservation Service 1987). Nonsoil is substrate that does not support erect emergent vegetation (e.g. cattails growing in shallow water) or woody vegetation (Tiner 1989).

The FWS definition has been frequently misinterpreted. According to Tiner (1989), in order for any area to be classified as wetland by FWS, the area must be periodically saturated or covered by shallow water, whether or not wetland vegetation or hydric soils are present. Tiner (1989) further explains that hydrophytes and hydric soils develop as a direct result of a wetland hydrologic regime. The hydrology responsible for creating and maintaining all wetlands is the most vital attribute. The presence of either hydrophytes or hydric soil alone does not in itself constitute a wetland. For example, a low-lying area dominated by a facultative wetland plant (e.g., red maple) should not be classified as a wetland without examining soils or hydrology.

D. Canada Committee on Ecological Land Classification

The Canadian definition of wetland has numerous similarities to U.S. agency definitions (Tarnocai 1980). A Canadian wetland is:

> "land that has the water table at, near, or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment."

E. Summary of Federal Definitions

Federal definitions, tested in the courts and having considerable detail, are used for both scientific and management purposes. In their wetland definitions, the COE, EPA, and SCS include only areas that are vegetated under normal circumstances, while the FWS definition encompasses both vegetated and nonvegetated areas. Except for the FWS inclusion of nonvegetated areas as wetlands, and the exemption for Alaska in the SCS definition, all four agencies use the same three basic elements - hydrology, vegetation, and soils - for defining wetlands. The Canadian definition exhibits an obvious exchange of concepts, differing mainly in its recognition that biological processes also distinguish wetlands from other habitats. All federal definitions focus on the determination and delineation of jurisdictional wetlands without differentiating between types, phases, or developmental stages.

F. Forested Wetlands

Federal agencies of the United States and Canada have not developed regulatory definitions of "forested wetland". According to the FWS *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin *et al*. 1979), "forest" is a taxonomic Class within the Estuarine and Palustrine wetland Systems, distinguished by the presence of woody vegetation at least six meters tall. The height criterion is arbitrary and an artifact of physiognomic life-form classification (Mueller-Dombois and Ellenberg 1974). The U.S. Forest Service requires that forested wetlands have a minimal stocking of 16.7 percent (based on all live stems) and productivity of 20 ft^3/ac/yr (Tansey 1989).

III NATURAL RESOURCE CLASSIFICATION AND MAPPING

A. Why Classify Forested Wetlands?

Classification is the ordering or arranging of objects into groups or sets on the basis of their similarities or relationships (Bailey *et al*. 1978). Frayer and others (1978) outlined three purposes of natural resource or land classification: (1) policy formulation; (2) information for land management decisions; and (3) coordination within and between agencies and groups.

Within policy formulation, policy development and policy implementation may require different levels of detail. For example, information used to develop or alter federal programs is generally much less detailed than that needed to implement the same programs (Frayer *et al*. 1978).

Natural resource classification at the local level serves the land manager in several ways. These include (1) inventory of current resources, (2) transfer of knowledge or experience about a studied area to a similar but unstudied area, (3) a framework for assessing local management opportunities and predicting the outcomes of treatments or actions, and (4) a way to communicate among managers, researchers, and the public (Frayer *et al*. 1978). In terms of the land management task of prescribing silvicultural treatments or forestry Best Management Practices, experience gathered elsewhere is transferred to the project site. This involves accurately identifying the "kind of place" or "environment" of the site (Frayer *et al*. 1978). "Without an adequate method of classification of ... wetland forest communities, it is very difficult to study, much less predict, responses to management practices" (Boyce and Cost 1974).

B. Approaches to Classification

Classification of forested wetlands and other land resources involves the delineation of landscape components and arranging them in groups on the basis of their similarities or relationships (Rowe 1984). The grouping of landscape components into classes establishes a framework for defining and describing common traits of the landscape and provides a basis for dividing resource continua into homogeneous units (Mabbut 1968). Classification differs from evaluation; the latter involves interpretation of diagnostic qualities, as in ecological land evaluation.

Diagnostic characteristics of land resource classes may be (1) relatively easily observable or measurable properties (traits) or (2) qualities having a complex character arrived at indirectly (indices). They vary widely among classification systems and are determined by the classification objective (Cheshire 1982) and properties of the resources to be classified. In striving to meet its objective, every classification carries its freight of assumptions about what is important in the landscape (Rowe 1971). The "best" classification fulfills the purposes it is designed to serve.

(1) Single Level vs. Hierarchical Classifications — Single level classifications divide the resource into units (classes) of equal status or level. Hierarchical classifications enable finer, low-level associations among diagnostic characteristics to be absorbed into broader, high-level relationships. Hierarchy provides flexibility; units may be grouped for generalization or subdivided for detail and resolution. A hierarchy enables differing fine-scale classifications to be uniformly coordinated at higher levels. This is a valuable adaptation to a varying resource since "one man's miscellany is another man's prime concern" (Clawson and Stewart 1965).

(2) Single- vs. Multifactor Classifications — Classifications of land resources may be single-factor or multifactor (Bailey *et al.* 1978). Single-factor classifications consider only one landscape attribute or measurement (such as soil or vegetation) and are thus incapable of indicating interactions among attributes that may influence ecological processes and management decisions (Cheshire 1982). Such classifications frequently require detailed knowledge of the single attribute and full command of specific nomenclature to be of practical value. Successful use of a single-factor classification to predict other characteristics of a site would be fortuitous. Furthermore, single-factor classifications rarely serve two purposes equally well (Grigg 1967). Interest in single-factor classifications is waning, although notable exceptions persist (Zonneveld 1981).

Multifactor approaches are favored because they integrate several ecological properties. They can be fairly simple, such that a few distinguishing characteristics suffice for type identification. Such a system can serve several purposes. For this reason, classifications developed for integrated resource planning rely on multifactor approaches. The utility of multifactor resource classifications in describing the spatial distribution of several resource values has been demonstrated (Bailey *et al*. 1978). The most informative forested wetlands classification will be based on the total landscape since this is the basis for management; single factors, such as vegetation, soil, geomorphology, or climate, are insufficient to support many forest management decisions (Rowe 1971, Rowe 1984). The evolving science of landscape ecology likely holds the key to understanding the fundamental ecological processes shaping a landscape and their interactions.

(3) Parametric vs. Physiographic Classifications - Mitchell (1979) differentiates broadly between the parametric and the physiographic approaches to land resource classification. The parametric approach involves the selection of specific attributes and defining quantitative limits that define the boundaries between classes. Classes are usually hierarchical, carefully defined, and mutually exclusive. The parametric approach is objective and facilitates the analysis of variation within and among classes (Cheshire 1982). A requirement for extensive field work and precise, detailed mapping are implicit in the approach, so that most applications focus on relatively small areas or particular values or potentials. Exceptions occur when remotely sensed data (i.e., from aerial photographs or satellite imagery) are suitable (Anderson *et al*. 1976, Speight 1977).

Two disadvantages of the parametric approach are (1) data pertaining to resource attributes are commonly poorly understood or incomplete, and (2) the choice of parameters for use in the classification is difficult. Parametric classifications are often devised for specific purposes and generally are not applicable to unintended uses (Cheshire 1982).

The physiographic (or landscape or genetic) approach to land classification requires recognition of natural units in landscapes and relates practical data to the units (Mitchell 1979). Natural units are based on the character, arrangement, and relationships of a complex of surface or near-surface attributes including geology, soils, vegetation, topography, and climate. This approach is successful because geomorphology - the form and substance of the earth's surface - fundamentally influences all other associated phenomena (Rowe 1971). It is "genetic" in the sense that the form and substance of the land influences the local climate, determines surface and subsurface hydrologic regime, selects the appropriate fauna and flora that can survive there, and shapes the subsequent development of soil. Rowe (1971) contends that a land classification securely based on geomorphology is bound to be relevant to a broad spectrum of land uses; the same land features that control biological and physical processes are those used in defining map units.

Three practical advantages of physiographic classifications are (1) they help explain the fundamental causes of landscape differentiation; (2) they assist reconnaissance; and (3) they enhance the appreciation of regions as a whole (Mitchell 1973). Units can be delineated on the basis of inherent features of the landscape that are relatively permanent and clearly visible (Cheshire 1982). Smallest components are uniform with respect to climate, geology, soils, and physical appearance. The landscape components have no definite criteria that limit their scale and complexity; smaller units can be combined into successively larger areas (Cheshire 1982). The landscape approach requires no prior knowledge about an area and is particularly well suited to aerial photograph interpretation. Units are recognized on the basis of visible features, not presumed causal relationships. Also, the approach lends itself to reconnaissance surveys of general interest to a wide variety of users involved with resource management. A disadvantage of physiographic classification is its inherent artistry; boundaries of physiographic units are rarely clear in nature.

Physiographic approaches may contain one or more parametric approaches nested within them: coincident parametric classifications can tailor a physiographic approach to fit specific needs. Cowardin (1982) explained how both approaches apply to wetlands classification: wetland basins are large, heterogeneous land features capable of holding water because of topography or soil type (and are basically recognizable physiographic units), whereas wetland zones within basins possess homogeneous (and measurable) hydrologic, edaphic, and biologic characteristics.

(4) <u>Summary</u> - Approaches to forested wetlands classification may be hierarchical or unstructured, single-factor or multifactor, and parametric or physiographic in the selection and use of diagnostic characteristics. Regardless of the fundamental classification structure, a successful land management classification should be (1) flexible, general, and of wide geographic applicability in order to predict many kinds of information over a range of environmental situations; (2) professionally credible, preferably through experimental validation; (3) formed on concepts and logic that are explainable to nontechnical people; (4) logical, consistent, and objectively quantifiable so as to function within an empirical, computer-operated information system; and (5) designed and documented so that regular professional staff can, with nominal training, use the system to identify and map field sites (Frayer *et al.* 1978).

C. Approaches to Mapping

Natural resource maps provide a visual account of land characteristics and extend the resource classification on a geographic basis. The purpose and objectives of the resource survey dictate both the scale and the criteria of the taxonomic and mapping units (Bailey 1988). The scale and criteria, in turn, impose a mapping method.

Mapping has two aims: typification and chorology (Zonneveld 1981). Typification is the characterization of the mapping units and employs either a taxonomic or regionalization (cartographic) approach (Bailey *et al.* 1978, Rowe 1984). The taxonomic approach groups landscape features with similar single or multiple characteristics into defined classes or mapping units. Taxonomic classification is primarily parametric and relies more on the grouping of diagnostic characteristics than geographical location. For example, classifications based on vegetation data collected from sample plots are taxonomic. Units are formulated by either agglomeration (grouping things on the basis of their similarities so that classes are built up by aggregation from below) or division (dissecting wholes into parts so that classes and units are arrived at by subdivision from above; Rowe 1978). Techniques of clustering (numerical analysis) and ordination (ordering of landscape features along ecological gradients) have been widely used for taxonomic classification of natural resources. Of the possible alternate groupings, the one that best satisfies the management purpose is selected. Classes are defined as simply and precisely as possible to facilitate identification and uniform application during mapping.

Regionalization is a subdivisive mapping procedure whereby a portion of the landscape is recognized as having a degree of internal homogeneity, as well as features that contrast with those of an adjacent area (Bailey *et al.* 1978). As it deals with geographically associated objects, a major contribution of regionalization in mapping is that it displays spatial patterns of ecological associations and the juxtaposition and interspersion of ecological units (Driscoll *et al.* 1984). Bailey (1988) suggested guidelines for choosing diagnostic criteria for regionalization at different landscape scales. Regionalizations are often superior to taxonomic typification in producing map units for forest management objectives. Regionalization is assisted through utilization of existing data – topographic maps, hydrographic charts, critical area maps, land use and land capability maps, ecological land surveys, geological and terrain maps, soils maps, aerial photographs and mosaics, forest inventory maps, river basin and watershed studies, migratory bird information, flood risk maps, water resource data, climate data, or others.

Chorology is the position of lines and units on a map. The difficulty of this task is eased if units are well defined and plot data or landscape features can be unambiguously identified as to their place in the classification scheme. Hierarchical regionalization allows chorologic determinations at different scales. Map scale is dependent on intended use. Usually, landform features are mapped at 1:250,000 or smaller, timber production areas at 1:50,000, and silvicultural operations at 1:10,000 to 1:20,000 (Pierpoint 1984). The National Wetlands Inventory uses aerial color-infrared photography at scales ranging from 1:60,000 to 1:130,000 to identify wetlands (Mitsch and Gosselink 1986). Photointerpretation is combined with field reconnaissance to define NWI boundaries. The NWI summarizes the information on 1:24,000 and 1:100,000 maps using an alphanumeric system.

Through regionalization one can extrapolate parametric plot data to larger surrounding areas and interpret the relationship between landscape components and ecological processes. Once units are mapped, several interpretations of diagnostic characters utilized in classification are possible. Map units defined by their diagnostic characters can be reinterpreted within the limits of the classification scheme. Land capability maps exemplify this process of interpretation following regionalization; rather than provide information on the diagnostic characteristics of the land, capability maps interpret the degree to which a desired management activity can be supported (Jurant *et al.* 1979).

IV NATIONAL WETLANDS INVENTORIES AND EVOLUTION OF WETLANDS CLASSIFICATIONS

Tracing changes in the purpose of national wetlands inventories and the evolution of wetlands classifications provides a historical perspective for forested wetlands classifications in the United States. Introduction of new classification schemes has often been disjointed. Efforts typically focused on a specific need and region of application without considering linkages to prior attempts at classification. No doubt the simultaneous evolution of national wetlands definitions was in part responsible for this disjointedness. Excellent overviews of this topic for both the United States and Canada exist and are drawn upon in the following discussion (Hofstetter 1983, National Wetlands Working Group 1988, Stegman 1976). Regional wetlands classification schemes influential in advancing our knowledge of forested wetlands or approaches to their classification are included.

A. United States

Shaler (1885, 1890) proposed and published possibly the earliest systems of wetland classification. He identified freshwater swamps and coastal forested wetlands based on physiography.

The first attempt at a national wetlands inventory was in 1906 when Congress, with an eye on wetland development, authorized the Department of Agriculture to develop data on the extent, character, and agricultural potential of remaining wetlands of the nation (Stegman 1976). A questionnaire was sent to one or more persons in each county east of the 115th meridian in an attempt to supplement or verify existing data. Eight of the western public land states were excluded, as were all coastal tidewater lands (Stegman 1976).

A second national inventory was conducted in 1922 by the Bureau of Agricultural Economics of the U.S. Department of Agriculture (Stegman 1976). It was based on data furnished by soil survey reports of the U.S. Bureau of Public Roads, topographic maps of the U.S. Geological Survey, various state reports, and the 1920 census of drainage. This report remains the basis for many reclaimable wetlands estimates.

Peatland classifications for the United States were proposed by Davis (1907) and Dachnowski-Stokes (1933). Drawing on European experiences, they emphasized the ecology and morphology of peat deposits. Davis's classification was based on landform, origin, and vegetation. Dachnowski-Stokes identified 4 Subgroups of moors, 9 Series of peat profiles, and 46 Types of peat and muck within 3 main groups of peat deposits – oligotrophic, mesotrophic, and eutrophic.

In the 1950s, maturation of second-growth bottomlands and freshwater hardwood swamps in the South precipitated a need for management. Several classifications arose using vegetation, habitat, and the quality, depth, and duration of water as diagnostic criteria (Braun 1950, Penfound 1952, Putnam 1951, Putnam *et al*. 1960).

In 1954, the third national wetlands inventory, exclusive of wetland-rich Alaska, was conducted (Shaw and Fredine 1956). It was based on the wetland classification of Martin and others (1953) which, until 1978, remained the only wetland classification designed for the entire country, although a number of regional wetland classification schemes were being used. The approach was novel in attempting to inventory remaining wetlands and evaluate their relative importance to waterfowl and, to a lesser degree, other wildlife (Stegman 1976). For years, this inventory was the basis for a wide spectrum of federal and state regulations and policies dealing with the preservation of wetlands.

Detailed overviews of wetland types found in each of the major regions of the United States are provided by Hofstetter (1983), who relates their distribution to the ecoregions of Bailey (1976) and the principal climatic types of Walter and Leith (1966). Regional classifications diverged. For example, Stewart and Kantrud (1971), working in the dynamic habitat of the glaciated prairies of North Dakota, found the classification of Martin and others (1953) inadequate. They devised a completely new hierarchical, regional system based on the dominant plant associations in the central or deepest portion of wetland basins. Class subdivisions were based on water permanence, salinity tolerance of indicator plant species, and the pattern or interspersion of emergent vegetation (Cowardin 1978). Although not a forested wetlands classification, the system is noteworthy for its hierarchical, ecological approach. Among other important contributions to regional wetlands classification are the peatland classification of Heinselman (1970), coastal system differentiation based on ecological function (Odum *et al.* 1974), and the wetland habitat classification of Golet and Larson (1974).

In the early 1970s, efforts within the FWS began in earnest to develop a new national wetlands classification scheme and update the outdated wetlands inventory. Successful utilization of aerial photography and satellite imagery to obtain wetland information influenced the approach (Anderson 1969, Anderson and Wobber 1973, Anderson *et al.* 1976). The plan utilized the latest remote sensing technology, facilitating periodic reinventories at acceptable precision and cost (Stegman 1976).

The new classification, *Classification of Wetlands and Deepwater Habitats of the United States*, was intended to be simple and easily understood, precisely delineating distinguishable or recognized wetland types (Cowardin *et al.* 1979). It groups ecologically similar habitats (not specifically for waterfowl) and is designed so that specific or definitive subinventories can be conducted to broaden coverage and extend utility. Also, it provides uniformity in concepts and terminology throughout the entire United States. This and other U.S. wetland classifications differ from those of Canada and other more northern regions in that they place less emphasis on the presence or absence of peat (Hofstetter 1983).

B. Canada

As in the United States, acceptance of a wetlands classification for Canada was delayed because of the diversity of users and the regional variations in wetlands (National Wetlands Working Group 1988). Approaches diverged from those employed in the United States because Canadian wetlands are greater in extent and differ in their primary diagnostic characters. Many Canadian classifications are more detailed with regard to palustrine peatlands. Canadian classifications placed greater emphasis on origin (development), morphology, and hydrologic and chemical function, rather than vegetation. The evolution of a Canadian wetland classification system has been superbly outlined by the National Wetlands Working Group (1988) which was the prime source for the following account.

Early investigations of the floristics of Canadian wetlands led to the recognition of plant communities that grow on different wetland types (Tansley 1911). Later classifications were highly structured according to the principles of phytosociology (Braun-Blanquet 1932), which utilizes the occurrence, dominance, and fidelity of various species to identify specific plant associations related to wetlands (Gauthier and Grandtner 1975).

Geomorphological criteria have been used by many authors to classify Canadian wetlands. One of the earliest classifications was based on the shape of peatlands – the high (hochmoor) and low (niedermoor) mires of German origin. Later, regional variations in peatland shape or tree cover were use to differentiate between various kinds of Hochmoor (Osvald 1925). However, this classification, developed for the oceanic, cool climate of northern Europe, was applicable only to areas of similar climatic conditions. Sjors (1961, 1963, 1969) noted the importance of microtopography of peatland surfaces. Others, including Tarnocai (1970) and Couillard and Grondin (1986), stratified wetlands by type of landform.

The chemistry and perceived origin of water in wetlands forms the basis of another Canadian classification. Differences in the chemical properties of the groundwater among broad mire types were recognized by Du Rietz (1949, 1954) and further investigated by Sjors (1950, 1961, 1963, 1969). Similarly, Gauthier (1980) defined wetlands on the basis of water chemistry and vegetation indicators. Classes defined by Sjors and Gauthier have been applied and further refined by Couillard (1978), Grondin and Ouzilleau (1980), Wells (1981), Rainville (1983), Gerardin *et al.* (1984), Lebel (1986), and Foster and King (1984). Hydrology was the main classification criterion used by Kulczynski (1949), Damman (1986), and Crum (1988).

A distinctly Canadian muskeg classification system was developed to suit Canadian conditions. This muskeg classification system is based on vegetation structure and topographic patterns seen from the air (Radforth 1969a, 1969b). It was originally designed for use by engineers who have minimal background in life sciences but who are concerned with physical characteristics of wetlands. The terminology did not find wide application among biologically oriented workers (Zoltai and Pollett 1983).

As the various classifications evolved, they tended to develop a broader base and be less rigidly concerned with a single diagnostic character. The "hochmoor" became "bogs" and the bogs were characterized by nutrient levels, origin of water, surface morphology, and specific kinds of vegetation (Wells 1981). Such gradual evolution emphasized the need for broadly based, multidisciplinary approaches to the classification of wetlands. The organic soil classification of Canada further strengthened the characterization of various kinds of wetlands (Canada Soil Survey Committee 1978).

Several regional classification systems have been developed in Canada. Wetland classification in western Canada was discussed by Millar (1976). Classification of wetlands in Quebec based on physiography was developed by Jaques and Hamel (1982) and Couillard and Grondin (1986). Ahti and Hepburn (1967) broadly classified wetlands of northern Ontario to obtain an estimate of potential caribou range; classes were similar to those of Sjors, but more emphasis was placed upon wetlands that support a tree cover. A wetland classification system for Ontario was proposed by Jeglum *et* *al.* (1974), which added marsh and swamp formations to the scheme of Sjors to cover the entire spectrum of wetlands.

The Ontario system is similar in several respects to the more recent Canadian Wetland Classification system that is currently used nationwide (National Wetlands Working Group 1988, Tarnocai 1980, Zoltai *et al.* 1975). As in the current national wetland classification system for the United States, information from repeated coverage of Landsat imagery and aerial photographs forms a basis for differentiating wetland types.

V <u>CLASSIFICATIONS THAT INCLUDE FORESTED WETLANDS</u>

Numerous wetland classifications have been proposed and incorporate a variety of diagnostic criteria to distinguish classes. For purposes of this discussion, classifications are grouped according to the primary criterion for definition of classes: water chemistry, hydrology, vegetation, soils, physiography, ecological/ecosystem, and forest management. Most include forested wetlands at some level in a classification hierarchy. Others offer an approach to classification that might be useful in distinguishing types of forested wetlands.

A. <u>Classifications Based on Water Chemistry</u>

Differentiation of two broad types of wetlands, bog and fen, on the basis of water chemistry is well entrenched in the literature. Swamps or carrs are generally fens with trees. Bogs tend to be acid and mineral poor, whereas fens are less acid or even alkaline and mineral rich. The concepts of oligotrophy and eutrophy, as applied to bogs and fens, were introduced to indicate nutrient status of the system; terms such as "ombrotrophic" (rain-fed) and "minerotrophic" (mineral-enriched) connote the nutrient content of groundwater (Du Rietz 1954). Sjors characterized bogs and fens by their water chemistry, as well as plant assemblages, and divided fens into poor, intermediate, and rich (Sjors 1950, 1961, 1963, 1969). Gauthier (1980) defined ombrotrophic bogs, very poor fens, moderately poor fens, intermediate fens, and moderately rich fens on the basis of water chemistry and vegetation indicators.

The source of water is known to influence water chemistry of wetlands. Terms describing wetland water sources are ombrogenous (rain), geogenous (rocks or soil), and limnogenous (lakes or rivers) (Gore 1983).

Salinity and pH are water chemistry modifiers at the Class and lower levels of the FWS national wetland classification scheme (Cowardin *et al.* 1979). Salinity has also been used to classify southern swamps and marshes (Penfound 1952) and nonforested prairie wetlands (Stewart and Kantrud 1972).

B. Classifications Based on Hydrology

Mire systems have been classified according to the hydrologic character of the waters that affect them. Rheophilous mire systems develop in mobile ground waters, ombrophilous mire systems in immobile groundwaters, and transitional mire systems either in rheophilous systems with restricted groundwater supply or in areas where the mire is in the process of changing from a rheophilous to an ombrophilous system (Kulczynski 1949). These hydrologic mire types differ with respect to the major ion content of their waters (Moore and Bellamy 1974).

The source of water supply, combined with basin configuration, is the basis for another classification, summarized by Damman (1986): (1) limnogenous (water source from ponds or streams and precipitation); (2) topogenous (static water source from runoff and precipitation, depressed topographically); (3) ombrogenous (water source is precipitation); and (4) soligenous (flowing water source from drainage and precipitation, sloping topography). Geogenous indicates either topogenous or soligenous water.

Heinselman (1963) incorporated water movement and water source in a multifactor forested wetlands classification for the northern Lake States. He noted that hydrology is related to forest site index.

Odum (1984) noted the influence of landscape position on wetland hydrology and drainage. Wetlands can be ranked along a gradient of increasing water flow and related nutrient access: rain-fed bogs (very low nutrient access), slight drainage - dry season (low nutrient access), larger runoff area (low-moderate nutrient access), strand flow (moderate nutrient access), and river and floodplain (high nutrient access). Productivity is expected to increase along this gradient. The ranking suggests relative system sensitivity to modifications of nutrient or hydrologic regimes.

Gosselink and Turner's (1978) Classification of Wetland Systems on a Hydrodynamic Energy Gradient was developed for nonforested freshwater wetlands, but can be applied to forested wetlands. Wetlands are classified into six types according to major driving forces - the source and velocity of water flow. The types and their "hydropulses" are: (1) raised-convex (seasonal precipitation and capillarity); (2) meadow (seasonal precipitation, capillarity; little upstream inflow); (3) sunken - concave (seasonal precipitation and upstream inflow); (4) lotic (seasonal precipitation, runoff, groundwater, and flowthrough); (5) tidal (tides); and (6) lentic (variable or seasonal overbank flooding).

Penfound's (1952) classification of swamps of the Atlantic and Gulf coastal plains and the Mississippi alluvial plain broadly subdivides freshwater swamps on the basis of water depth and duration of inundation. Deep swamps are freshwater, woody communities with surface water throughout most or all of the growing season. Shallow swamps are freshwater, woody communities where the soil is inundated for only short periods during the growing season. Peaty swamps are acidic, peat-forming, sclerophyllous woody communities with surface water only during part of the growing season.

C. Classifications Based on Vegetation

Classification by dominant species, or dominance-typing, is a widely used approach that is based on easily observable diagnostic characters. Dominance-types are determined on the basis of species importance – density, cover, stocking, or a combination of these measures. Dominance-types often distinguish forested wetlands at finer levels in a classification hierarchy composed of broader classes based on other diagnostic criteria. For instance, types within wetland classes were named according to the dominant vegetation by Boissoneau (1981) in Canada. Also, Penfound's (1952) system recognizes sixteen freshwater and saltwater woody plant communities based on species dominance within broader classes based on hydrology. Heinselman (1963) felt that plant dominance-types are of more value in the classification of peatlands than with mineral soils because the plants themselves build the peats. Plant dominance-types are also effective groupings for mapping purposes.

Another floristic approach to wetland classification is the phytosociologic one, which was pioneered by Braun-Blanquet (1932). Communities are classified after all of the plant species of a site (the total flora) are examined and evaluated for the presence of diagnostic indicator species. Plant associations are named after the indicator species. Crum (1988) used Braun-Blanquet phytosociological designations at lowest levels of a hierarchical wetlands classification system with some success.

Vegetative physiognomy (plant morphology, growth-form, or life-form) is a criterion incorporated in numerous plant community and wetland classifications. Plant communities are grouped by the dominant physiognomic class of the uppermost stratum or the stratum of highest coverage in the community (Whittaker 1975). In its simplest application, wetland plant physiognomy can be reduced to woody, shrubby, or graminoid (Botch and Masing 1983), but it is usually more complex. Such classifications have been suggested by Raunkiaer (1934), Mueller-Dombois and Ellenberg (1974), and UNESCO (1973). Physiognomic approaches are generally taken when describing broad vegetation areas (e.g., global, continental) for mapping purposes, although they have been used with success on small areas (Mader 1985). The relevance of physiognomic status remains uncertain in almost all vegetation classifications (Gore 1983). For instance, vegetation structure is not well correlated with peat formation. Physiognomic characterizations should be used in conjunction with other wetland features; for example, physiognomy could be subordinately supplemented with species dominance-types, as in The Nature Conservancy's natural community classification (Allard 1989).

Although an easily understood and obtainable diagnostic character for wetland classification, vegetation is not always the most satisfactory. Vegetation is not permanent; it may reflect developmental stage or past management. Also, vegetation may not respond robustly to changing environmental conditions.

Reviews of popular classifications based on vegetation that include forested wetlands follow.

(1) Potential Natural Vegetation – Kuchler (1964) proposed a classification and regionalization of potential natural vegetation for the conterminous United States. This classification describes the potential vegetation at one point in plant community succession if human influence were removed. The system is based primarily on vegetation and a few other factors that are not precisely defined. Water regime and type of soil are not included. There are 116 plant communities. Ten types of inland wetlands are identified, five dominated by trees: cypress savanna, conifer bog, northern floodplain forest, southern floodplain forest, and pocosin. The extent of Kuchler's wetlands was depicted by Turner and others (1981). Two major criticisms of Kuchler's system are that it is difficult to apply on the ground in the process of identification (Bailey *et al.* 1978), and that units are too large to be of practical value other than for broad land-use and resource planning.

Braun's (1972) description and regionalization of the deciduous forests of eastern North America is more detailed than Kuchler's. She identified nine forest regions in the eastern United States based on mature vegetation of original forests and underlying ecological factors (climate, physiography, soil). Her classification provides a useful adjunct to understanding successional relationships within Eyre's Forest Cover Types (Eyre 1980). The classification is not applicable to most forested wetlands, although some distinctions are suggested for subdivision of bottomland hardwoods, and descriptions are given for common inland swamps and bog forests. Modern classifications of Eastern forested wetlands were influenced by Braun's descriptions.

(2) Forest Cover Types of the United States and Canada – Eyre (1980) revised the Society of American Foresters (SAF) (1954) national system of forest cover types. This is a single-factor, parametric approach based on species dominance. Trees define the forest cover; predominance is determined by basal area, and the name is usually limited to one or two species. If vegetation is lacking, locality (environmental) factors define forest cover type. Specific criteria for recognition of a cover type are: (1) the dominant cover must be trees; that is, tree crowns should cover at least 25 percent of the area; (2) the type must occupy a fairly large area in the aggregate, but not necessarily in continuous stands (many types occur sporadically and merge into others over short distances); and (3) recognition of forest cover type must be based entirely on biological considerations (Eyre 1980).

Huffman and Forsythe (1981) show the relationship of 36 SAF forest cover types, including coniferous types, to the soil-moisture gradient and hydrologic regime in floodplains. Although transitional areas are a problem in all classifications, the SAF system has been criticized because defining boundaries between types are lacking.

Only contemporary forest cover is considered in the SAF system, in contrast to Kuchler's (1964) system for potential vegetation. However, some SAF descriptions of climax forest cover types resemble Kuchler's plant communities. The SAF classification is not intended for intensive land management, as are forest habitat type classifications (Pfister *et al*. 1977). Forest cover types are similar, but more detailed than the forest type groups and local forest types of the U.S. Forest Service (USFS) (U.S. Forest Service 1967). A comparison between the SAF system and USFS Renewable Resources Evaluation Group (RRE) type groups is shown in Tables 1 and 2 (See Table 3 for a list of USFS type groups). Whereas the USFS system poorly discriminates among forested wetlands, the SAF system gives at least 25 types that may be considered forested wetlands.

(3) National Forest Regions – Single-factor classifications of national forestland based on vegetation have been prepared for both the Canada and the United States (Rowe 1972, U.S. Forest Service 1967, U.S. Forest Service 1968). They describe the forest geography of each country. A forest region is defined as a major geographic belt or zone broadly uniform in vegetation physiognomy and composition (dominant tree species; Eyre 1980).

In the United States, the USFS uses its forest type groups as the basis for reporting periodic forest inventory estimates. Twenty type groups are utilized for U.S. forests (Table 3; U.S. Forest Service 1967). Classification is based on species composition of the overstory, especially stocking of dominants and codominants. Type groups are separated into local forest types similar to SAF forest cover types, the use of which varies by region (Eyre 1980). For instance, 48 local types, including several forested wetland types, are identified in the Southeast region (U.S. Forest Service 1985). Local types are assigned to individual plots during measurement and are seldom used for regional or national reporting.

The USFS distinguishes "wetland," "bottomland," or "lowland" hardwoods from other forest communities. Such inventory designations approximate the extent of forested wetlands and refer to forest communities that occur on frequently flooded stream margins; in swamps, bays, and wet pocosins where water may stand for long or short periods of time; and in depressions and poorly drained areas of the flatwoods, dry pocosins, rolling uplands, and narrow streams of the Piedmont. For the eastern United States, wetland hardwoods are equivalent to the combined oak-gum-cypress and elm-ash-cottonwood type groups (Boyce and Cost 1974). Plots

TABLE 1. Relationship of SAF forest cover type designations to U.S. Forest Service Renewable Resources Evaluation Group (RRE) forest type groups in the eastern United States. SAF cover type name is followed by RRE type group code number in parentheses. See Table 3 for RRE type group names. Adapted from Eyre (1980).

BOREAL FOREST REGION

Boreal Conifers

Jack Pine (1); Balsam fir (2); Black spruce (2); Black spruce-tamarack (2); White spruce (2); Tamarack (2)

Boreal Hardwoods

Aspen (10); Pin cherry (10); Paper birch (10)

NORTHERN FOREST REGION

Spruce-fir Types

Red spruce (2); Red spruce-balsam fir (2); Red spruce-Fraser fir (2); Red spruce-yellow birch (2); Red spruce-sugar maple-beech (2); Northern white cedar (2); Paper birch-red spruce-balsam fir (2)

Pine and Hemlock Types

Red pine (1); Eastern white pine (1); White pine-hemlock (1); Eastern hemlock (1); White pine-northern red oak-red maple (1); Hemlock-yellow birch (1 or 9)

Northern Hardwoods

Sugar maple (9); Sugar maple-beech-yellow birch (9); Sugar maple-basswood (9); Black cherry-maple (9); Beech-sugar maple (9); Red maple (9)

Other Northern Types

Northern pin oak (6); Gray birch-red maple (10); Black ash-American elm-red maple (8); Hawthorn (6 or 9)

CENTRAL FOREST REGION

Upland Oaks

Post oak-blackjack oak (6); Bur oak (6); Bear oak (6); Chestnut oak (6); White oak-black oak-northern red oak (6); White oak (6); Black oak (6); Northern red oak (6)

Other Central Types

Yellow poplar (6); Yellow poplar-eastern hemlock (6); Yellow poplar-white oak-northern red oak (6); Black locust (6); River birch-sycamore (7); Silver maple-American elm (8); Sassafras-persimmon (6); Pin oak-sweetgum (7); Pitch pine (4); Eastern redcedar (5 or 6)

SOUTHERN FOREST REGION

Southern Yellow Pines

Sand pine (4); Longleaf pine (3); Longleaf pine-slash pine (3); Shortleaf pine (4); Virginia pine (4); Loblolly pine (4); Loblolly pine-shortleaf pine (4); Slash pine (3); South Florida slash pine (3); Pond pine (3)

Oak Pine Types

Longleaf pine-scub oak (5); Shortleaf pine-oak (5); Virginia pine-oak (5); Loblolly pine-hardwood (5); Slash pine-hardwood

TABLE 1. Continued.

Bottomland Types

Cottonwood (8); Willow oak-water oak-diamondleaf oak (7); Live oak (7); Swamp chestnut oak-cherry bark oak (7); Sweetgum-willow oak (7); Sugarberry-American elm-green ash (8); Sycamore-sweetgum-American elm (8); Black willow (8); Overcup oak-water hickory (7); Baldcypress (7); Baldcypress-tupelo (7); Water tupelo-swamp tupelo (7); Sweetbay-swamp tupelo-redbay (7)

Other Southern Types

Ashe juniper-redberry (Pinchot) juniper (no RRE type given); Mohrs ("shin") oak (6); Mesquite (no RRE type given); Southern scrub oak (6); Southern redcedar (4); Cabbage palmetto (5); Sweetgum-yellow poplar (6 or 7); Atlantic white cedar (7); Pondcypress (7)

TABLE 2. Relationship of SAF forest cover type designations to U.S. Forest Service Renewable Resources Evaluation Group (RRE) forest type groups in the western United States. SAF cover type name is followed by RRE type group code number in parentheses. See Table 3 for RRE type group names. Adapted from Eyre (1980).

NORTHERN INTERIOR (BOREAL)

White spruce (17); Black spruce (17); Paper birch (20); White spruce-aspen (17); White spruce-paper birch (17); Black spruce-white spruce (17); Black spruce-paper birch (17); Balsam poplar (20);

HIGH ELEVATIONS

Mountain hemlock (17); Engelmann spruce-subalpine fir (17); Red fir (17); Whitebark pine (19); Bristelcone pine (19); California mixed subalpine (17)

MIDDLE ELEVATIONS, INTERIOR

Interior Douglas-fir (11); White fir (17); Western larch (16); Grand fir (17); Western white pine (14); Blue spruce (17); Aspen (20); Lodgepole pine (15); Limber pine (19); Rocky Mountain juniper (19)

NORTH PACIFIC

Red alder (20); Black cottonwood-willow (20); Sitka spruce (12); Western hemlock (12); Western redcedar-western hemlock (12); Western hemlock-sitka spruce (12); Coastal true fir-hemlock (12); Pacific Douglas-fir (11); Douglas fir-western hemlock (11); Port Orfard cedar (11); Western redcedar (12); Redwood (18); Oregon white oak (20); Douglas fir-tanoak-Pacific madrone (11)

LOW ELEVATIONS, INTERIOR

Interior ponderosa pine (13); Western juniper (13); Bur oak (20); Cottonwood-willow (20); Pinyon-juniper (19); Arizona cypress (13); Western live oak (20); Mesquite (no RRE type given)

SOUTH PACIFIC, EXCEPT FOR HIGH MOUNTAINS

Sierra Nevada mixed conifer (17); Pacific ponderosa pine (13); Pacific ponderosa pine-Douglas-fir (13); Jeffrey pine (13); Blue oak-Digger pine (19); California black oak (19); Knobcone pine (19); Canyon live oak (20); California coast live oak (20);

TABLE 3. U.S. Forest Service Renewable Resources Evaluation Group (RRE) forest type groups for the United States (Eyre 1980).

(1) White-red-jack pine
(2) Spruce-fir
(3) Longleaf-slash pine
(4) Loblolly-shortleaf pine
(5) Oak-pine
(6) Oak-hickory
(7) Oak-gum-cypress
(8) Elm-ash-cottonwood
(9) Maple-beech-birch
(10) Aspen-birch
(11) Douglas-fir
(12) Hemlock-Sitka spruce
(13) Ponderosa pine
(14) Western white pine
(15) Lodgepole pine
(16) Larch
(17) Fir-spruce
(18) Redwood
(19) Noncommercial
(20) Hardwoods

dominated singly or in combination by the tupelos, sweetgum, wetland oaks, or cypress are classified in the oak-gum-cypress type. Plots dominated singly or in combination by elm, ash, or cottonwood are classified in the elm-ash-cottonwood type.

Boyce and Cost (1974) recognized deficiencies in USFS forested wetlands classification. First, type groups are mixtures of hardwood forest communities, the species of which occur in varying combinations as influenced by surface and soil water and management actions. Second, it is difficult to develop a practical system of classification; compositions of Forest Survey plots indicate that very few fit SAF forest cover types (Eyre 1980) or the plant community descriptions of Braun (1972). The situation is even worse in the western United States where forested wetlands are housed among several type groups. Recent USFS attempts to discriminate differences among forested wetlands are discussed in a later section.

The Tennessee Valley Authority's (TVA) continuous forest inventory system is similar to the USFS system with respect to wetland classes; that is, TVA classes of forested wetlands include approximately the same level of detail as the USFS classification (Tansey 1989).

In Canada, a hierarchical system of 8 forest regions and 90 forest sections are recognized on the basis of topography and soil types. Rowe (1972) provided a map of major forest regions based on dominant cover types. In contrast with the Canadian wetlands classification system (National Wetlands Working Group 1988), the national forest classification is too general to identify differences among forested wetlands. As recently as 1980, a Canadian national forest inventory or inventory classification system did not exist (Eyre 1980).

The U.S. and Canadian forest classifications suffer from similar problems. As with SAF forest cover types, they lack defining boundaries between types. Also, discrimination of forested wetlands is poor. For example, coniferous forested wetlands are not separated from upland coniferous forests. Even the USFS local forest type designations oversimplify the diversity of the forested wetlands resource for many management purposes. Finally, categories of forestland used to approximate the extent of the forested wetlands resource do not match forested wetlands delineations in current jurisdictional interpretations. The USFS is now attempting to correct this discrepancy through expanded data collection.

(4) Forest Habitat Types – The concept of habitat types is well developed for the western United States and western Canada (Alexander 1985, Klinka 1988, Pfister 1988), under development in Wisconsin and Michigan (Kotar 1986), but little-used in the East (Jones *et al*. 1984). Numerous forest habitat type classifications have been prepared for the western United States (Alexander 1985, Pfister 1976). Although not specific to any ecological community, forested wetland types are inherently incorporated into habitat type classification methodology. Classification of riparian habitat types is currently incomplete: only 10 types have been identified in the West (Alexander 1988).

Habitat typing is a site classification method that utilizes the entire plant community as an integrated indicator of environmental factors. It is based on potential climax trees and understory vegetation (Daubenmire 1968, Daubenmire and Daubenmire 1968, Pfister 1984, Pfister and Arno 1980). It is founded on the premise that environmental factors influence species reproduction, competition, and plant community development (Pfister 1976). Land capability within habitat types, in the sense of Daubenmire (1968) and Pfister (1976), is an expression of all the environmental factors as they apply to biological potential of a given resource on a specific unit of land. The concept is similar to Braun-Blanquet's (1932), but introduces successional stages and is without his stringent taxonomic hierarchy. Habitat types (or community types if the climax vegetation is uncertain) differ from forest habitat regions (sensu Hodgkins *et al*. 1979); the latter are based on physiography.

Habitat type classifications can aid in intensive management of forested wetlands: relative resource potentials (i.e., land capability for timber production) are assigned and regeneration systems are recommended. However, the system has several disadvantages. First, plant assemblages with wetland affiliation are not well established, although some classifications identify wetland types within physiographic provinces (e.g., Alexander 1988, Franklin and Dyrness 1973). Also, habitat types do not provide information on geology, topography, or soils – characters that aid classification and management. Finally, the system has limited utility in guiding forestry BMPs in areas with a high degree of human disturbance since potential vegetation is difficult to determine (Williams *et al*. 1988).

(5) Natural Community Classification – The Nature Conservancy (TNC) has taken a natural community approach to protecting

biological diversity. The concept maintains that preservation of species is accomplished through protection of the processes and organismal interactions in their environment. Natural communities are identified, inventoried, mapped, and then evaluated for protection.

TNC provides national and regional coordination, but Natural Heritage Programs, TNC affiliates, develop unique classifications for each state (Allard 1989). The classifications are based primarily on physiognomic, floristic, and ecological characteristics of existing vegetation, but environmental factors may be utilized if these are important in distinguishing the communities of a given area. The overall classification system is hierarchical, with five levels, and is national in scope. At highest levels, distinction between aquatic and terrestrial plants and physiognomy of vegetation are important. Plant associations (elements) refine the classification at the lowest level. Community names are drawn from numerous established Natural Heritage classifications, USFS local forest types, and SAF forest cover types. Nomenclature at lower hierarchical levels often varies by state. Through TNC's draft "Crosswalk," a matrix of classification terminology, roughly equivalent state-designated communities are related to each other, to USFS, and to SAF terms. A community characterization abstract is prepared for each element and includes location, cross-references to terminology, description of salient features, and dominant or typic plant species. Mapping and inventory at the element level is now in process. TNC envisions extending the classification to cover international natural communities.

D. Hydric Soils Classifications

Recent advances in wetland soils classification have propelled the sciences of wetland delineation and classification. The hierarchical and parametric approach taken in soil classification has aided the differentiation of forested wetlands, not only on a legislative or ecological basis, but also on a management basis. The hydric soils classification for the United States is intended for a number of applications: land-use planning, conservation planning, mapping, mitigation planning, and assessment of potential wildlife habitat, in addition to classifying and delineating wetlands (U.S. Soil Conservation Service 1987).

Hydric soil is "a soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor growth and regeneration of hydrophytic vegetation" (U.S. Soil Conservation Service 1987). The list of hydric soils encompasses a broad range of hydrologic regimes and includes both drained and undrained soils. Some areas with hydric soils do not support predominantly hydrophytic vegetation and wetland hydrology and thus are not wetlands according to some definitions. Criteria for hydric soil designation are listed in Table 4. Each of the soils is assigned

TABLE 4. Criteria for hydric soil designation (U.S. Soil Conservation Service 1987).

(1) All Histosols except Folists, or

(2) Soils in Aquic suborders, Aquic subgroups, Albolls suborder, Salorthids great group, or Pell great groups of Vertisols that are:

  (a) somewhat poorly drained and water table less than 0.5 ft. from the surface at some time during the growing season, or

  (b) poorly drained or very poorly drained and have either (i) water table at less than 1.0 ft. from the surface at some time during the growing season if permeability is equal to or greater than 6.0 in./hr. within 20 inches, or (ii) water table at less than 1.5 ft. from the surface at some time during the growing season if permeability is less than 6.0 in./hr in any layer within 20 inches, or

(3) Soils that are ponded during any part of the growing season, or

(4) Soils that are frequently flooded for long duration or very long duration during the growing season.

---

to a Capability Class and Subclass (Klingebiel and Montgomery 1961). The Capability Class is derived from a parametric land classification system where soils are grouped by their potentialities, limitations for sustained production, risks of soil damage, and erosion hazard.

The U.S. Soil Conservation Service's (1981) Land Resource Regions provide a useful framework for grouping soil regions of the United States by their ability to support forestry and other major land uses. Land resource units are characterized by a particular pattern of soils, climate, and water resources.

The organic soil classification of Canada provided detailed descriptions of soil characteristics associated with various kinds of Canadian wetlands (Canada Soil Survey Committee 1978). Within the hierarchical system, wetland soils are categorized in the Organic, Cryosolic, and Gleysolic orders. Criteria include the type and quantity of organic material, the proximity of the water or permafrost table, and the degree of reducing conditions due to waterlogging. The classification permitted the production of maps that show the distribution of organic soils in Canada.

E. Physiographic/Geomorphic Classifications

(1) Physiography of the United States and Canada – Several efforts toward physiographic delineation of land have been put forth. Those of Fenneman (1931, 1938), Thornbury (1965) and Hunt (1967, 1974) are national in scope. In these, major emphasis is placed on landform and climate. Since broad geographic areas are covered, small-scale is necessitated. Units are regionalized for

mapping, but they are too large for practical value in natural resources planning. Although not hierarchical in themselves, they offer a national framework for more detailed classification schemes.

(2) Land Use and Land Cover Classification System for Use with Remote Sensor Data — The land use and land cover classification system for use with remote sensor data (Anderson *et al.* 1976) is national in scope. It provides uniform categorization at generalized first and second hierarchical levels. At these levels, data from both conventional sources and remote sensors on high-altitude aircraft and satellite platforms are accommodated. Third and fourth levels are open to development of more detailed land-use classifications for particular needs, recognizing that primary categories for one user group may be of secondary importance to another (Anderson *et al.* 1976). Efforts were made to make the system compatible with classification systems of federal agencies involved in land-use inventory and mapping. The classification is presented in Table 5.

Level I information is efficiently and economically obtained from Landsat imagery. Wetlands, including forested wetlands, are specifically identified at this level, relying on vegetation types and detectable surface water or soil moisture (Anderson *et al.* 1976). Inasmuch as vegetation responds to changes in moisture conditions, remote sensor data acquired over time allows detection of fluctuating hydrologic conditions. Level II categories are obtained accurately from high-altitude photographs supplemented with available data (e.g., topographic maps and low-altitude photographs). Forested wetlands are separated from nonforested wetlands at Level II. More detailed classification levels place greater dependence on high resolution remote sensor data and supplemental ground surveys. For instance, the use of substantial amounts of supplemental information in addition to remotely sensed data at scales of 1:15,000 to 1:40,000 is anticipated at Level III. Supplemental information includes ground surveys of soil types and duration of flooding. Level IV requires even more supplemental information and remotely sensed data at a much larger scale.

There are disadvantages to the system too. Thus far, refinement beyond Level II has not occurred. Furthermore, the system relies on somewhat dated technology. Interpretation of wetland boundaries lacks the precision for legal determinations, and some jurisdictional wetland types are not included in the system: e.g. shallow water areas where aquatic vegetation is submerged, and some cultivated or drained wetlands.

(3) Physiographic Classification of Southern Forest Lands — A coordinated effort by state agricultural research services resulted in a physiographic classification of forestlands in the South (Evans *et al.* 1983, Hodgkins 1965, Hodgkins *et al.* 1976, Hodgkins *et al.* 1979, Myers *et al.* 1986, Pehl and Brim 1985). Work was

TABLE 5. Land use and land cover classification for use with remote sensor data. Forested wetlands are identified at Level II (Anderson *et al.* 1976).

LEVEL I	LEVEL II
1 Urban or Built-up Land	11 Residential
	12 Commercial and Services
	13 Industrial
	14 Transportation, Communications and Utilities
	15 Industrial and Commercial Complexes
	16 Mixed
	17 Other
2 Agricultural Land	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other
3 Rangeland	31 Herbaceous Range
	32 Shrub-Brushland Range
	33 Mixed
4 Forest Land	41 Deciduous
	42 Evergreen
	43 Mixed
5 Water	51 Streams and Canals
	52 Lakes
	53 Reservoirs
	54 Bays and Estuaries
6 Wetland	61 Forested
	62 Nonforested
7 Barren Land	71 Dry Salt Flats
	72 Beaches
	73 Sandy Areas Other than Beaches
	74 Bare Exposed Rock
	75 Strip Mines, Quarries, and Gravel Pits
	76 Transitional Areas
	77 Mixed
8 Tundra	81 Shrub and Brush Tundra
	82 Herbaceous Tundra
	83 Bare Ground Tundra
	84 Wet Tundra
	85 Mixed
9 Perennial Snow or Ice	91 Perennial Snowfields
	92 Glaciers

initiated by the Forest Site Classification Committee of SAF in 1956. The original objective was to define and delineate a system of habitat regions (site regions) in Alabama, Georgia, and Florida for forest productivity assessment. The initiative was in response to shortcomings of the U.S. Soil Conservation Service (SCS) Cooperative Soil Surveys. With regard to information on forest site productivity, the Soil Surveys were outdated, rough, without regionwide uniformity, and lacking some important ecological features (Hodgkins *et al.* 1979).

Habitat regions were described in terms of permanent features — climate, topography, parent rock material, and physical properties of the soil profile (Hodgkins 1965). (Prior efforts had imparted great significance to vegetation maps, including forest type maps, casting doubt on the accuracy of some site boundaries; Hodgkins 1965.) Beginning work unified terminology and scale in all three states, at times eliminating smaller map units (primarily alluvial floodplains). Mapping of wetlands was attempted only in Florida. Province VII, the Alluvial Floodplains Province, was acknowledged as a major ecological category, but was not mapped and users were referred to Putnam (1951) for alluvial floodplain classification. Shortcomings of the early version of the physiographic classification were its large scale, lack of field validation, exclusion of climatic data, and poor resolution for forested wetlands.

By 1979, this classification assumed a stronger identity by adopting the hierarchical land cover classification promulgated by Anderson and others (1976). The newer version serves as a basic classification framework, a modified version of the "holistic" Canadian Ecological (Bio-Physical) Land Classification (Lacate 1969), but with less emphasis on biotic features. Similarities to the Land System Inventory of the USFS Intermountain and Rocky Mountain Regions are also apparent (Wertz and Arnold 1973). Physiographic classification of southern forestlands diverges on two important points. First, the authors maintain that vegetation is not a good indicator of productivity; it is not permanent and hardwoods do not indicate pine site index satisfactorily. Second, climatic factors are incorporated. Extension of the classification across the South to include AL, FL, MS, LA, GA, NC, SC, TN, and TX is envisioned.

At broad levels, the classification can be used for regional planning; at its lowest levels, physical factors affecting management may be included (e.g., equipment trafficability, access). The hierarchy has seven organizational elements (Table 6): (1) Climatic Region; (2) Physiographic Province (includes the Alluvial Floodplains Province which dissects otherwise distinct climatic regions and physiographic provinces); (3 and 4) Habitat Region and Subregion (smallest elements from satellite imagery); (5) Land Type (uniform geomorphology; unmapped except by Hodgkins *et al.* 1979); (6) Land Subtype (similar to the physiographic site type of Hills [1960]; uniform topographic situation, geologic

TABLE 6. Southern physiographic land classification (Hodgkins *et al.* 1979).

Level	Classification Category	Distinguishing Characteristics
A	Climatic region	Regional rainfall/temperature
B	Physiographic province	Major geologic/landform system
B1	Habitat region	Broad geologic/landform system
B2	Habitat subregion	Characteristic topography type
B3	Land type	Local geology; general soil profile
B4	Land subtype	Local topographic characteristics
B5	Habitat type	Local feature significant to productivity or use

material, and soil profile; unmapped); and (7) Habitat Type (local site factors affecting forest productivity; unmapped). Physiographic areas less than ten square miles (outliers) have not been delineated (Evans *et al.* 1983).

Although several forested wetlands were identified at the Land Type level, any of several forested wetlands classifications presented in this review could be logically absorbed at this point in the classification hierarchy. The authors suggest four physiographic categories: wet depressions and slopes, small floodplains, large floodplains, and loam flats (includes pine wetlands, many drained). They relied on Landsat bands 5 and 7 to separate categories. Band 7 was excellent for discriminating hardwood-forested bottomlands from upland (pine-forested) areas, for stream basin delineation, and for drainage pattern and density recognition. It also identified the Coastal Marsh Province included by Evans *et al.* (1983), Myers *et al.* (1986), and Pehl and Brim (1985).

(4) Physiographic/Geomorphic Classification of Forested Wetlands – Rowe (1984) emphasized that landforms provide the "skeletal structure" for delineating and classifying landscape ecosystems of interest to forestry. They are the primary controllers of fluxes into and out of terrestrial ecosystems (Rowe 1984). Landscape position influences the availability of nutrients and water and the productivity and structural properties of the wetland. Natural disturbances and anthropogenic impacts on wetlands will vary in consequence and magnitude depending on landscape position (Brown 1989).

Some authors have used geomorphic approaches to stratify wetlands according to their sensitivity to impacts and capacity for affecting water quality (Brinson 1988, Brown 1989, Coulliard and Grondin 1986, Lugo *et al.* 1988). Such classifications recognize that wetland physiography fundamentally influences throughflows of water and nutrients, sediment depositional regimes, and elemental recycling rates.

Wetlands have been divided into three physiographic categories: basin (or depressional), riverine, and fringe (Brinson 1988). These categories are analogous to those of Couillard and Grondin (1986) for Quebec: peatland, riverine, and tidal. The latter authors further subdivide their system to provide more detailed levels of classification. Lugo and others (1988) outline the core environmental factors and structural and functional indices of each broad physiographic type.

Basin wetlands (sensu Brinson 1988) are characterized by vertical fluctuations of water table, long hydroperiod, low hydrologic energy, and low nutrient levels. They tend to be restricted to headwater regions, capture drainage from small areas, and receive precipitation as the predominant source of water. Vegetation zonation usually exhibits a concentric pattern.

Riverine wetlands are primarily affected by water flowing downstream and normally have short hydroperiod, high hydrologic energy, and high nutrient levels. They occur throughout the landscape. Vegetation patterns are arranged parallel to the direction of water flow. The dominant water transport mechanism varies with stream order. Riparian transport, groundwater discharge, and surface water runoff from uplands dominate small, low-order streams. Overbank transport, water transport from the stream channel to the floodplain when discharge exceeds the channel capacity, dominates floodplains along large, high-order streams.

Fringe wetlands have long hydroperiod, high hydrologic energy, variable nutrient levels, and frequent flushing by bidirectional water flow. They tend to be located at the base of a drainage unit and next to a large body of water. Vegetation zonation is perpendicular to the direction of water flow.

(5) <u>Classifications Based on Wetland Morphology</u> — Classifications based on morphology (shape) are useful; they are simple in application, easily understood, and relevant to hydrology. Several classifications of European and Canadian bogs and fens are based on wetland morphology. Osvald (1925) classified European raised bogs by peat profile in relation to the surrounding topography as: (1) continental raised bogs (wooded and tree covered); (2) Baltic raised bogs (classic bogs); (3) Atlantic raised bogs (plateau-topped); and (4) upland raised bogs (blanket bogs). Moore and Bellamy (1974) regionalized the bogs and fens of Europe on a morphological basis. Similar to Osvald, Crum (1988) categorized primary, secondary, and tertiary peatlands by the level of peat relative to the flow of minerotrophic soil water.

The Canadian Muskeg Classification System is based on wetland shape (Radforth 1952, 1969a, 1969b). The main feature of this classification is the identification of the organic terrain (muskeg) morphology, shown by vegetation patterns or structures in the peat. Morphology is identified from the air and classified as one of several "airform" patterns. When viewed from low altitude (330 m) or mid-altitude (3300 m), the wetland morphology can be classified into six basic patterns and three subpatterns (Radforth 1969b). Subcategories are according to the vegetation cover and peat structure. Vegetation is expressed either as pure coverage classes or as mixtures (MacFarlane 1958). In northern Canada, only 18 cover combinations occur with any frequency, and these consist of combinations of no more than two or three cover classes. Importance of each class is shown by its position in the cover formulae: the predominating class is in the first position (Radforth 1969a). If the cover class is less than 25 percent, it is not shown in the cover formula. Information on surface cover is complemented by a characterization of peat based on structure (Radforth 1969a). The main categories are amorphous-granular, fine-fibrous, and coarse-fibrous, each further subdivided by such features as granules, fibers, or wood content. A total of 17 peat structure categories have been identified.

Microtopography of peatland surfaces indicates habitat variations, especially in moisture regime and water chemistry (Sjors 1961, 1963, 1969). Sjors introduced a classification in which morphologically distinct microhabitats such as hummocks, ridges, flarks, and lawns are recognized.

Heinselman (1963) provided a classification of Minnesota wetlands based, in part, on surface patterns and peat characteristics. He presented wetland types within a theory of wetland formation and bog succession.

F. Ecosystem Classifications

Ecosystem or biophysical classifications are multifactor, ecological approaches to land classification. They stress the relationships among landscape components rather than treat each as a separate characteristic. Although some resource planning and monitoring decisions can be based on evaluation of a single diagnostic criterion, many are better served by combining criteria. Ecological units are usually defined by three factors – physiography, soils, and vegetation – and have more or less predictable responses to extensive management (Barnes *et al.* 1982). Most ecosystem classifications are not specific to forested wetland ecosystems, but contain them at some level in a classification hierarchy. They offer an operational framework in which detailed forested wetlands classifications can be incorporated.

(1) Ecological Land Classification Framework for the United States – A uniform land classification for the entire United States was attempted in the early 1980s. It was intended to address multiple-use resource management needs and comply with enacted legislation (e.g., National Environmental Policy Act of 1970, Federal Land Policy and Management Act of 1976, Forest and Rangeland Renewable

Resources Planning Act of 1974 as amended by the National Forest Management Act of 1976, and The Soil and Water Resources Conservation Act of 1977; Barnes *et al*. 1982, Driscoll *et al*. 1984). These laws require several federal agencies to assess the condition and status of the nation's lands and renewable natural resources on a periodic basis and exchange information among agencies to help in decision making (Driscoll *et al*. 1984).

An interagency effort (Bureau of Land Management, USFS, FWS, Geological Survey, and SCS) drew upon international experience with ecological land classification (Brink *et al*. 1965, Christian and Stewart 1968, Isachenko 1973, Wiken and Ironside 1977) as well as SCS land resource regions (Austin 1981) and USFS efforts (ECOCLASS and modified ECOCLASS [Driscoll *et al*. 1984]) when drafting the classification system. Five ecological land classifications, compared by Bailey (1981) in Table 7, formed a starting point. They are multifactor (integrated) hierarchical approaches uniting vegetation, soil, landform, climate, and water, and characterize ecologically important interactions based on known functional relationships.

The interagency committee eventually produced the Ecological Land Classification Framework for the United States (Driscoll *et al*. 1984). The classification suggests a series of homogeneous ecological response units, each a product of existing hierarchies for three diagnostic criteria – soil, vegetation, and water – and attaches landform descriptors in the absence of a separate hierarchy (Table 8). Since this classification incorporates the wetland classification system of Cowardin and others (1979) to represent the water element, forested wetlands can readily be absorbed as refinements of the national system. SCS's hydric soils classification offers refinement of the soils element for forested wetlands. The vegetation hierarchy is derived from the UNESCO (1973) physiognomic system at higher levels (Class, Subclass, Group, Formation) and from floristic or habitat type classification (Daubenmire 1968) at lower levels (Series, Association). Series designations are essentially SAF cover types.

A final version of a national land classification has not been agreed upon, nor will it be in the near future (Larson and Schlatterer 1984). A single uniform classification system that meets the needs of even one agency is not feasible. The cost of implementing such a system, including conversion of existing databases, would be too high and much information useful for monitoring trends would be lost. Regional approaches to land classification, which vary considerably with respect to the criteria used, are too well entrenched to be circumvented (Bailey 1984). Also, soil and wetlands are the only diagnostic criteria with uniform, nationally accepted systems of taxonomy.

TABLE 7. System of units in five ecological land classifications (Bailey 1981).

Australian land research approach[1]	British land unit approach[2]	Canadian ecological land classification[3]	Soviet Union landscape approach[4]	United States land systems/ ecosystem approach[5]
			zone	
				domain
	land zone			division
	land region	ecoregion	province	province
	land district	ecodistrict		section
			landscape	
land system	land system	ecosection		district
land unit	land type	ecosite	urochishcha	landtype association
land type	land phase			land type
site		ecoelement		landtype phase
			facia	site

References: 1 - Christian and Stewart (1968); 2 - Brink *et al.* (1965); 3 - Wilken and Ironside (1977); 4 - Isachenko (1973); 5 - Wertz and Arnold (1972), Bailey (1976)

TABLE 8. The three classification hierarchies – soil, vegetation, and water – incorporated in U.S. ecological land classification (Driscoll *et al.* 1984).

Soil Element	Vegetation Element	Aquatic Element
order	class	system
suborder	subclass	subsystem
great group	group	class
subgroup	formation	subclass
family	series	dominance type
series	association	

(2) Canada Land Inventory and Ecological (Bio-Physical) Land Classification – In 1963, Canada established the Canada Land Inventory (Lacate and Romaine 1978, Perret 1976). Its objectives were to determine the capability of the land to support agriculture (including forestry) and to examine alternative uses of land. Capability is the inherent potential of land to produce sustained yield of a specific crop or recreation value under proper management (Perret 1976).

USDA's Land Capability Classification formed a starting point for the Canadian inventory (Klingebiel and Montgomery 1961). The latter differed in that all lands could potentially be rated for a variety of uses (Lacate and Romaine 1978). Separate interpretive classifications for several land uses were developed, each a seven-class system with subclasses to describe dominant limitations on the use.

One of the interpretive classifications is the Land Capability Classification for Forestry (Canada Land Inventory 1970, McCormack 1967). All mineral and organic soils were classified by their inherent ability to grow commercial timber. Each of the seven classes was associated with a productivity range based on the mean annual increment of the species adapted to the site at or near rotation age; subclasses indicated limitations to tree growth (Lacate and Romaine 1978). Major management efforts such as fertilization or drainage were not considered; only the natural state of the land. The classification was based on soil surveys, forest inventory maps and reports, and biophysical land surveys. Land capabilities were presented at a generalized reconnaissance scale of 1:125,000 to 1:250,000 and data were stored in a geographic information system (Lacate and Romaine 1978).

There has been an attempt to compose a single land classification scheme for all Canada. The Canada Land Inventory became predecessor to the Ecological (Bio-Physical) Land Classification in Canada (Environmental Conservation Service Task Force undated, Thie and Ironside 1977). The system is a hybrid of earlier systems described by Hills (1960) and Christian and Stewart (1968). It provides a framework for delineating lands for specific environmental impact analyses, recognizing that the nature of the project, the type and complexity of the environment, and the existing data base control information needs. It is a hierarchical system with a fundamentally physiographic approach. Levels include ecoprovince, ecoregion, ecodistrict, ecosection, ecosite, and ecoelement (Table 9). At lowest hierarchical levels, vegetation patterns are emphasized, including proportions, types, and distribution of species within a forest ecosystem, as are other biological factors. Although forested wetlands are not specifically identified, an ecoelement (common map scale 1:10,000 to 1:2,500) identifies plant associations or subassociations, or sections of small streams. The Canadian Wetland Classification

TABLE 9. Levels of generalization in Canadian ecological land classification (Environmental Conservation Service Task Force undated).

LEVEL OF GENERALIZATION Common map scale*	EXAMPLES OF COMMON BENCHMARKS FOR RECOGNITION					
	Geomorphology	Soils	Vegetation	Climate	Water	Fauna
ECOREGION 1:3,000,000 TO 1:1,000,000	Large order landforms or assemblages of regional landforms	Great groups associations thereof	Plant regions or assemblages of plant regions	Meso or small order macro	Large water basins	Assemblages of faunal communities
ECODISTRICT 1:500,000 to 1:1,000,000	Regional landform or assemblages thereof	Subgroups or associations thereof	Plant districts or assemblages of plant districts	Meso or large order micro	Drainage pattern; water quality	Faunal community or some specialized habitat
ECOSECTION 1:250,000 to 1:50,000	Assemblages of local landforms or a local landform	Family or associations thereof	Plant associations or assemblages thereof community	Large order micro to small order micro	River reaches lakes and shoreland	Specialized habitat within a community or a lower order
ECOSITE** 1:50,000 to 1:10,000	A local landform or portion thereof	Soil series or an association of series	Plant association or community	Small order micro	Subdivision of above	Portions of a community or total habitats of some small species
ECOELEMENT 1:10,000 to 1:2,500	Portion of or a local landform	Phases of soil series or a soil series	Parts of a plant assoc. or sub-association	Small order micro	Sections of small streams	

* Map scales should not be taken too restrictively, as they will vary with the setting and objectives of the survey

** More so than others, this level is frequently subdivided into phases to indicate a passing or temporary state (e.g. seral)

System (see (6) below) is one specific application of the Canadian land classification.

(3) Wetland Classification for Waterfowl Habitat – The U.S. Fish and Wildlife Service (FWS) devised a national classification of wetlands for the inventory of waterfowl and other wildlife habitats (Martin *et al*. 1953). The classification, commonly referred to as Circular 39, has four broad categories that contain 20 basic wetland types. The categories are based on wetland location (inland vs. coastal) and salinity (saline vs. fresh). These are thought to influence vegetation, potential food supply, and nesting potential of an area. Secondary considerations are water depth during the growing season, degree of seasonal flooding, and dominant life form of vegetation.

Several acknowledged weaknesses of the Martin classification are: (1) it deals primarily with waterfowl habitat and inadequately with other wildlife and environmental values; (2) basic data are not organized or stored for easy access (it is not hierarchical); and (3) it lacks the specificity necessary for research or regional needs (Leitch 1966, Stegman 1976). The classification ignores ecologically critical distinctions between fresh and subsaline inland wetlands and often places dissimilar habitats in the same class (Cowardin *et al*. 1976). Consequently, highly productive wetlands in the prairies were placed in the same class as impounded bogs, and boreal spruce forests fell into a class with cypress-gum forests. Also, information on soils was lacking.

Chamberlain (1960) produced a wetland classification for waterfowl habitat in Florida. The system includes four freshwater types, distinguished mainly by hydrologic location and broad vegetative type. Subtypes relate to the permanence of surface water, dominant vegetation, and proportion of water area vegetated.

Golet and Larson (1974) classified Northeastern wetlands to evaluate wetland wildlife production and diversity. They refined the system of Martin and others (1953) by writing more detailed descriptions and subdividing classes on the basis of finer differences in plant life-forms (Cowardin *et al*. 1979). Their system includes 24 subclasses, 5 size categories, 6 site types describing hydrology and topographic position, 8 cover types, 3 vegetative interspersion types, and 6 surrounding habitat types.

(4) National Wetlands Inventory – The National Wetlands Inventory (NWI) is a national mapping project undertaken principally by the FWS. A wetlands classification scheme, *Classification of Wetlands and Deepwater Habitats of the United States*, was developed primarily to serve as the foundation for the NWI, providing units for inventory and mapping (Cowardin et al. 1979, Tiner 1989). Other objectives of the classification system are: (1) to describe ecological units having certain homogeneous natural attributes, (2) to arrange these units in a system that

would facilitate resource management decision making, and (3) to provide consistent concepts and terminology that could be used for the entire United States (Cowardin *et al.* 1979). The system uses the term "habitat" neither strictly in the wildlife sense (as niche for a particular species) nor for potential vegetation (sensu Pfister and Arno 1980).

The NWI groups sites by similarities in hydrologic, geomorphologic, chemical, and biological diagnostic characteristics. It is hierarchical and objective. Definitions of hierarchical elements were written specifically for this classification. Exceptions are Ecoregions adapted from Bailey (1976, 1978) and soil definitions from the U.S. Soil Conservation Service (1975, 1987).

The classification has five Systems: marine, estuarine, riverine, lacustrine, and palustrine. Forested wetlands are either estuarine or palustrine Systems – by definition, the other Systems exclude wetlands dominated by trees. Systems are divided into Subsystems on the basis of hydrologic characteristics, such as tidal, subtidal, intertidal, perennial, intermittent, or littoral. The Subsystems are further divided into Classes on the basis of substrate (e.g., aquatic bed, rock bottom) or, in the case of palustrine subsystems, vegetation (e.g., moss-lichen wetland, scrub-shrub wetland). The wetland Classes can be further divided into Subclasses according to the predominant life-form of the covering vegetation. For example, needle-leaved evergreen or broad-leaved deciduous are forested wetland Subclasses. If vegetation covers less than 30 percent of the substrate, the physiography and composition of the substrate are used to distinguish subclasses. Vegetated Subclasses can be further subdivided into dominance types on the basis of dominant plant species.

The wetland classes and their subdivisions can be more precisely described by the use of modifiers. Water chemistry modifiers include salinity and pH values. The soil modifier is commonly limited to mineral vs. organic, but the hydric soils classification (U.S. Soil Conservation Service 1987) affords additional detail. Other special modifiers are anthropogenic influences on wetlands, such as drainage, impoundment, or farming (National Wetlands Working Group 1988). Parameters used in other wetland classifications, such as the origin, quality, or quantity of water, and the genesis of the wetland, are not considered.

Direct comparison to other wetland classifications is hindered because (1) the criteria selected for categories usually differ, (2) many classifications are only regional in scope, and (3) the elements classified are not always consistent among the various classifications (Cowardin *et al.* 1979). The Cowardin system differs from the Circular 39 classification of Martin and others (1953) in that it is not biased toward wetlands of value to wildlife. Furthermore, it is hierarchical and allows the user to select a far greater level of detail than the 20 types of Shaw and Fredine (1956); much emphasis is placed on detailed definitions for all elements (Cowardin 1978; Table 10).

Golet and Larson's (1974) modification of the Martin system for wetland habitats in the glaciated Northeast is similar to that of Cowardin's; type descriptions are detailed, hierarchical subdivisions based on vegetative differences, and site and cover type modifiers are included (Table 11). However, Golet and Larson restricted Type 1, seasonally flooded basins or flats, to river floodplains and did not separate coastal (tidal) fresh wetlands from nontidal wetlands.

The Cowardin classification differs from Stewart and Kantrud's (1971) classification of prairie wetlands. The latter applies to entire wetland basins – small and discrete in the prairie pothole region – whereas the former does not (Cowardin 1978). Stewart and Kantrud's seven wetland Classes – based on water permanence – are readily related to Cowardin water regime modifiers; and their Subclasses – denoting variations in salinity – are roughly equivalent to Cowardin water chemistry modifiers (Cowardin *et al.* 1979). Unlike Stewart and Kantrud's classification, the Cowardin system encompasses forested wetlands.

Cowardin and others (1976) compared the diagnostic criteria of their system to criteria used in the Functional Classification of Coastal Ecological Systems by Odum and coworkers (1974). In contrast to Cowardin's, Odum's system is structured around sources of energy inflow, types of stress, and the resulting diversity of organisms and niches. Also, mangroves are the only forested wetlands included in Odum's classification.

The Cowardin system has become widely recognized and accepted. It would not be proper to discuss or develop new approaches to the study of forested wetlands without acknowledging this work. Although criticized for not satisfying specific needs in its present form, the hierarchical system is malleable for absorption into broader national land classification systems or for refinement for regional or evaluation-specific applications.

(5) Wetland Classification for the Tennessee Valley Region – A wetland classification system was specifically developed for the Tennessee Valley Region (TVR) (Carter and Burbank 1978). It was developed with the benefit of prior attempts, primarily the work of Anderson and others (1976), Cowardin and others (1976), and Golet and Larson (1974). The Anderson system, which provided a national classification framework, is compared to the TVR system in Table 12. The Cowardin system was a logical model because it has ties to the National Wetlands Inventory, and many diagnostic characters came from the Golet and Larson system. In contrast to the Cowardin system, the TVR system retained traditional wetland names (marsh, swamp, bog, prairie, and meadow). The latter two classification systems are compared in Table 13.

TABLE 10. Relationship between the Circular 39 wetland classification (Martin *et al.* 1953) and the current *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin *et al.* 1979).

Circular 39 type, and references for examples of typical vegetation	Classification of wetlands and deepwater habitats		
	Classes	Water regimes	Water chemistry
Type 1—Seasonally flooded basins or flats Wet meadow (Dix and Smeins 1967; Stewart and Kantrud 1972) Bottomland hardwoods (Braun 1950) Shallow-freshwater swamps (Penfound 1952)	Emergent Wetland Forested Wetland	Temporarily Flooded Intermittently Flooded	Fresh Mixosaline
Type 2—Inland fresh meadows Fen (Heinselman 1963) Fen, northern sedge meadow (Curtis 1959)	Emergent Wetland	Saturated	Fresh Mixosaline
Type 3—Inland shallow fresh marshes Shallow marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland	Semipermanently Flooded Seasonally Flooded	Fresh Mixosaline
Type 4—Inland deep fresh marshes Deep marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland Aquatic Bed	Permanently Flooded Intermittently Exposed Semipermanently Flooded	Fresh Mixosaline
Type 5—Inland open fresh water Open water (Golet and Larson 1974) Submerged aquatic (Curtis 1959)	Aquatic Bed Unconsolidated Bottom	Permanently Flooded Intermittently Exposed	Fresh Mixosaline
Type 6—Shrub swamps Shrub swamp (Golet and Larson 1974) Shrub-carr, alder thicket (Curtis 1959)	Scrub-Shrub Wetland	All nontidal regimes except Permanently Flooded	Fresh
Type 7—Wooded swamps Wooded swamp (Golet and Larson 1974) Swamps (Penfound 1952; Heinselman 1963)	Forested Wetland	All nontidal regimes except Permanently Flooded	Fresh
Type 8—Bogs Bog (Dansereau and Segadas-vianna 1952; Heinselman 1963) Pocosin (Penfound 1952; Kologiski 1977)	Scrub-Shrub Wetland Forested Wetland Moss-Lichen Wetland	Saturated	Fresh (acid only)
Type 9—Inland saline flats Intermittent alkali zone (Stewart and Kantrud 1972)	Unconsolidated Shore	Seasonally Flooded Intermittently Flooded Temporarily Flooded	Eusaline Hypersaline
Type 10—Inland saline marshes Inland salt marshes (Ungar 1974)	Emergent Wetland	Seasonally Flooded Semipermanently Flooded	Eusaline
Type 11—Inland open saline water Inland saline lake community (Ungar 1974)	Unconsolidated Bottom	Permanently Flooded Intermittently Flooded	Eusaline
Type 12—Coastal shallow fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Irregularly Flooded Semipermanently Flooded-Tidal	Mixohaline Fresh

TABLE 10. Continued.

	Classification of wetlands and deepwater habitats		
Circular 39 type, and references for examples of typical vegetation	Classes	Water regimes	Water chemistry
Type 13—Coastal deep fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Semipermanently Flooded-Tidal	Mixohaline Fresh
Type 14—Coastal open fresh water Estuarine bays (Stewart 1962)	Aquatic Bed Unconsolidated Bottom	Subtidal Permanently Flooded-Tidal	Mixohaline Fresh
Type 15—Coastal salt flats Panne, slough marsh (Redfield 1972) Marsh pans (Pestrong 1965)	Unconsolidated Shore	Regularly Flooded Irregularly Flooded	Hyperhaline Euhaline
Type 16—Coastal salt meadows Salt marsh (Redfield 1972; Chapman 1974)	Emergent Wetland	Irregularly Flooded	Euhaline Mixohaline
Type 17—Irregularly flooded salt marshes Salt marsh (Chapman 1974) Saline, brackish, and intermediate marsh (Eleuterius 1972)	Emergent Wetland	Irregularly Flooded	Euhaline Mixohaline
Type 18—Regularly flooded salt marshes Salt marsh (Chapman 1974)	Emergent Wetland	Regularly Flooded	Euhaline Mixohaline
Type 19—Sounds and bays Kelp beds, temperate grass flats (Phillips 1974) Tropical marine meadows (Odum 1974) Eelgrass beds (Akins and Jefferson 1973; Eleuterius 1973)	Unconsolidated Bottom Aquatic Bed Flat	Subtidal Irregularly Exposed Regularly Flooded Irregularly Flooded	Euhaline Mixohaline
Type 20—Mangrove swamps Mangrove swamps (Walsh 1974) Mangrove swamp systems (Kuenzler 1974) Mangrove (Chapman 1976)	Scrub-Shrub Wetland Forested Wetland	Irregularly Exposed Regularly Flooded Irregularly Flooded	Hyperhaline Euhaline Mixohaline Fresh

TABLE 11. Relationship between the classification of wetland habitats in the glaciated Northeast (Golet and Larson 1974) and the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin *et al.* 1979).

Golet and Larson (1974)	Cowardin et al. (1979)				
	SYSTEM	CLASS/SUBCLASS	ORDER	WATER REGIME	WATER CHEMISTRY
1. Open Water (OW)					
a. vegetated (OW-1)	Palustrine Lacustrine Riverine	Floating-leaved Bed	Mineral Organic	Permanently flooded	Fresh
b. nonvegetated (OW-2)	Palustrine Lacustrine Riverine	Submergent Bed Bottom	Mineral Organic	Permanently flooded	Fresh
2. Deep Marsh (DM)					
a. dead woody (DM-1)	Palustrine Lacustrine	Forested Wetland Shrub Wetland	Mineral Organic	Permanently flooded Semipermanently flooded	Fresh
b. shrub (DM-2)	Palustrine Riverine-Tidal	Deciduous Shrub Wetland	Mineral Organic	Permanently flooded Semipermanently flooded	Fresh
c. sub-shrub (DM-3) d. robust (DM-4) e. narrow-leaved (DM-5) f. broad-leaved (DM-6)	Palustrine Riverine Lacustrine	Emergent Wetland	Mineral Organic	Permanently flooded Semipermenantly flooded	Fresh
3. Shallow Marsh (SM)					
a. robust (SM-1) b. narrow-leaved (SM-2) c. broad-leaved (SM-3)	Palustrine Riverine Lacustrine	Emergent Wetland	Mineral Organic	Seasonally flooded Semipermanently flooded	Fresh
d. floating-leaved (SM-4)	Palustrine Lacustrine	Floating-leaved Bed	Mineral Organic	Semipermanently flooded	Fresh

TABLE 11. Continued.

Golet and Larson (1974)	Cowardin et al. (1979)				
	SYSTEM	CLASS/SUBCLASS	ORDER	WATER REGIME	WATER CHEMISTRY
4. Seasonally Flooded Flats (SF)					
a. emergent (SF-1)	Palustrine	Emergent Wetland	Mineral Organic	Seasonally flooded	Fresh
b. shrub (SF-2)	Palustrine	Deciduous Shrub Wetland	Mineral Organic	Seasonally flooded	Fresh
5. Meadow (M)					
a. ungrazed (M-1) b. grazed (M-2)	Palustrine	Emergent Wetland	Mineral Organic	Seasonally flooded	Fresh
6. Shrub Swamp (SS)					
a. sapling (SS-1)	Palustrine	Deciduous Forested Wetland	Mineral Organic	Seasonally flooded Semipermanently flooded	Fresh
b. bushy (SS-2) c. compact (SS-3)	Palustrine	Deciduous Shrub Wetland	Mineral Organic	Seasonally flooded Semipermanently flooded	Fresh
d. aquatic (SS-4)	Palustrine	Deciduous Shrub Wetland	Mineral Organic	Permanently flooded Semipermanently flooded	Fresh
7. Wooded Swamp (WS)					
a. deciduous (WS-1)	Palustrine	Deciduous Forested Wetland	Mineral Organic	Seasonally flooded Semipermanently flooded	Fresh
b. evergreen (WS-2)	Palustrine	Evergreen Forested Wetland	Mineral Organic	Seasonally flooded Semipermanently flooded	Fresh
8. Bog (BG)					
a. shrub (BG-1)	Palustrine	Deciduous Shrub Wetland Evergreen Shrub Wetland	Organic	Saturated	Fresh/acid
b. wooded (BG-2)	Palustrine	Evergreen Forested Wetland	Organic	Saturated	Fresh/acid

TABLE 12. Relationship between the wetland classification for the Tennessee Valley Region (Carter and Burbank 1978) and the land cover classification for use with remote sensing data (Anderson *et al.* 1976).

Tennessee Valley Region			Anderson
Wetland Classes	Wetland Subclasses		Level II Class
OW-1 Open Water	(OW-1a)	Vegetated	Open Water
	(OW-1b)	Nonvegetated	
FW-1 Bottomland Hardwood	(FW-1a)	Upper Bottomland Hardwood	Forested Wetland
	(FW-1b)	Lower Bottomland Hardwood	
FW-2 Swamp	(FW-2a)	Forested Swamp	
	(FW-2b)	Shrub Swamp	
	(FW-2c)	Dead, Woody Swamp	
M-1 Marsh	(M-1a)	Wet Meadow	Nonforested Wetland
	(M-1b)	Emergent Marsh	
	(M-1c)	Seasonally Emergent Marsh	
M-2 Seasonally Dewatered Flats	(M-2a)	Vegetated	
	(M-2b)	Nonvegetated	
M-3 Agriculture Subject to Flooding			Agriculture

TABLE 13. Relationship between the wetland classification system for the Tennessee Valley Region (Carter and Burbank 1978) and the national classification of wetlands and deepwater habitats (Cowardin *et al.* 1979).

Systems			
Tennessee Valley Region		Cowardin Classification	
CLASS	SUBCLASS	CLASS AND SUBCLASS	WATER REGIME MODIFIERS
OW-1 Open Water	OW-1a Vegetated Open Water	Floating-leaved Aquatic Bed Floating Aquatic Bed Submergent Vascular Aquatic Bed Submergent Algal Aquatic Bed Submergent Moss Aquatic Bed	Permanently Flooded
	OW-1b Nonvegetated Open Water	Organic Bottom Mud Bottom Sand Bottom Cobble/Gravel Bottom Boulder Bottom Bedrock Bottom	Permanently Flooded
FW-1 Bottomland Hardwood	FW-1a Upper Bottomland Hardwood	Broad-leaved Deciduous Forested Wetland	Temporarily Flooded
	FW-1b Lower Bottomland Hardwood	Broad-leaved Deciduous Forested Wetland	Temporarily Flooded Saturated Seasonally Flooded
FW-2 Swamp	FW-2a Forested Swamp	Broad-leaved Deciduous Forested Wetland Needle-leaved Deciduous Forested Wetland	Semipermanently Flooded Permanently Flooded Intermittently Exposed
	FW-2b Shrub Swamp	Broad-leaved Deciduous Scrub/Shrub Wetland Broad-leaved Evergreen Scrub/Shrub Wetland	Saturated Seasonally Flooded Semipermanently Flooded Permanently Flooded Intermittently Exposed
	FW-2c Dead Woody Swamp	Dead Forested Wetland Dead Scrub/Shrub Wetland	Semipermanently Flooded Permanently Flooded
M-1 Marsh	M-1a Wet Meadow	Persistent Emergent Wetland	Saturated Temporarily Flooded
	M-1b Emergent Marsh	Persistent Emergent Wetland	Seasonally Flooded Semipermanently Flooded Intermittently Exposed
	M-1c Seasonally Emergent Marsh	Nonpersistent Emergent Wetland Floating-leaved Aquatic Bed	Semipermanently Flooded Permanently Flooded

TABLE 13. Continued.

Systems			
Tennessee Valley Region		Cowardin Classification[1]	
CLASS	SUBCLASS	CLASS AND SUBCLASS	WATER REGIME MODIFIERS
M-2 Seasonally Dewatered Flats	M-2a Seasonally Dewatered Flats Vegetated	Vegetated Flat	Seasonally Flooded Semipermanently Flooded
	M-2b Seasonally Dewatered Nonvegetated	Mud Flat Sand Flat Sand Beach/Bar Cobble/Gravel Flat Cobble/Gravel Beach/Bar	Seasonally Flooded Semipermanently Flooded
M-3 Agriculture Subject to Flooding		Persistent Emergent Wetland	Temporarily Flooded Seasonally Flooded

[1] Based on operational draft, October 1977.

Wetland types of this classification are limited to broad floodplains of larger rivers and narrow, steep floodplains of mountain streams. Wetland Classes and Subclasses are based on water regime and vegetation. Soil type is not included as a diagnostic criterion, but could be added as a modifier. Vegetation is classified by life-form – physical structure or growth habit (Golet and Larson 1974). Two Classes apply to forested wetlands: bottomland hardwood (dominated by mixed hardwood species, flooded annually during winter or early spring or covered locally with a few centimeters of surface water), and swamp (semipermanently to permanently flooded wetland dominated by woody vegetation). Bottomland hardwood is divided into two Subclasses: upper bottomland hardwood (relatively short inundation by floods, seldom flooded during the growing season) and lower bottomland hardwood (annually inundated by December through March floods). Swamp is divided into three Subclasses: forested swamp (living trees cover at least 30 percent of the area), shrub swamp (not forested wetland), and dead woody swamp (dead trees constitute at least 70 percent of the vegetation).

It is not clear why the Cowardin system cannot be used in the Tennessee Valley Region, regardless of its nontraditional terminology. The two classifications were developed simultaneously and, since the authors were in communication, show much overlap.

(6) Canadian Wetland Classification System – This system was developed by the National Wetlands Working Group of Canada as part of the Ecological (Bio-Physical) Land Classification. It is the official wetland classification for Canada and attempts to synthesize existing regional systems at the national level (Tarnocai 1980, National Wetlands Working Group 1988, Zoltai *et al.* 1975). To facilitate synthesis, the country was divided into 20 wetland Regions.

The classification is based on ecological parameters that influence the growth and development of wetlands. The parameters are both biotic (flora, fauna, peat) and abiotic (hydrology, water quality, basin morphology, climate, bedrock, soil) (National Wetlands Working Group 1988). The wetland classification is a hierarchical system of three levels, which recognizes that certain specific applications may require additional refinement. The broadest category, wetland Class, is based on vegetation physiognomy, hydrology, and water quality. There are five wetland Classes -- bog, fen, swamp, marsh, and shallow open water. Of these, only swamp regularly supports forested wetlands; bog and fen may have sparse layers of trees. The second hierarchical level, wetland Form, is defined by surface morphology, surface pattern, landscape position, water type, and proximity to water bodies. A total of 69 Forms are recognized (Table 14). For example, swamp can be divided into seven Forms: basin, flat, floodplain, peat margin, shore, spring, or stream. The third level, wetland Type, is based on the physiognomy of the vegetation cover; 20 are

TABLE 14. Wetland classes and forms in the Canadian Wetland classification system (National Wetlands Working Group 1988).

Wetland class/form
Bog
Atlantic plateau
Basin
Blanket
Collapse scar
Domed
Flat
Floating
Lowland polygon (high-centre)
Mound
Northern plateau
Palsa
Peat mound
Peat plateau
Polygonal peat plateau
Shore
Slope
String
Veneer
Fen
Atlantic ribbed
Basin
Channel
Collapse scar
Feather
Floating
Horizontal
Ladder
Lowland polygon (low-centre)
Net
Northern ribbed
Palsa
Shore
Slope
Snowpatch
Spring
Stream
Swamp
Basin
Flat
Floodplain
Peat margin
Shore
Spring
Stream
Marsh
Active delta
Channel
Coastal high
Coastal low
Estuarine high
Estuarine low
Floodplain
Inactive delta
Kettle
Seepage track
Shallow basin
Shore
Stream
Terminal basin
Tidal freshwater
Shallow Water
Channel
Delta
Estuarine
Kettle
Non-tidal
Oxbow
Shallow basin
Shore
Stream
Terminal basin
Thermokarst
Tidal
Tundra pool

recognized. These include treed (coniferous and hardwood), shrub (tall, low, and mixed), forb, graminoid (grass, reed, tall rush, low rush, sedge), moss, lichen, aquatic (floating and submerged), and nonvegetated. The system includes an option for adding a fourth level – wetland Variety – enabling specialized applications. Diagnostic criteria for wetland Variety can be floristic or phytosociological, or it can be based on hydrologic characteristics, soil type, bearing strength, trafficability, forest productivity, drainage suitability, etc. (Zoltai and Pollett 1983).

(7) Functional Classification of Ecological Systems – Classifications of aquatic ecosystems are based on functional, rather than more narrow structural or compositional, criteria. For instance, Odum and coworkers (1974) developed a classification system for coastal communities based on novel diagnostic characters related to the prominent process that dominates an ecosystem's functional activity. These characters include sources of energy inflow, types of stress, and the resulting diversity of organisms and niches. Five general categories house 46 systems determined by latitude, human influence, and the degree of natural stress. For instance, sedimentation and salinity are dominant factors in certain wetland ecosystems. Although the Odum classification only includes mangrove forested wetlands, types important in a forest management context could be classified in a similar manner.

Similarly, limnologists have classified lakes on the basis of functional activity rather than simple diagnostic criteria, such as aquatic vegetation (Rowe 1984). Lake ecosystems are typically classified according to morphometry, sediments, chemistry of water, and organisms, using all of the characteristics that define functional entities (Rowe 1984).

(8) U.S. Forest Survey – The USFS Renewable Resources Evaluation Group, formerly the Forest Survey, utilizes a parametric approach to classify sample plots and land areas into ecological classes. The array of data collected permits multiple classifications, thus satisfying specific needs and applications. Forest type classification for vegetation (described previously under the heading of Classifications Based on Vegetation) is an important component of the survey. However, the national survey also includes a hierarchical physiographic classification based on soil moisture and drainage, topography, aspect, and soil characteristics (Tansey 1989). At its highest level (used to report national statistics) 5 physiographic classes are recognized: xeric, xeromesic, mesic, hydromesic, and hydric. Subdivisions of classes at this level vary among regions. For instance, in the wetland rich Southeast region, physiographic diversity is categorized into 13 classes; 6 are affiliated with wetlands (narrow floodplains, broad floodplains, deep swamps, small drains, bays and wet pocosins, and other hydric; Table 15). An earlier version of the Southeast region classification included additional physiographic classes that would likely have addressed forested wetlands (natural

TABLE 15. U.S. Forest Service southeast region physiographic site classification (Tansey 1989).

Code	Physiographic class
	XERIC--These sites are normally low or deficient in moisture available to support vigorous tree growth. Generally, these areas receive adequate rainfall in the Southeast but experience a rapid loss of available moisture because of runoff, percolation, evaporation, transpiration, etc.
01	Dry mountain tops and slopes - Ridge tops and slopes with thin soil, rock outcrops, and considerable exposure to wind and sun. Includes most mountain slopes with a southern or western exposure.
02	Deep sands - Sites with a deep, sandy surface subject to rapid loss of moisture following precipitation. In the Southeast, typical examples include the sand hills, ridges, and flats along the Fall Line and sites along the beach and shores of lakes and streams.
03	Other xeric - All dry physiographic sites not described.
	MESIC--These sites have moderate but adequate moisture available to support vigorous tree growth except for periods of extended drought. Some of these sites are subject to occasional flooding during periods of heavy or extended precipitation.
04	Flatwoods - Flat or fairly level sites outside the floodplains of rivers and streams. Excludes deep sands as well as wet, swampy sites.
05	Rolling uplands - Hills and gently rolling terrain and associated small streams. Excludes deep sands, all hydric sites, and streams with associated floodplains.
06	Moist mountain slopes and coves - Mountain coves and moist slopes with relatively deep, fertile soils. Often these sites have a northern or eastern exposure and are partially shielded from wind and sun. Includes moist mountain tops and saddles.
07	Narrow floodplains - Floodplains less than 1/4 mile in width along rivers and streams. Consider the floodplain on both sides of the stream in determining the width. These sites are normally well drained but are subject to occasional flooding during periods of heavy or extended precipitation. Includes associated levees, benches, and terraces within a 1/4-mile limit. Excludes swamps and sloughs with year-round water problems within the 1/4-mile limit.

TABLE 15. Continued.

Code	Physiographic class
08	Broad floodplains - Floodplains 1/4 mile or wider along rivers and streams. These sites are normally well drained but are subject to occasional flooding during periods of heavy or extended precipitation. Includes associated levees, benches, and terraces. Excludes swamps and sloughs with year-round water problems.
09	Other mesic - All moderately moist physiographic sites not described.
	HYDRIC--These sites generally have year-round abundance or overabundance of moisture.
10	Deep swamps - Low, wet, flat forested areas, usually quite large in extent, which are flooded for long periods of time except during periods of extended drought. Soil and moisture conditions are generally quite favorable for forest growth of selected species. Excludes cypress ponds and small drains.
11	Small drains - Narrow, streamlike, wet strands of forest land often without a well-defined stream channel. These areas are poorly drained or flooded throughout most of the year except during periods of extended drought, and drain the adjacent, higher ground.
12	Bays and wet pocosins - Low, wet, boggy sites characterized by peaty or organic soils. May be somewhat dry during periods of extended drought.
13	Other hydric - All other hydric physiographic sites. Includes cypress ponds and other hydric conditions not described.

stream levees, cypress strands, cypress ponds, willow heads and strands, and marl flats and forested prairies), but these were deleted in the mid-1980s due to infrequent use (Tansey 1989).

The survey also includes a forest management classification. Parameters include slope, aspect, accessibility and terrain, within-forest operability, hydrology description (stream size, flow, and proximity), soil erodability, as well as other criteria that identify the potential site productivity for timber. These are essentially elements of terrain classification for forest management and are discussed in greater detail in a later section. Since the Forest Survey forest management classification targets all forestland, it is insufficient for specific prescriptions of management practices in forested wetlands, although it suggests a reasonable starting point.

Survey results are handled in a number of ways for specific applications. For example, restricting data analysis to survey plots that likely fall within jurisdictional forested wetland (based on physiography and vegetation) provides estimates of acreage and timber volumes that supplement the National Wetlands Inventory (Lea 1988). The result is an improvement over traditional "wetland hardwoods" reporting (Boyce and Cost 1974).

The Forest Survey has expanded data collection to respond to changing forested wetlands resource assessment needs. It has become "hard to find enough room on the data sheet" to include all of a state's requests for information. In fact, data collection may vary from state to state. In North Carolina, federal guidelines for delineating jurisdictional wetlands are being applied to continuous forest inventory plots; plots are classified according to wetland vegetation, soil, and hydrologic parameters (Federal Interagency Task Force for Wetland Delineation 1989).

G. Forested Wetlands Classifications

Since Shaler's (1885, 1890) early systems of forested wetlands classification, few forested wetlands classifications have been national in scope. Shaler acknowledged that freshwater swamps and coastal forests could be categorized on the basis of their landform position. His classification for freshwater swamps is simple: (1) river swamps (terrace swamps and estuarine swamps); (2) lake swamps (lake margins and quaking bogs); (3) upland swamps (wet woods and climbing bogs); and (4) ablation swamps.

Although comprehensive national forested wetlands classifications are lacking, several good classifications have been developed regionally. The following discussion is limited to regional classifications in the United States. Excellent summaries of Canada's regional wetland classifications inclusive of forested wetlands have been prepared by Zoltai and Pollett (1983) and the National Wetlands Working Group (1988).

Regional forested wetlands classifications are products of traditional approaches to forestland and ecological classification and often emphasize the predominant diagnostic characteristics that distinguish the forested wetlands of the region. However, our knowledge of the functions that determine the character of forested wetlands is incomplete. Therefore, most regional forested wetlands classifications are relatively simple, single-level, single-factor parametric approaches based on the composition of vegetation. The following discussions are limited to studies that categorize forested wetlands and does not apply to those that provide detailed ecological or botanical descriptions of a locality. Emphasis is placed on forested wetlands of the southeastern United States because of their great extent, diversity, and economic importance. Also, forested wetlands terminology in the Southeast has become especially confusing, thus complicating interpretation of forested wetlands classifications contained in state Best Management Practice guidelines.

(1) Southern Bottomlands — Southern bottomlands have been described by several authors (Braun 1972, Hosner 1962, Putnam 1951, Smith and Linnartz 1980). Perhaps the terminology of Putnam (1951) has become most widely accepted by those practicing forestry. Putnam recognizes two major site types along river systems: first bottoms and terraces (terraces = older and higher bottoms). Within each of these groups are four secondary sites – ridges, flats, sloughs, and swamps. A fifth secondary site – new land or sand bars – is particular to the first bottoms. The site types apply to the floodplains of all major streams.

The topographic condition of most bottomlands is generally flat, but variations in elevation are identifiable because of differences in physical conditions as well as vegetation (Figure 1; Budelsky and Weaver 1977). The area between the river and the levee is referred to as batture land, frontlands, or river front (Hosner 1962, Putnam and Bull 1932, Smith and Linnartz 1980). It appears to coincide with the first bottoms used by Braun (1972) and Putnam (1951). The first bottoms, developed from recent deposits as a result of frequent flooding by the present drainage system, may also extend beyond the levee.

The area immediately landward of the levee, unless strongly affected by the present drainage system, is the first terrace (Hosner 1962, Putman 1951) or backswamp (Wharton *et al.* 1982) and is comparable to Braun's (1972) second bottom. The first terrace is the product of older drainage systems and exemplifies features of former river fronts. Further landward, the first terrace may be abruptly terminated by the occurrence of a second terrace or extensions of uplands. Water and sediments enter the first terrace from the river during extreme flood events, from backup of first terrace streams during moderate river floods, and from drainage originating in surrounding uplands.

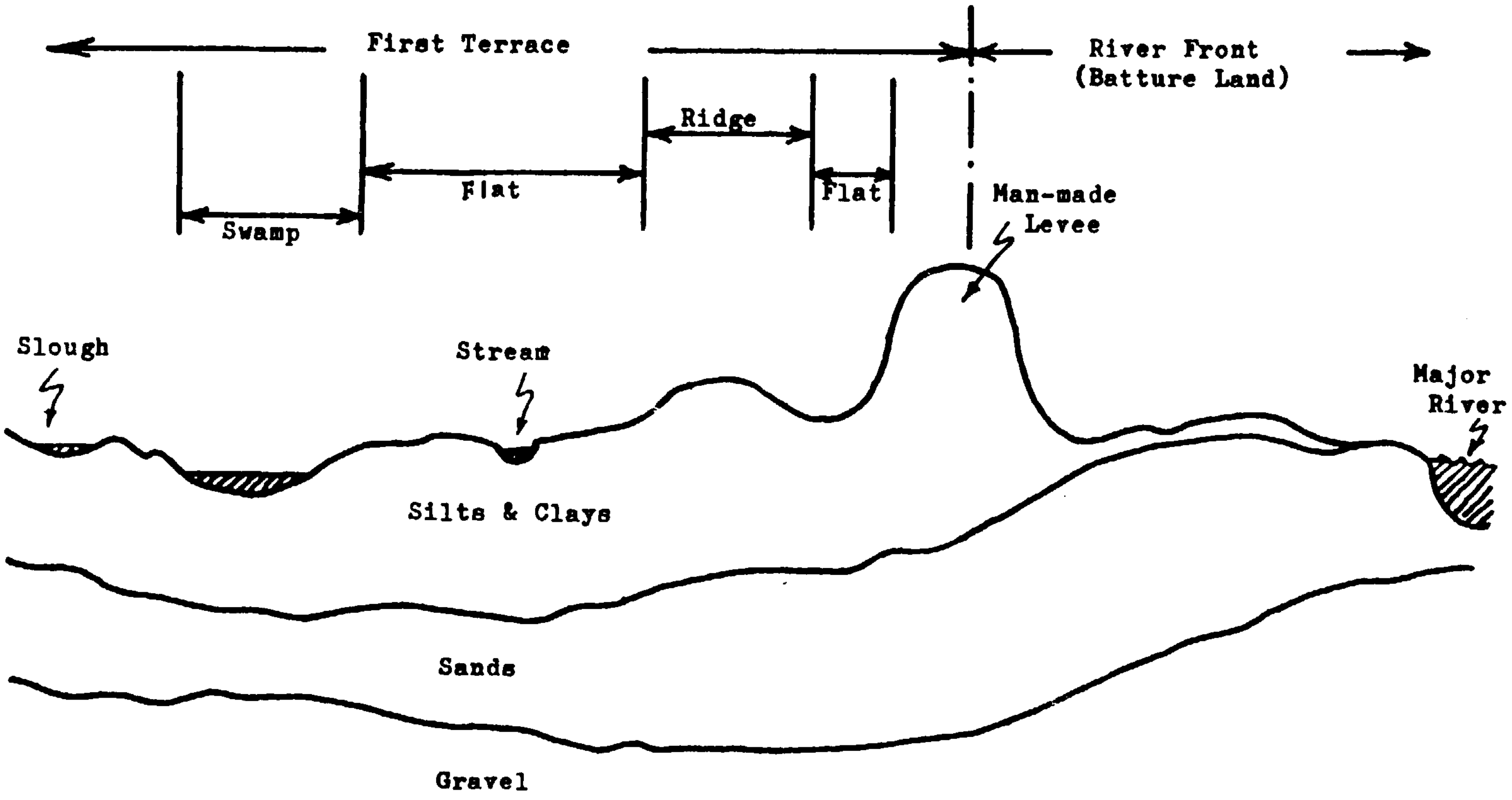
Variations in elevation within the bottoms and terraces produce microtopographic conditions that are identified as ridges, flats, sloughs, and swamps (Figure 1). Ridges, former streambanks, represent the highest elevations and, although only several feet above the surrounding land, they are inundated only during periods of flood and drain quickly after the source of water abates. Flats represent the general terrain between the ridges and are subject to frequent inundation, which may remain through late winter and spring. Sloughs are shallow depressions, in which water collects from drainage within the first terrace, that may retain water into the first half of the growing season. Swamps are recognizable depressions in which water may remain throughout the year, except during period of extreme drought.

Forest vegetation of southern bottomlands appears to be as heterogeneous as the physiographic features. Organizing the species into type groups provides an increased degree of order with which to appreciate species-site associations. Putnam (1951) recognized eight forest types – sweet gum-water oaks; white oaks-red oaks-other hardwoods; hackberry-elm-ash; overcup oak-bitter pecan; cottonwood; willow; riverfront hardwoods; and cypress-tupelo gum – but readily admitted that categorization may be difficult due to natural variation. Eyre (1980) listed 23 forest cover types that logically could be included under the designation of bottomland hardwoods – 36 if broadly interpreted to include softwoods (Huffman and Forsythe 1981). Hosner (1962) simplified the classification into six type groups, Smith and Linnartz (1980) into three groups, and Stubbs (1973) into two groups.

Budelsky and Weaver (1977) interpreted Hosner's forest type classification. Two of Hosner's six type groups, cottonwood-willow and the mixed soft hardwoods, occupy sites within the river front topographic classification. Cottonwood predominates on the better drained flats and ridges, while willow occupies the poorer drained flats and sloughs. The mixed soft hardwoods type group – mostly silver maple, American elm, boxelder, and green ash – is found on the same better-drained sites as the cottonwood, but individual species associate with willow in poorly drained areas. The remaining four type groups are usually associated with site conditions found in the first terrace, but also occur in the front areas if sufficient alluvial deposits have accumulated. The mixed oak type group – characterized by swamp chestnut, cherrybark, shumard, white and southern red oaks – is found primarily on the lighter textured ridges and better drained flats. The sweetgum-water oaks type group – containing water, willow, nutall, and pin oaks – is associated with heavy textured, poorly drained soils in flats and shallow sloughs, whereas the overcup-water hickory type group occupies very poorly drained, heaviest soils on similar sites. Finally, cypress-tupelo-mixed hardwoods is found in the wet, deep sloughs and swamps.

Smith and Linnartz (1980) recognized only three type groups – cottonwood-willow, cypress-tupelo, and mixed bottomland hardwoods

FIGURE 1. Topographic features of bottomlands (Budelsky and Weaver 1977).



(Table 16). The cottonwood-willow type group includes eastern cottonwood and black willow as the dominant species and is found on newly formed land along rivers. The cypress-tupelo type group is dominated by baldcypress, water tupelo, and swamp tupelo and occurs chiefly in low, poorly drained flats, deep sloughs, and swamps in first bottoms and terraces. Finally, the mixed bottomland hardwoods are dominated by sweetgum, water oak, willow oak, nutall oak, swamp chestnut (cow) oak, cherrybark oak, green ash, sugarberry, hackberry, American elm, overcup oak, and water hickory. The mixed bottomland hardwoods type group is found on all major and minor stream bottoms and associated terraces, the major species varying according to the site.

Type groups are reasonable descriptions of general vegetation patterns. Application in the field requires considerable experience and involves subjective interpretations. Ambiguities that may be encountered can be appreciated if one examines the associated species in each of Hosner's (1962) type groups (Budelsky and Weaver 1977). American elm and red maple each occur in five of the six type groups, sugarberry in four, and green ash, overcup oak and sweetgum each can be found in three.

The National Wetlands Technical Council has suggested an ecological zone concept for discrimination of southern bottomland hardwoods (Clark and Benforado 1981, Wharton *et al.* 1982). It is largely a multifactor, ecosystem classification recognizing distinct assemblages of plants and animals associated with particular landforms, soils, and hydrologic regimes. While the classification acknowledges that floodplains occupy an aquatic continuum between permanent water and terrestrial upland, six zones are identified (Figure 2): I – open water (river channels, oxbow lakes, and permanently inundated backsloughs); II – swamp (channel margins, swales, sloughs); III-V – active floodplain (swales [III], flats and backswamps [IV], levees, relict levees, and terraces [V]); and VI – the floodplain-upland transition. The zones may be arranged in discreet bands, but they commonly exhibit a mosaic pattern. Characteristic soils, hydrologic regimes, flora, and fauna are associated with each zone (Wharton *et al.* 1982). Plant communities covering zones II through V were classified into 75 bottomland hardwood dominance-types. These dominance-type designations elaborate Eyre's (1980) forest cover types; some are equivalent.

The ecological zone concept should prove useful for assessing the relative value of zones for performing important wetland functions (Table 17). Also, the system facilitates understanding of broad floodplain community patterns and has a variety of ecological and management applications in floodplain forests. Regeneration methods, relative production capacity, soil bearing strength, habitat quality, and other forest management considerations may be related to the zones. Its use is complicated by several problems: (1) recognition of zones in the field is not

TABLE 16. Description of the major forest type groups of southern bottomland hardwoods (Smith and Linnartz 1980).

	Importance					
Type Group	Extent	Commercial Value	Sites Occupied	Major Species	Associated Species	Comments
Cottonwood and willow	Minor	Cottonwood, high; willow, low to medium value	Newly formed land along rivers; cottonwood predominates on ridges and better-drained flats; willow predominates on the wetter low flats, sloughs, and depressions	Eastern cottonwood Black willow	Pecan American sycamore Sugarberry Hackberry Green ash American elm Red maple Silver maple Boxelder Baldcypress Waterlocust Honeylocust	Pioneer species, succeeded by the associated, more tolerant species; cottonwood has very rapid growth rate, excellent quality, and is a prized species for veneer and hardwood pulp; willow also grows rapidly but is less valuable; both are extremely intolerant and require bare, moist, mineral seedbed for natural regeneration
Cypress-tupelo	Minor, except in lower Mississippi River Valley and coastal areas.	High value when baldcypress predominates; otherwise low to medium value	Chiefly in low poorly drained flats, deep sloughs, and swamps in first bottoms and terraces; common in swamps of coastal plains and river estuaries	Baldcypress Water tupelo Swamp tupelo	Pondcypress Swamp cottonwood Red maple Water hickory Black willow American elm Overcup oak Nuttall oak Laurel oak Waterlocust Persimmon Sweetbay Green ash	A permanent type; commonly in mixture but each species may be found in pure, even-aged stands; water tupelo is the component in swamps of alluvial flood-plains and estuaries; swamp tupelo predominates in nonalluvial and coastal swamps
Mixed bottomland hardwoods	Major; found on all major and minor stream bottoms and associated terraces	Depends on major species; mostly medium to high value, except overcup oak-water hickory on poorly drained slackwater sites	All sites; major species vary according to site: sweetgum and water oaks prevalent on heavy-textured soils of flats and low ridges; sweetgum and mixed oaks on ridges and better drained flats; overcup oak and water hickory on heavy clays of low, poorly drained flats and shallow sloughs	Sweetgum Water oak Willow oak Nuttall oak Swamp chestnut oak (Cow oak) Cherrybark oak Green ash Sugarberry Hackberry American elm Overcup oak Water hickory	Laurel oak Pin oak Shumard oak White oak Pecan American sycamore Boxelder Hickory spp. Red maple Silver maple Cedar elm Winged elm Persimmon Honeylocust Waterlocust Pumpkin ash White ash River birch Baldcypress Black tupelo Swamp tupelo American beech Southern magnolia	Species associations depend on sites and successional stage; some species associations are transitional between pioneer cottonwood-willow type and more permanent associations; past high-grading has increased proportion of poorer species, such as the elms, sugarberry, boxelder, and maple; minor stream bottoms in Coastal Plain usually contain fewer species overall, with smaller proportion of wet-site species

FIGURE 2. Multifactor classification of ecological zones within southern bottomland hardwood forests (Clark and Benforado 1981).

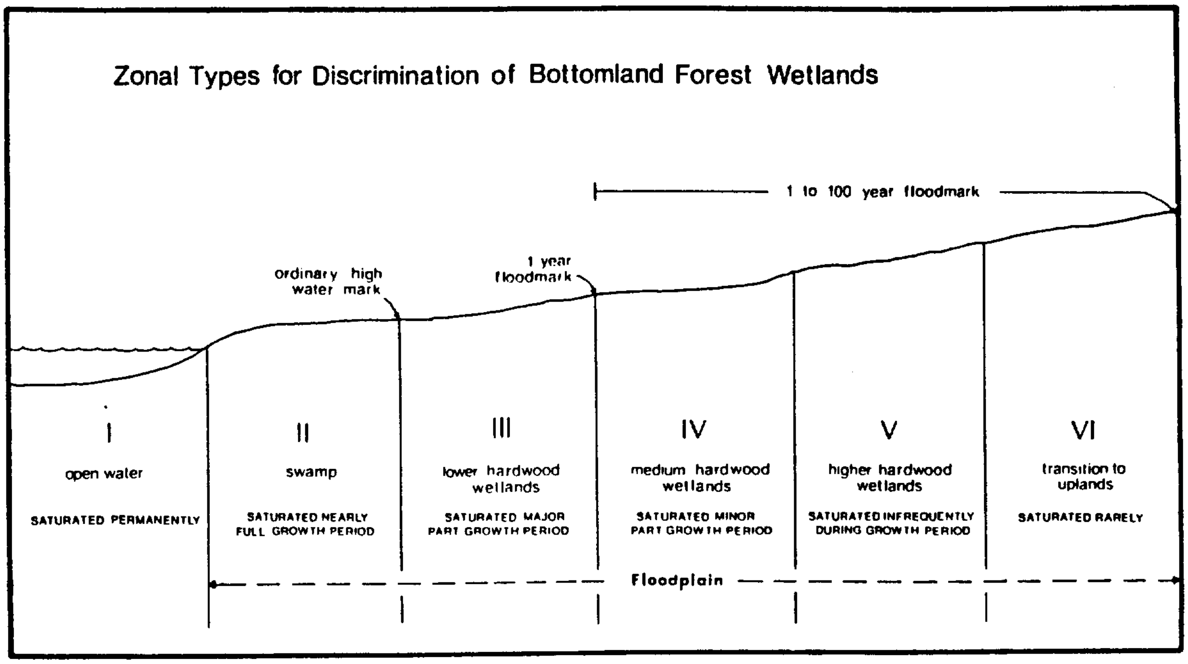


TABLE 17. Relative values of bottomland hardwood ecological zones (BLH types) for provision of wetland functions († = low, negligible, or not known; Clark and Benforado 1981).

Value Type	BLH Type			
	II	III	IV	V
Nutrient Output	High	High	High	Medium
Primary Productivity	Medium	Medium	High	Medium
Water Quality Improvement	High	High	High	Medium
Physical Buffer Against Erosion	High	High	Medium	†
Flood Storage	†	Medium	High	Medium
Waterfowl	Medium	High	High	†
Zooplankton (food base)	High	High	Medium	†
Aquatic Animals	High	High	Medium	†
Endangered Species	†	†	Medium	Medium
Shorebirds and Wading Birds	High	High	†	†
Non-game Birds	†	Medium	Medium	Medium
Fish (adult)	High	High	High	Medium
Fish (young)	Medium	High	High	Medium
Terrestrial Wildlife	†	Medium	Medium	High

always straightforward; (2) plant and animal species overlap zones; and (3) natural levees are excluded.

(2) Southeastern Coastal Plain – Smith and Linnartz (1980) provided an overview of hardwood sites other than bottomlands in the Southeastern Coastal Plain: creek bottoms (associated with small intermittent and free-flowing creeks, which may vary in width from a few hundred feet to a mile or more); muck swamps, coastal swamps, estuarine swamps (flooded year-round from impoundment of rainwater and seepage); bays (peaty swamps where the permanent water table appears to be at or near the soil surface); and hammocks (bay-galls, well-drained flatwood sites not associated with a stream but with ample moisture for growth of hardwoods). Their classification intends to distinguish forested wetlands on the basis of silvicultural differences.

A useful overview of pocosin wetlands was prepared by Gresham (1989). Ash and others (1983) adapted the national wetland classification system (Cowardin *et al.* 1979), including appropriate environmental modifiers to divide pocosins into three categories based on vegetative dominance-types: (1) palustrine, scrub/shrub, broad-leaved evergreen, titi-honeycup wetland; (2) palustrine, forested, needle-leaved evergreen, pond pine wetland; and (3) palustrine, forested, broad-leaved evergreen, sweet bay-red bay-loblolly bay wetland. The bay wetland type is similar to what Monk (1966) and Nelson (1986) called bayhead and bay forest, respectively. Nelson (1986) also provided distinctions between true coastal plain pocosins, streamhead pocosins, and swale pocosins. Streamhead pocosins are floristically similar to true coastal plain pocosins but are located in the fall-line sandhills.

Monk (1966) described three types of freshwater swamps of north-central Florida based on dominant species: (1) cypress swamps; (2) mixed (deciduous) hardwood swamps; and (3) bayheads (evergreen hardwoods). Cypress swamps vary in nutrient status, acidity, and alkalinity, depending on physiography – slough, inland lagoon, pond, lake, or flatwoods depression. The mixed hardwood swamps and bayheads occur along creeks, rivers, sloughs, and depressions. Soils of mixed hardwood swamps are usually mineral. Bayheads, in addition to having peaty soils, have lower nutrient status, are more acid, and are not flooded as deeply as mixed hardwood swamps. Monk's mixed hardwood swamps correspond well with Penfound's (1952) shallow swamps, although some are more like deep swamps. Bayheads correlate with Penfound's (1952) red bay-sweet bay community type within the peaty swamp series.

Wharton and others (1976) elaborated Monk's classification of forested wetlands in Florida, placing 25 forested wetland types within a five-group hierarchy based on the nature of hydrologic inputs. Cypress ponds (domes) and other nonstream swamps receive hydrologic inputs from precipitation and groundwater. Cypress strands are distinguished by slowly flowing water. River swamps and floodplains include continuously flooded alluvial swamps and periodically flooded riparian forests. Finally, saltwater swamps (mangroves) are affected by tides and saltwater.

(3) Northern Wetlands and Peatlands – The diversity of northern wetlands has been described in terms of size, sediments, hydrology, chemistry, and vegetation (Hofstetter 1983). Forested wetlands in the North-Central region include floodplain swamp forests (containing a rich variety of deciduous tree species as well as eastern hemlock and red spruce) and wetlands associated with lake margins and poorly-drained depressions (generally coniferous forests in northern parts of the region and deciduous hardwood forests in southern parts; Curtis 1959, Hofstetter 1983). These are analogous to Braun's (1972) mixed deciduous and coniferous swamp forests. Hardwood species are numerous and include cottonwood, green ash, red and silver maples, American elm, oaks, American beech, pecan, sycamore, blackgum, sweetgum, persimmon, white birch, and others. Coniferous species include eastern hemlock, black spruce, eastern white cedar, larch, and balsam fir.

Heinselman (1963) produced a classification of wetlands for the northern Lake States. Heinselman's is a single-level, multifactor, parametric approach based on water movement pattern or water regime, physical features of the peatland, peat characteristics, and natural vegetation. The classification shows similarities to Canadian and European peatland classifications. Peatland types include mineral-influenced (soligenous) swamp, transitional bog, weakly soligenous poor bog, muskeg (semi-ombrogenous "mosses"), string bog (strangmoor), string bog and island complex, poor fens and treeless bogs lacking strangmoor, and disturbed peatlands. Of these, only mineral-influenced swamp, transitional bog, and weakly soligenous poor bog have important timber value. Variation among peatland types in groundwater levels, bog slopes, water movement, peat characteristics, peat depth, distance from margin, substratum characteristics, soil temperature, soil freezing, and floristics was related to site productivity. A useful glossary of peatland terms is attached to Heinselman's classification.

Cool, high-latitude forest regions of Alaska, northeastern coastal Maine, northern Michigan, Wisconsin, and Minnesota, and northwestern Washington are rich in peatlands and have been classified according to a methodology that is notably Canadian and European in style (Dachnowski-Stokes 1933, Dachnowski-Stokes 1941, Osvald 1925).

(4) Southwestern Riparian Forests – Szaro (1989) used cluster analysis to identify 20 riparian forest and 8 scrubland community types in the Southwest. Clustering of parametric vegetative data produced a hierarchical classification: all levels are structured by vegetative composition. Unlike western habitat types based on potential (climax) vegetation, riparian community types are based on present (existing) vegetation. Community types are named after their dominant vegetation, which results from a complex of

environmental disturbances including grazing, flooding, regulation and damming of streams, and other human influences. Elevation is a force that drives the distribution of forested wetlands, stratifying riparian forest and scrub community types.

(5) Western United States — Habitat type methodology is the most common approach to classification of western forestlands, including forested wetlands. As mentioned in a previous section, habitat types are fundamental landscape units that support homogeneous potential (climax) vegetation. In some cases, the community type, rather than habitat type, is the appropriate term for landscape units if the successional development pattern of an area is uncertain.

Forested wetlands are closely associated with lakes and sounds, and riparian communities that occur mostly as narrow, interrupted bands along faster streams or continuous, wider bands in broad mountain valleys (Walters *et al.* 1980). Alexander (1988) reviewed the literature and noted 10 riparian habitat types, although others are possible. The riparian habitat types he identified include one *Pinus ponderosa* type, two *Abies concolor* types, four *Picea pungens* types, two *Populus tremuloides* types, and one *Picea engelmannii* type. Other types dominated by willow, alder, ash, maple, hemlock, and redwood are often considered forested wetlands.

(6) Prairie Wetlands — Although wetlands are common in portions of the prairie region, only a small percentage of these are forested (Olson 1981, Stewart and Kantrud 1971). Forested wetlands are limited to the floodplains of major prairie rivers. Along riverbanks and levees, two forested wetland types are recognized: willow-poplar and elm (Weaver 1960). Flats along large rivers contain maple and ash in addition to poplar and willow species.

H. Classifications for Prescription of Forest Management Practices

(1) Forest Site Classification — Forest site classifications parallel ecosystem classifications in a number of ways: physical, chemical, and biological features of the land are integrated within classification criteria (Hills 1960, Jones 1988, Smalley 1979). Bailey (1981) and Carmean (1975) traced the development of this concept and Kilian (1981) reviewed site classification systems for forestry. Jones (1988) explained how numerical and discriminate analyses could be used to group vegetation and soils "to develop practical, management-oriented classifications for the commercial forest for the planning and conducting of harvesting and silviculture". Although site classification is applied to all forestlands, detailed characterizations that can be used to distinguish forested wetlands are obtained if appropriate criteria are emphasized.

The Food and Agriculture Organization of the United Nations (FAO 1984) composed an integrated forestland evaluation scheme for land-use planning based on "land qualities." Land qualities are attributes of the land that have distinctive influence on the suitability of land for use; they are measurable diagnostic characteristics. Included are qualities affecting forest growth, volume, and yield, forest management and conservation, and recreation potential. The international FAO system could be adapted to forested wetlands if greater emphasis is placed on the appropriate, but as yet unspecified, characteristics.

The USFS Land System Inventory was designed specifically for use in the Intermountain and Northern Regions of the United States. The purpose of this system is to inventory land potential and provide a basis for management decisions. It is a hierarchical system with highest levels — Province, Section, and Subsection — defined by climatic and geologic properties of land, and lowest levels — Landtype Association, Landtype, Landtype Phase, and Site — defined by soils, landforms, and climax plant communities (Wertz and Arnold 1973, U.S. Forest Service 1976). Floodplains and alluvial basins are broken out at the Subsection level. Most forest planning is done at the Landtype level — mapped areas 64-640 acres in size. Planning includes qualitative interpretations of land potential — soil erosion hazard, timber, browse, and forage productivity, hydrologic behavior, and operability (e.g., roads and equipment). Unfortunately, qualitative interpretations of land potential are not well developed for wetlands. However, the hierarchical approach and incorporation of diagnostic criteria pertinent to forest management provide a good model for the development of a forested wetlands classification for prescription of forest management practices. Use of vegetative data distinguishes this system from highest levels of the Physiographic Classification of Southern Forest Lands and shows the influence of the Ecological (Bio-Physical) Land Classification of Canada in its development.

Smalley (1979) used forest site classification approach for the Eastern Interior uplands, but separated terraces and stream bottoms on the basis of drainage. Smalley's approach is parametric, using a variety of available data sources. Productivity and management problem information is presented in a format similar to the Woodland Suitability ratings of the Soil Conservation Service — productivity, management problems (including equipment limitations and erosion hazard), and species desirability. The Cumberland Plateau area and adjacent lands have been mapped at the Land Type level — visually identifiable areas that have similar soils and productivity and have resulted from similar climate and geological processes (Wertz and Arnold 1975).

The soil-woodland rating of the U.S. Soil Conservation Service measures three aspects of the soil's suitability for wood crops: (1) productivity, (2) limiting soil properties, and (3) other site factors (McCormack *et al.* 1981). Although the rating identifies wetness limitations (high water table, flooding), the system lacks detail for differentiating forested wetlands.

(2) Terrain Classification – Terrain classification is a system for describing forest resource accessibility and operational and economic potential for timber extraction (Rowan 1974, Samset 1975, Segebaden *et al.* 1967). However, classification is based primarily on technical, rather than economic, measures of accessibility. Although it was first developed in hilly regions, terrain classification is also used in Nordic countries that have an abundance of forested wetlands (Berg 1981). It differs from site classification in that less emphasis is placed on the total ecological characterization of land. It is parametric in its approach; that is, although aerial photo interpretation is useful in terrain classification, additional data must be gathered. Classes of terrain can be delineated on maps for planning forest management and operations.

Terrain classification is applied to logged areas as well as terrain embraced in roads of the transportation network. The land area is divided into more or less homogeneous terrain units. An operational unit comprises terrain units that are linked by a transport network.

For specific areas, both descriptive and functional classifications of the terrain may be used to define mapping units (Rowan 1977). Descriptive terrain classification considers diagnostic characteristics (geomorphologic, hydrologic, vegetative, ecologic), without consideration of work methods. If the forest area is large, terrain descriptions must be general. Functional terrain classification takes operational methods and equipment into account. Whereas the descriptive terrain classification remains useful for a long period of time, the functional classification usually has only short-term value because of expected improvements in methods and equipment.

Descriptive classification criteria may vary from region to region. In areas of variable topography, physiographic types might denote general landform. In flat terrain, terrain units may be based on roughness criteria, bearing capacity, or mechanical composition of the soil. Within terrain units, a more detailed terrain description may be prepared with separate classifications for logging and silviculture. For logging, classifications might include soil bearing capacity, ground roughness, slope, and other factors (Table 18; Berg 1981, Mellgren 1980, Rolston 1968). Soil bearing capacity has been described in a number of ways – soil type, soil moisture, field layer, and type of vegetation are commonly combined in an index.

TABLE 18. Factors included in a number of terrain classification systems for forestry (Berg 1981).

	Terrain factors																	Remarks
	Soil type	Field-layer vegetation	Moisture content	Ground bearing capacity	Surface resistance to scarification	Slash	Ground roughness obstacles on surface	Stumps	Subsurface stones and rock	Slope	Slope: Type	Slope: Length	Terrain topography	Humus type	Shrub and tree layer	Snow and frost	Precipitation	
Putkisto 1947		*	*			*	*		*									
Finnish National Defence 1963	*			*			*			*								Highly functional
Skogsarbeten 1969	*	*	*	*			*			*						*		Secondary, for logging
Haarlaa, Asserståhl 1972 (NSR)	(*)	(*)	(*)			(*)	(*)			(*)					(*)	(*)		Proposed recommendations, primary
Samset 1975				*						*	*	*	*					Regional, descriptive
Samset 1975	*	*	*				*		*	*				*				Detailed, secondary
Eriksson, Nilsson, Skråmo 1978 (NSR)	*	*	*			*	*	*	*	*	*			*	*	*	*	Primary
Nilsson, Berg 1979	*	*	*		*	*		*	*									Secondary, for silviculture

Within this approach, differentiation among forested wetlands is possible. For instance, a distinction is drawn between soil substructures — noncohesive soil (sand and gravel), cohesive soil (silt and clay), and peat soil (Samset 1975). Also, surface structure or cover — humus, peat, and vegetative cover (fibers and roots) — influences bearing capacity (Samset 1975). Other considerations are the number of anticipated equipment passes, hauling distance, and operational method (e.g., type of equipment). Suitability for summer and winter operations also can be assessed.

Hassan (1979) proposed a terrain classification to be used for selection of the most efficient tree planting machine on a given site by regrouping USFS Southeast region physiographic classes. Of Hassan's five terrain classes, three apply to forested wetlands: (1) swamps-hardwood; (2) organic-wet-level; and (3) mineral-well drained-level.

Swamps-hardwood includes deep swamps and is almost always organic, wet, and level. Harvesting on such sites may require use of high lead systems. Regeneration is usually achieved by natural sprouting of hardwoods. Hassan recommended that ground vehicles not be used on this class.

Organic-wet-level includes bays and wet pocosins, sites which are almost always organic, wet, and level. Boggy conditions, low land, and peaty soils characterize this class. Forest management plans for this class call for chopping and/or shearing, burning, and bedding followed by pine tree planting. Low ground pressure and all-terrain vehicles, such as wide-tracked tractors and wheeled vehicles equipped with terra tires, are recommended for operating on this terrain.

The mineral-well drained-level class includes wide stream margins, narrow stream margins, flatwoods, and dry pocosins, combining three USFS classes. Terrain is composed of mineral soil with some organic content, is level, and is well-drained and floods during periods of excessive rainfall. Flooding is usually in late winter or early spring. After harvest, sites of this class are often planted with pine; chopping/shearing and bedding are recommended before planting.

(3) Hardwood Site Type Classifications — A hardwood site type classification that was adopted by the American Pulpwood Association (APA) originated in the late 1960s with the purpose of stratifying hardwood ecosystems for establishment of permanent forest growth and yield plots (Kellison *et al.* 1981, Kellison *et al.* 1988). Site types are defined as land formations with unique soil and water characteristics and species compositions and are intended as management units. These types were formulated from prior ecological classifications and emphasize bottomlands. Conventional terminology is melded with site type criteria — an integration of physiographic position, hydrology, soils, and

vegetation. Nine forested wetland site types are identified for use in the southern and southeastern United States: muck swamp, red river bottom, black river bottom, branch bottom, cypress strand, cypress dome, Piedmont bottomland, peat (headwater) swamp, and wet flat. Due to its emphasis on commercial hardwoods, wet pinelands and coastal hardwoods are not included in this classification. Tansey (1989) compared the APA hardwood site type classification with USFS Southeast region physiographic classes and showed that the two systems do not correspond completely (Table 19).

The APA hardwood site type classification is widely used throughout the Southeast. Recognition of site types is considered essential for proper management of wetland hardwoods. Messina and others (1983) used the hardwood site type classification when characterizing the biomass, nutrient, and energy content of southeastern wetland hardwood forests. Although the system was originally conceived for site productivity classification, it has been adopted by numerous forestry concerns and was used as a springboard classification for numerous state BMP guidelines. However, critical analysis reveals some deficiencies: (1) the system is not hierarchical, (2) site types lack rigorous definition, and (3) it is not well suited to the Mississippi and other large river bottoms. It is often difficult to assign a site type to a particular location. Furthermore, the system is incompatible with many other classifications. Like Putnam's (1951) bottomland hardwood classification, it encompasses mesic hardwood sites not included in the federal wetland definition as well as jurisdictional forested wetlands.

(4) <u>EPA Interpretations for Management of Forested Wetlands</u> — The U.S. Environmental Protection Agency (EPA) is developing draft guidance for interpretation of wetlands forest management regulations. When referring to specific forested wetlands, EPA uses the System and Class levels within the wetlands classification of Cowardin and others (1979) to provide a national framework and consistency with other agencies. When forested wetlands must be identified with greater precision, an available regional forested wetlands classification is employed (Muir 1989). These generally use vegetation as the primary diagnostic criteria. For instance, USFS plant dominance-types are often referred to in the West, whereas Natural Heritage plant community types are used in the East and North-Central regions.

(5) <u>State Forested Wetlands Classifications</u> — States are individually preparing forestry Best Management Practice (BMP) guidelines for implementing water quality protection under Sections 208, 319, and 404 of the Clean Water Act. Many of these guidelines contain forested wetlands classifications.

Forested wetlands classifications of Virginia, South Carolina, Georgia, Florida, Alabama, and North Carolina resemble the site type classification of the APA (Kellison *et al.* 1988). Mr. John Godbee of Union Camp Corp. compiled a list of forested wetlands

TABLE 19. Relationship between APA southern hardwood site types (Kellison *et al.* 1981) and the U.S. Forest Service Renewable Resources Evaluation Group's Southeast region physiographic classes (Tansey 1989). Numbers in parentheses are USFS physiographic codes (see Table 15).

SITE TYPES	Physiographic Class
1. Muck Swamp	**Deep Swamps** (10)
2. Peat Swamp	**Bays and Wet Pocosins** (12)
3. Wet Flat	**Flatwoods** (4) most likely but not all flatwoods would qualify depending on fertility and drainage.
4. Red River Bottom	**Narrow** (7) or **Broad Stream Margins** (8).
5. Black River Bottom	**Narrow** (7) or **Broad Stream Margins** (8). Possibly a **Deep Swamp** (10) if in a slough or oxbow.
6. Branch Bottom	Wetter sites would best be described with **Small Drain** (11). More well-drained sites on 2nd terrace would be **Flatwoods** (4) or a floodplain.
7. Bottomland	Well-drained: **Narrow and Broad Floodplains** (7&8), **Flatwoods** (4), possibly **Rolling Upland** (5) if on the lower slope.
8. Coves, Gulfs	**Moist Mountain Slopes and Coves** (6).

nomenclature used in these six southern states and arranged types within four physiographic classes (Table 20) (North Carolina Division of Forest Resources 1989). South Carolina's classification (South Carolina Forestry Commission 1988) is essentially that of Kellison and others (1988). Virginia and Florida elaborated the APA definitions and presented the site types within four broad site classes based on water movement (flowing vs. still) and soil (mineral vs. organic) (Florida Division of Forestry and Florida Forestry Association 1988, Virginia Department of Forestry 1988). Such a hierarchical grouping resembles the forested wetlands classification of Wharton and others (1976). Virginia has further utilized the hierarchical classification structure to recommend BMPs for groups of forest types with common management needs. Alabama guidelines contain slightly modified classes based on soil/site relations and timber type — alluvial river, creek bottoms, branch bottoms, cypress ponds, and muck swamps (Alabama Forestry Commission 1988).

The classification in North Carolina's BMP guidelines for forestry in wetlands shows the greatest divergence from the APA classification and is influenced by Putnam (1951), Braun (1972), and local experience (North Carolina Department of Environment, Health, and Natural Resources 1990). Two broad categories, alluvial and nonalluvial, encompass ten forested wetland associations: muck swamp forest, bottomland or first terrace hardwood forest, headwater or second terrace hardwood forest, black river bottom forest, swamp forest, wet flats, pocosin, pine savanna, bay forest, and perched forest. Associations are well-defined; BMPs are suggested for each association.

(6) Streamside Management Zones — Streamside management zones (SMZs, streamside management units, or riparian management areas) are vegetated areas adjacent to the banks of streams and bodies of open water, which protect bank edges, filter sediment from overland flow, maintain stream temperature norms, and maintain water quality. Special management consideration is given to these areas to comply with water quality standards set by Section 319 of the 1987 Amendments to the Clean Water Act. SMZs may be divided into classes; this varies from state to state. Some states (e.g., Louisiana) only identify the SMZ as distinct from adjacent areas having little influence on the stream. South Carolina recognizes primary and secondary SMZs; primary SMZs are closest to the stream and exert the greatest influence on the stream. Other states (e.g., North Carolina) have a wider SMZ for wider streams and steeply sloping adjacent lands. Still another approach is to classify SMZs on the basis of water use of the stream.

The USFS prepared an SMZ classification for the Pacific Northwest (Swank 1985). Water use and the potential effects of on-site changes on downstream uses are the criteria for defining four stream classes. Specifically, these criteria are domestic water supply, fisheries, water quantity, and water permanence.

TABLE 20. Forested wetlands nomenclature contained in the forest management practice guidelines of six southern states and arranged by four physiographic classes (North Carolina Division of Forest Resources 1989).

FORESTED WETLANDS CLASSIFICATION BY PHYSIOGRAPHIC CLASS

			AL	FL	SC	NC	VA
FLOOD PLAINS, TERRACES AND BOTTOMLAND							
	Black River Bottoms	Coastal Blackwater Stream					
		Black River Bottom		X	X	X	X
	Red River Bottoms	Alluvial River Bottom	X	X			
		Red River Bottom (Swamp)			X		X
		Bottomland or first Terrace			X	X	
		Headwater or second Terrace				X	
	Branch Bottoms	Branch Bottom	X	X	X		X
		Creek Bottom	X				
		Bay Forests				X	
	Muck Swamps	Muck Swamps	X	X	X	X	X
		Cypress-Gum Swamps					
WET FLATS							
	Pine Hammocks- Pine Savannas	Wet Flats			X	X	X
		Wet Hammocks		X			
		Pine Savannas				X	
		Cypress Strands		X			X
	Pocosins	Pocosins				X	
PEAT SWAMPS AND CYPRESS DOMES							
		Peat Swamps		X	X		
		Swamp Forests				X	
		Cypress Ponds/Swamps	X	X			
GULFS, COVES, LOWER SLOPES ADJACENT TO STREAMS							
		Perched Forests				X	
		Gulfs/Coves			X		

Management goals are established for each class of stream. Only forested wetlands immediately adjacent to streams are considered.

Pacific states have incorporated the USFS SMZ concept into their Forest Practice Acts. Washington has prepared BMPs for SMZs based on stream class and width (Washington State Forest Practices Board 1988). Oregon's BMPs also use stream classes, recognizing three divisions within SMZs – Aquatic area and Riparian management area, the latter of which is further subdivided into Riparian area and Riparian area of influence (Oregon Department of Forestry 1987).

Virginia also employs stream classification to set SMZ width (Virginia Department of Forestry 1988). Water use categories are formed by whether the stream is a warm water fishery, cold water fishery, or municipal water supply.

VI LOCATION AND EXTENT OF FORESTED WETLAND TYPES

A. United States

The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (FWS) determines the status of U.S. wetlands and identifies major areas where wetlands are in greatest jeopardy from a national standpoint. National statistics as well as detailed wetland maps are products of the inventory.

The NWI status and trends project provides data, by state and region, on the extent of wetland Systems and Classes defined in the national wetlands classification system (Cowardin *et al.* 1979). National statistics are presented for forested wetlands as a Class, but not for different types (Subclasses) of forested wetlands. Not all states generate maps and statistics of forested wetlands beyond the Class level.

The initial NWI status and trend reports were based on data collected circa 1954 and 1974 (Frayer *et al.* 1983, Shaw and Fredine 1956, Tiner 1984). Hofstetter (1983) presented the earlier survey results and portrayed the relationship of swamp, bog, and peatland distributions to Bailey's (1976, 1978) ecoregions. In 1954, palustrine forested wetlands covered 55,707,400 acres, including 22,200,000 acres of seasonally flooded basins or flats and 17,300,000 acres of wooded swamps (Brinson *et al.* 1981, Frayer *et al.* 1983). In 1974, total forested wetlands covered only 49,713,400 acres, a decrease of 5,994,000 acres. Since estuarine forested and estuarine scrub/shrub wetland Classes were combined in Frayer's report, separate figures for each Class are not available. The total for the two Classes was 592,100 acres in 1954. This decreased by 19,100 acres to 573,000 acres in 1974 (Frayer *et al.* 1983). The magnitude of relative changes in forested wetlands acreage varied among states (Tiner 1984).

Other estimates of the extent of forested wetlands have been conducted over the years. National forest surveys that included southern bottomland hardwoods were undertaken in 1906 (Mattoon 1915) and 1922 (Gray *et al.* 1923). A number of state and local wetland surveys that addressed forested wetlands were conducted between 1965 and 1975 (U.S. Dept. of the Interior 1976). Brinson and others (1981) reviewed estimates of riparian and floodplain areas, as well as estimates of stream and river length.

USFS Forest Survey data is commonly used to estimate the extent of forested wetlands (Lea 1988, Smith and Linnartz 1980, Turner *et al.* 1981, Wharton *et al.* 1982). Use of the survey is popular because it provides data for several points in time since the 1930s and has statistically defined confidence limits. However, due to the selection criteria for vegetative dominance-types, the survey's usefulness as an estimator of the extent of forested wetlands is limited to the East and is best when restricted to the South and Southeast. Wharton *et al.* (1982) provided areal estimates of bottomlands and other forested wetlands for four southeastern states – FL, GA, NC, and SC – utilizing USFS local forest type designations. Smith and Linnartz (1980) presented estimates of areas and volumes of commercial bottomland and wetland hardwoods in fifteen southern states from 1970s USFS inventory data. The latter authors' estimate of forested wetlands in those fifteen states was 33,170,000 acres supporting 36.056 billion cubic feet of growing stock. Turner and others (1981) reported the areal extent of commercial and noncommercial bottomland hardwoods for all eastern states based on USFS oak-gum-cypress and elm-ash-cottonwood type groups. They contended that a net areal loss occurred prior to 1940, followed by a net increase from 1940 to 1960, then a steady decline after 1960. In 1970, they estimated about 58 million acres of bottomland hardwoods in the conterminous United States, with 55 percent in AL, AR, GA, FL, KY, LA, MS, MO, NC, SC, TN, and VA. Lea (1988) gave estimates of the extent of bottomland hardwoods in 16 northeastern and southeastern states. Noteworthy in Lea's figures is the attempt to improve estimates for the Southeast by including oak-pine and oak-hickory forest type groups on hydric physiographic site types along with the oak-gum-cypress and elm-ash-cottonwood type groups.

The most recent estimates of the extent of southern bottomland hardwoods comes from the U.S. Forest Service (1988). The report covers the 12-states that constitute the USFS Southeastern and Southern regions. Areas (in acres) of bottomland hardwoods are estimated for the regions over a 33-year period: 36,747,00 in 1952; 35,953,000 in 1962; 31,732,000 in 1970; 30,861,000 in 1977; and 30,192,000 in 1985. The latest figure amounts to 17 percent of all timberland. Other data provided in the report were acreage of bottomland hardwoods by individual states; the proportion of timberland in the bottomland hardwood management type by county; softwood and hardwood supplies, timber removals, and net annual growth in the bottomland hardwoods management type; and inventory of softwood and hardwood growing stock in the bottomland hardwoods management type.

Once the National Wetland Inventory maps have been completed, it will be useful to consider the distribution of forested wetlands in relation to broad ecological regionalizations. Either the ecoregions of Omernik (1987) or ecoregions of Bailey (1976, 1978) could be used for this purpose.

B. Canada

The extent of wetlands in Canada is not known with any degree of accuracy. In some provinces (e.g., New Brunswick and Newfoundland, Ontario) surveys have been completed; in others, surveys are underway or in the planning stage (Ketcheson and Jeglum 1972, National Wetlands Working Group 1988). Zoltai and Pollett (1983) pooled information on distribution of wetlands in Canada from regional sources — published reports, maps of the Canada Soil Survey and Canada Land Inventory, surficial deposit maps of the Geological Survey of Canada, and "knowledgeable resource managers." Their estimate was that wetlands occupy 18 percent of Canada's total land surface. The most recent estimates indicate that about 14 percent of Canada, or 127.2 million hectares, is covered by wetlands — mostly treeless peatland and marsh (National Wetlands Working Group 1988). Forested wetlands, including peatlands and hardwood swamps, represent 2 percent of the overall economic value of the Canadian national forest industry (National Wetlands Working Group 1988).

The National Wetlands Working Group (1988) indicated the distribution of Canada's wetlands and suggested a wetlands regionalization based on 7 zones and 20 regions.

VII CONCLUSION

Classification and mapping are powerful tools for forested wetlands managers, scientists, and conservationists. They improve our ability to generalize and extrapolate research results, transfer management experience, and track changing land uses (Hirsch *et al.* 1978). Although many approaches to land and natural resources classification in the United States and Canada have evolved, few have specifically targeted forested wetlands. Of those that include forested wetlands at some level in a classification hierarchy, a wide variety of diagnostic characters distinguish them. In this review, classifications have been broadly grouped according to primary diagnostic character(s) used: water chemistry, hydrology, vegetation, soils, and physiography. A category containing holistic, ecologically based classifications is also included.

Classification of land resources generally and forested wetlands in particular has become increasingly complex and sometimes confusing during the past 50 years. This complexity is attributable to several factors. First, fundamentally different approaches to classification have emerged as classifiers have adapted systems to specific objectives and regional variations among landscapes. Within a region, the complexity of identifiable patterns or the extent of ecologically significant natural resource features are reflected by the classification scheme. Second, classification frameworks suitable for multiple management objectives require multifactor classification structures. Classifications based on single diagnostic characters often result in inappropriate units for management. Third, inconsistent use of terms and the melding of colloquial and technical vocabularies challenges full comprehension and interpretation of the various classification schemes. Finally, in the process of drafting classifications for specific areas and management objectives, classifiers have often disregarded the need to incorporate their systems into a broad-scale hierarchical framework. Such a framework bridges terminology and facilitates class definitions and the understanding of ecological relationships within and among types. Coordination to ensure compatibility and consistency among existing classification systems and to minimize redundancy and overlap is needed now more than ever. However, regional approaches to natural resource and forested wetlands classification are well entrenched in their use and, in many cases, impractical to change.

Existing forested wetlands classification schemes have been successful to varying degrees. Ideally, a classification scheme for forested wetlands should have certain qualities. It should meet stated objectives; in fact, objectives often determine the diagnostic criteria. The classification scheme will likely need to be modified if objectives are restated. No single classification approach can serve all purposes (Hirsch *et al*. 1978).

The classification system should also be cost effective and lead to improved understanding and management of the wetland resource. It should utilize existing information and known ecological relationships. Reliance on intensive data collection in the field is neither practical nor affordable over large areas. A multipurpose classification has a greater chance of being cost effective. Connections with other classifications affords the use of prior inventories, experience, and research.

Practicality is a feature of a successful classification system. The classification system must be flexible and translate to real-life applications. It should be based on characteristics that are observable in the field or inferred from easily obtained measurements. Classes must be well-defined and understood by users. Regional or conventional terminology fosters acceptance, but novel terms can be successfully introduced if classification development is coupled with training and marketing techniques. Among users, consistent recognition of types on aerial photographs or in the field is a requirement. If mapping is desired, units suitable for that purpose need to be defined.

State-of-the-art technology and new knowledge should support classifications and their modifications. Remote sensing technology continues to improve in resolution and interpretation of spectral reflectance patterns. Also, new scientific information (e.g., effect of landscape position, ecological relationships, cumulative effects) has an impact on forested wetland evaluation and determination of relative importance. "It would be ideal if the set of forcing functions that determines the character and distribution of each major type of wetland in the United States could be identified, if each component could be ranked according to importance, and if the favorable ranges for each component were known. While much is known about a limited number of representatives of certain wetland types, there is still much to be learned." (Hofstetter 1983).

The classification should mesh with a hierarchical approach. Existing nationally recognized and hierarchical land classifications are available. Consideration of forested wetlands within such a hierarchy shows relationships at different levels of detail and the relationship of forested wetlands to other land types. Classifications may be physiographic for broad areas, yet permit the incorporation of specific parametric data for detailed management classifications. Divisions and criteria on which to base classifications at lower hierarchical levels might vary regionally (e.g., within ecoregions). Classifications should be developed in coordination with other efforts. Classifiers should receive input from all concerned interests and agencies to enable crossover between disciplines and regions.

Mapping facilitates inventory, planning, and management (Austin 1981, Bailey 1980). When transferred to maps, periodic reinventories show changes in land-use patterns over time. Although maps are not intended products of all forested wetlands classifications, they are often constructed to portray the spatial relationships of the broadest classes in a hierarchy or detailed types within areas of limited extent. Individual ecological units should be structured such that homogeneous units are stable over time. Climate, physiography, and physical geography, as they affect plant communities and soils, are the primary criteria for regionalizing ecosystems and placing map boundaries (Driscoll *et al.* 1984).

Functions and values associated with forested wetlands are now known to be more numerous than previously suspected. Forested wetlands managers will need to rely more on multipurpose classifications and maps in the future. For example, a multifactor classification is needed to assist foresters in complying with water quality management standards set forth in forestry Best Management Practices guidelines that govern activities in forested wetlands.

Under the current regulatory environment, the number of classifications and classification approaches for wetland forest management has increased rapidly. Confusion has arisen, partly as a result of varying legislative objectives relevant to forestry, and partly as a result of policy makers, managers, and regulators wading through old and new knowledge and scientific concepts. Recently adopted or proposed state classifications for forested wetlands management are difficult to apply across state boundaries and difficult to link to ecological and scientific studies because they generally result from compromises on typification and the blending of ideas. This is not surprising since a single approach for all situations and types is not practical, nor is it desirable since objectives and management priorities will likely differ from region to region in response to state legislation, environmental concerns, and the natural processes that distinguish forested wetlands. The challenge is to use consistent terminology and emphasize similar diagnostic characteristics over as wide an area as possible. Technical gains from a fresh approach to classification must be balanced with the acceptance and economy gained by using an existing scheme.

Given the present state of affairs and the need for coordinated forested wetlands classification and management, development of a widely applicable forested wetlands classification might proceed as follows. At finer levels in a forested wetlands classification hierarchy, land capability or terrain classification would seem logical approaches to refine site-specific silvicultural prescriptions contained within forestry Best Management Practices (Hassan 1979). Walmsley (1976) noted that at this level silvicultural interpretations in conjunction with forest classifications are commonly of two types, one that addresses features that directly affect timber management (e.g., regeneration methods, type of cut) and another that indicates the effect of timber harvesting activities on soils and other resources (e.g., type of equipment, soil type, soil moisture, landscape position, soil strength parameters). Such interpretations could be developed and specifically adapted to forested wetlands, using existing knowledge and information supplemented with necessary research. Logical products of forested wetlands interpretations are three classes of maps (Moon 1979): (1) engineering (e.g., road-associated problems, suitability for tractor logging); (2) silvicultural (e.g., preferred species composition, productivity classes, brush hazard); and (3) management impact on productivity or other resources (e.g., potential sediment yield, environmental protection areas).

At the next broader hierarchical level, the detailed units identified for forestry BMP recommendations could be incorporated into regional conventions for forested wetlands classification based on major ecological factors (e.g., geology, topography, hydrology, plant dominance-types, hydric soils, stream classification, site types, or functional attributes). Also, geomorphic classification can be introduced at this level of scale (Brinson 1988, Brown 1989). The state of Virginia's BMP guidelines demonstrate that forested wetlands capability or terrain classes can be incorporated into a hierarchy of site types based on water movement and soil type – classes are combined where similar BMPs apply. A strong case has been made for retaining traditional regional systems of forestland classification at this level (Larson and Sclatterer 1984, Rowe 1984).

An equally strong case can be made for linking regional classifications within a broader classification hierarchy. Regional forested wetlands classifications can logically be absorbed within the national wetlands classification (sensu Cowardin *et al*. 1979). This, in turn, can be accommodated within physiographic forest habitat classification (sensu Hodgkins *et al*. 1979) or Bailey's (1983) ecoregions; either would prove useful for aggregating classes at the next highest level. In our "global age," a level linking ecoregions and biomes in the biosphere should not be overlooked!

Ultimately, information about forested wetlands resources, classification schemes, and management objectives can be linked to foster knowledge, interpretation, communication, acceptance of classification schemes, and intelligent use of the resource.

ACKNOWLEDGMENT

The author is indebted to Laura Mansberg for editing this manuscript.

VIII GLOSSARY

Black river bottom – Floodplain of a major water system originating in the southeastern coastal plain (Kellison *et al*. 1988).

Bog – A peat-accumulating wetland (Hochmoor) that has no significant inflows or outflows and supports acidophilic mosses, particularly sphagnum (Gore 1983, Mitsch and Gosselink 1986).

Bottomland – Lowlands along streams and rivers, usually on alluvial floodplains that are periodically flooded. These are often forested and sometimes called bottomland hardwood forests (Mitsch and Gosselink 1986).

Branch bottom – Relatively flat, alluvial land along minor drainage system which is subject to minor overflow (Kellison *et al*. 1988).

Carr – A wooded fen.

Cypress dome – Isolated peaty acid depression, usually found in Florida, which is moist or inundated for weeks or months at a time (Kellison *et al*. 1988).

Cypress strand – Low basin in south Georgia and northern Florida with slowly flowing shallow water during the wet season (Kellison et al. 1988, Mitsch and Gosselink 1986).

Estuarine wetland – Tidal wetland that is usually semienclosed by land but has open, partly obstructed, or sporadic access to the open ocean; the ocean water is at least occasionally diluted by freshwater runoff from the land (Cowardin *et al.* 1979).

Fen – A peat-accumulating wetland (Niedermoor) that receives some drainage from surrounding mineral soil and usually supports marshlike vegetation (Gore 1983, Mitsch and Gosselink 1986).

Flark – Usually an elongated, wet, and muddy depression in patterned peatlands (National Wetlands Working Group 1988).

Floodplain – A flat expanse of land bordering an old river (Cowardin *et al.* 1979).

Forested wetland – A wetland with at least 30% areal coverage by trees (Cowardin *et al.* 1979).

Hammock – Poorly drained flat areas between larger streams underlain by clay and limestone. See Pocosin (Florida Division of Forestry and Florida Forestry Association 1988).

Hummock – Within a wetland, a small elevation or mound with an ice or gravel core and dense vegetation, with irregular or conical shape (National Wetlands Working Group 1988).

Hydric soil – Soil that is wet long enough to periodically produce anaerobic conditions, thereby influencing the growth of plants (Cowardin *et al.* 1979).

Marsh – A type of wetland dominated by grass-like or herbaceous plants (Hofstetter 1983).

Minerotrophic – Refers to wetlands that receive nutrients from mineral groundwater by flow and percolation in addition to precipitation (National Wetlands Working Group 1988).

Mire – European term for any peat-accumulating wetland (Mitsch and Gosselink 1986).

Moor – German and Fennoscandian term for peatland. A highmoor is a raised bog, while a lowmoor is a peatland in a basin or depression that is not elevated above its perimeter (Gore 1983, Mitsch and Gosselink 1986).

Muck swamp – Very poorly drained organic soil area, usually with standing water, in broad expanses between tidewater and upstream runs, along blackwater rivers and branch bottoms, and in sloughs and oxbows of red rivers (Kellison *et al.* 1988).

Muskeg – Large expanses of peatlands or bogs; particularly used in Canada and Alaska (Mitsch and Gosselink 1986).

Oligotrophic – Designation for peatlands formed of plants growing in "soft" waters that are poor to extremely poor in nutrients (National Wetlands Working Group 1988).

Ombrophilous – A term for vegetation growing under ombrotrophic conditions.

Ombrotrophic – Designation for areas entirely dependent on nutrients from precipitation (National Wetlands Working Group 1988).

Palustrine wetland – All nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.05% (Cowardin *et al.* 1979).

Peat swamp – Broad interstream headwater swamps and true pocosins from which blackwater rivers and branch bottoms originate (Kellison *et al.* 1981).

Peatland – A generic term for any wetland that accumulates partially decayed plant matter (Mitsch and Gosselink 1986).

Piedmont bottomland – Floodplain along Piedmont drainage. Stream channels are well defined and floodplains are narrower and better drained than in red river bottoms.

Pocosin – Acid, poorly drained organic or mineral soil areas on broad, flat topographic plateaus on the southeast coastal plain (Gresham 1989).

Red river bottom – Floodplain of a major drainage system originating in the southeast Piedmont or mountains (Kellison *et al.* 1988).

Rheophilous – A term for vegetation growing under conditions of flowing water which has passed through mineral soil (Gore 1983, Mitsch and Gosselink 1986).

Riparian – Designation for land associated with floodplains and streambanks of rivers and streams.

Sclerophyllous – A term for vegetation characterized by internal tissue composed of hard thick-walled cells.

Slough – A swamp or shallow lake system in northern and midwestern United States. Also, a slowly flowing shallow swamp or marsh in southeastern United States (Mitsch and Gosselink 1986).

Streamside management zone (unit) – An area adjacent to the banks of streams and bodies of open water where extra precaution is necessary in carrying out forest practices in order to protect bank edges and water quality (South Carolina Forestry Commission 1988).

Swale – An area of land lower than its surroundings, often lower than the water table, thus retaining water (National Wetlands Working Group 1988).

Swamp – Wetland dominated by trees or shrubs (U.S.). In Europe, a forested fen could be called a swamp. In some areas reed grass-dominated wetlands are also called swamps (Mitsch and Gosselink 1986).

Wet flat – Similar to peat swamps and true pocosins, but better drained than these because of higher elevation (Kellison *et al*. 1981).

Wetland – Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water (see Chapter III: What Is a Wetland?).

IX LITERATURE CITED

Ahti, T. and R.L. Hepburn. 1967. Preliminary studies on woodland caribou range, especially on lichen stands, in Ontario. Ontario Dept. Lands and For., Res. Rep. (Wildlife) No. 74.

Akins, G.J. and Q.C. Jefferson. 1973. Coastal wetlands of Oregon. Oregon Coastal Conservation and Development Commission, Florence, Oregon. 159 pp.

Alabama Forestry Commission. 1988. Water quality management guidelines and best management practices for Alabama wetlands (unpublished draft). Alabama Forestry Commission, Montgomery, AL. 23 pp.

Alexander, R.R. 1985. Major habitat types, community types, and plant communities in the Rocky Mountains. USDA For. Serv., Rocky Mountain Forest and Range Expt. Sta., Fort Collins, CO. Gen. Tech. Rep. RM-123. 105 pp.

Alexander, R.R. 1988. Forest vegetation on national forests in the Rocky Mountain and Intermountain Regions: habitat types and community types. USDA For. Serv., Rocky Mountain Forest and Range Expt. Sta., Fort Collins, CO. Gen. Tech. Rep. RM- 162. 47 pp.

Allard, D.J. 1989. Community classification for Region 8 lands: a first step for maintaining community diversity in a multi- use setting. Unpublished proceedings of the Association of Southeastern Biologists Annual Meeting, April 5-8, 1989. 2 pp.

Anderson, J.R., E.E. Hardy, J.T. Roach and R.E Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Government Printing Office, Wash., DC. U.S. Geol. Survey Prof. Paper 964. 28 pp.

Anderson, R.R. 1969. The use of color infrared photography and thermal imagery in marshland and estuarine studies. NASA Earth Resources Aircraft Program Status Review III:40-1-40-29.

Anderson, R.R., R.G. Brown, and R.D. Rappleye. 1968. Water quality and plant distribution along the upper Patuxent River, Maryland. Chesapeake Science 9:145-156.

Anderson, R.R. and F.J. Wobber. 1973. Wetlands mapping in New Jersey. Photogr. Eng. 39:353-358.

Ash, A.N., C.B. McDonald, E.S. Kane and C.A. Pories. 1983. Natural and modified pocosins: literature synthesis and management options. USDI Fish and Wildl. Serv., Wash., DC. FWS/OBS-83/04.

Austin, M.E. 1981. Land resource regions and major land resource areas of the United States. USDA Soil Conserv. Serv., Wash., DC. Agric. Hdbk. 296 (Rev. Ed.). 156 pp.

Bailey, R.G. 1976. Ecoregions of the United States. USDA For. Serv., Intermountain Region, Ogden, UT. [map].

Bailey, R.G. 1978. Ecoregions of the United States. USDA For. Serv., Intermountain Region, Ogden, UT. 77 pp.

Bailey, R.G. 1980. Description of the ecoregions of the United States. USDA For. Serv. Wash., DC. Misc. Publ. 1319. 77 pp.

Bailey, R.G. 1981. Integrated approaches to classifying land as ecosystems. P. 95-109. IN P. Laban (ed.). Proc. of the Workshop on Land Evaluation and Forestry. International Workshop of the IUFRO/ISSS. November 10-14, 1980, Wageningen, The Netherlands. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 355 pp.

Bailey, R.G. 1983. Delineation of ecosystem regions. Environ. Manage. 7:365-373.

Bailey, R.G. 1984. Integrating ecosystem components. P. 181-188. IN J.G. Bockheim (ed.). Forest Land Classification: Experiences, Problems, Perspectives. Proc. of a Symp. held at the University of Wisconsin at Madison on March 18-20, 1984. Dept. of Soil Science, University of Wisconsin, Madison. 276 pp.

Bailey, R.G. 1988. Ecogeographic analysis: a guide to the ecologic division of land for resource management. USDA For. Serv. Wash., DC. Misc. Publ. 1465. 16 pp.

Bailey, R.G., R.D. Pfister and J.A. Henderson. 1978. Nature of land and resource classification - a review. J. For. 76:650- 655.

Barnes, B.V., K.S. Pregitzer, T.A. Spies and V.H. Spooner. 1982. Ecological forest site classification. J. For. 80:493-498.

Berg, S. 1981. Terrain classification for forestry in the Nordic countries. P. 152-166. IN P. Laban (ed.). Proceedings of the Workshop on Land Evaluation and Forestry. International Workshop of the IUFRO/ISSS. November 10-14, 1980, Wageningen, The Netherlands. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 355 pp.

Boissonneau, A.N. 1981. Canadian initiatives in wetland inventory. P. 109-115. IN A. Champagne (ed.). Proceedings of the Ontario Wetlands Conference. September 18-19, 1981 at Toronto, Ontario. Federation of Ontario Naturalists, Don Mills, Ontario. 193 pp.

Botch, M.S. and V.V. Masing. 1983. Mire ecosystems in the U.S.S.R. P. 95-152. IN A.J.P. Gore (ed.). Ecosystems of the World. Vol. 4B. Mires: Swamp, Bog, Fen and Moor. Elsevier Scientific Publ. Co. Amsterdam, The Netherlands. 479 pp.

Boyce, S.G. and N.D. Cost. 1974. Timber potentials in the wetland hardwoods. P. 131-151. IN M.C. Blount (ed.). Water Resources: Utilization and Conservation in the Environment. Proc. of the Southeast Region Water Resources Symp. held at Fort Valley State College, Fort Valley, GA on February 28- March 1, 1974. 451 pp.

Braun, E.L. 1950. Deciduous Forests of Eastern North America. Collier MacMillan Publ. Co., Inc., New York. 596 pp.

Braun, E.L. 1972. Deciduous Forests of Eastern North America. Hafner, New York. 596 pp.

Braun-Blanquet, J. 1932. Plant Sociology: the Study of Plant Communities. McGraw-Hill, New York. 439 pp.

Brink, A.B.A., J.A. Mabbutt, R. Webster and P.H.T. Beckett. 1965. Report of the working group on land classification and data storage. Military Engrg. Exp. Establ. Rep. No. 940. Christchurch, England. 97 pp.

Brinson, M.M. 1988. Strategies for assessing the cumulative effects of wetland alteration on water quality. Environ. Manage. 12:655-662.

Brinson, M.M., B.L. Swift, R.C. Plantico and J.S. Barclay. 1981. Riparian ecosystems: their ecology and status. USDI Fish and Wildl. Serv., Kearneysville, WV. FWS/OBS-81/17. 155 pp.

Brown, M.T. 1989. Forested wetlands in urbanizing landscapes. P. 19-26. IN D.D. Hook and R. Lea (eds.). Proceedings of the symposium: the Forested Wetlands of the Southern United States. July 12-14, 1988, Orlando, FL. USDA For. Serv., SE For. Expt. Sta., Asheville, NC. Gen. Tech. Rep. SE-50. 168 pp.

Budelsky, C.A. and G.T. Weaver. 1977. Bottomland forest ecosystems and their relation to water quality. P. 43-61. IN G.M. Aubertin (ed.). Proceedings "208" Symposium Non-point Sources of Pollution from Forested Land. October 19-20, 1977 at Carbondale, IL, Dept. of Forestry, Southern Illinois University, Carbondale, IL. 400 pp.

Canada Land Inventory. 1970. Land capability classification for forestry. Dept. Regional Economic Expansion, Ottawa. C.L.I. Rep. 4. 72 pp.

Canada Soil Survey Committee. 1978. The Canadian system of soil classification. Research Branch, Canada Department of Agriculture. Publ. No. 1646. Ottawa, Ontario. 164 pp.

Carmean, W.H. 1975. Forest site quality evaluation in the United States. Adv. Agron. 27:209-269.

Carter, V. and J.H. Burbank. 1978. Wetland classification system for the Tennessee Valley Region. Tennessee Valley Authority, Div. of Forestry, Fisheries, and Wildlife Dept., Norris, TN. Tech. Note No. B24. 36 pp.

Chabreck, R.H. 1972. Vegetation, water and soil characteristics of the Louisiana coastal region. La. Agric. Exp. Stn. Bull. 664. 72 pp.

Chamberlain, E.B., Jr. 1960. Florida waterfowl populations, habitats and management. Florida Game and Freshwater Fish Comm., Tallahassee. Tech. Bull. No. 7. 62 pp.

Chapman, V.J. 1976. Mangrove Vegetation. J. Cramer (publisher). 447 pp.

Chapman, V.J. 1974. Salt Marshes and Salt Deserts of the World. 2nd supplemented edition. J. Cramer (publisher). 392 pp.

Cheshire, H.M. 1982. A physiographic system of forestland classification for North Carolina. M.S. Thesis, Department of Forestry, North Carolina State University, Raleigh, NC. 56 pp.

Christian, C.S. and G.A. Stewart. 1968. Methodology of integrated surveys. P. 233-280. IN Proc. Toulouse Conf. 1964, Aerial Surveys and Integrated Studies. UNESCO, Paris.

Clark, J.R. and J. Benforado (eds.). 1981. Wetlands of Bottomland Hardwood Forests. Proc. of a Workshop on Bottomland Hardwood Forest Wetlands of the Southeastern United States held at Lake Lanier, GA, June 1-5, 1980. Elsevier Scientific Publishing Co., Amsterdam. 401 pp.

Clawson, M. and C.L. Stewart. 1965. Land Use Information. A Critical Survey of U.S. Statistics including Possibilities for Greater Uniformity. The Johns Hopkins Press for Resources for the Future, Inc. Baltimore, MD. 402 pp.

Couillard, L. 1978. Etude de la vegetation de deux tourbieres de l'Ile a Samuel, archipel de Mingan. Memoire de fin d'etudes, Department of Biology, Laval University, Quebec, Quebec. 153 pp.

Couillard, L. and P. Grondin. 1986. La vegetation des milieux humides du Quebec. Les publications du Quebec. Quebec Ministry of Environment. Quebec, Quebec. 400 pp.

Cowardin, L.M. 1978. Wetland classification in the United States. J. For. 76:666-668.

Cowardin, L.M. 1982. Some conceptual and semantic problems in wetland classification and inventory. Wildl. Soc. Bull. 10:57-60.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1976. Interim classification of wetlands and aquatic habitats of the United States. Addendum. IN J.H. Sather (ed.). Proc. of the National Wetland Classification and Inventory Workshop. USDI Fish and Wildl. Serv., Off. of Biol. Serv., Wash., DC. 248 pp. + Addendum (110 pp.).

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. USDI Fish and Wildl. Serv., Wash., DC. FWS/OBS-79/31. 103 pp.

Crum, H.A. 1988. A Focus on Peatlands and Peat Mosses. The University of Michigan Press, Ann Arbor. 306 pp.

Curtis, J.T. 1959. The Vegetation of Wisconsin. University of Wisconsin Press, Madison, WI. 657 pp.

Dachnowski-Stokes, A.P. 1933. Peat deposits in U.S.A. Their characteristic profiles and classification. P. 1-140. IN K.V. Bulow (ed.). Handbuch der Moorkunde 7. Springer-Verlag, Berlin.

Dachnowski-Stokes, A.P. 1941. Peat resources in Alaska. USDA, Wash., DC. Tech. Bull. No. 769. 84 pp.

Damman, A.W.H. 1986. Hydrology, development, and biochemistry of ombrogenous peat bogs with special reference to nutrient relocation in a western Newfoundland bog. Can. J. Bot. 64:384-394.

Dansereau, P. and F. Segadas-vianna. 1952. Ecological study of the peat bogs of eastern North America. I. Structure and evolution of vegetation. Can J. Botany 30:490-520.

Daubenmire, R. 1968. Plant Communities, A Textbook of Plant Synecology. Harper and Row, New York. 300 pp.

Daubenmire, R. and J.B. Daubenmire. 1968. Forest vegetation of Eastern Washington and Northern Idaho. Wash. Agric. Expt. Sta. Tech. Bull. 60. 104 pp.

Davis, C.A. 1907. Peat, essays on its origin, uses, and distribution in Michigan. P. 95-395. IN Report State Board Geological Survey Michigan for 1906.

Dix, R.L. and F.E. Smeins. 1967. The prairie, meadow, and marsh vegetation of Nelson County, North Dakota. Can. J. Botany 45:21-53.

Driscoll, R.S., D.L. Merkel, D.L. Radloff, D.E. Snyder and J.S. Hagihara. 1984. An ecological land classification framework for the United States. USDA For. Serv., Wash., DC. Misc. Publ. 1439. 56 pp.

Du Rietz, G.E. 1949. Huvudenheter och Huvudgranser I Svensk Myrvegetation. Svensk Bot. Tidskr. 43:274-309.

Du Rietz, G.E. 1954. Die Mineralbodenwasserziegergrenze als Grundlage einer naturlichen Zweigliederung der nord- und mitteleuropaischen Moore. Vegetatio 5-6:571-585.

Eleuterius, L.M. 1972. The marshes of Mississippi. Castanea 37:153-168.

Eleuterius, L.M. 1973. The distribution of certain submerged plants in Mississippi Sound and adjacent waters. P. 191-197 IN J.L. Christmas (ed.) Cooperative Gulf of Mexico Estuarine Inventory and Study. Mississippi Gulf Coast Research Laboratory, Ocean Springs, MS.

Environmental Conservation Task Force. Undated. Ecological land survey guidelines for environmental impact analysis. Federal Environmental Assessment Review Off., Lands Directorate, Environment Canada. Ecological Land Classification Series, No. 13. 42 pp.

Eriksson, T., G. Nilsson and G. Skramo. 1978. The inter-nordic project of forest terrain and machines in 1972-1975. Acta Forestalia Fennica, Vol. 164.

Evans, D.L., P.Y. Burns, N.E. Linnartz and C.J. Robinson. 1983. Forest habitat regions of Louisiana. School of Forestry and Wildlife Management, LA. State University Agric. Center, Baton Rouge, LA. Res. Pap. No. 1. 23 pp.

Eyre, F.H. (ed.). 1980. Forest Cover Types of the United States and Canada. Society of American Foresters, Wash., DC. 148 pp.

Federal Interagency Committee for Wetland Delineation. 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S.D.A. Soil Conservation Service, Wash., DC. Cooperative Tech. Publ. 76 pp. plus appendices.

Fenneman, N.M. 1931. Physiography of Western United States. McGraw-Hill Book Co., New York. 534 pp.

Fenneman, N.M. 1938. Physiography of the Eastern United States. McGraw-Hill Book Company, Inc., New York. 691 pp.

Florida Division of Forestry and Florida Forestry Association. 1988. Management guidelines for forested wetlands in Florida. Florida Department of Agriculture and Consumer Services Division of Forestry and Florida Forestry Association, Tallahassee. 46 pp.

FAO. 1984. Land evaluation for forestry. Food and Agriculture Organization of the United Nations, Rome. FAO Forestry Pap. 48. 123 pp.

Foster, D.R. and G.A. King. 1984. Landscape features, vegetation and developmental history of a patterned fen in south-eastern Labrador, Canada. J. Ecol. 72:115-143.

Franklin, J.F. and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA For. Serv., Pacific Northwest For. and Range Expt. Sta., Portland, OR. Gen. Tech. Rep. PNW-8. 417 pp.

Frayer, W.E., L.S. Davis and P.G. Risser. 1978. Uses of land classification. J. For. 76:647-649.

Frayer, W.E., T.J. Monahan, D.C. Bowden and F.A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the conterminous United States, 1950's to 1970's. Dept. of Forest and Wood Sciences, Colorado State University, Fort Collins, CO. 31 pp.

Gauthier, R. 1980. La vegetation des tourbieres et les sphaignes du parc des Laurentides, Quebec. Forest Ecology Laboratory, Laval University. Etudes Ecologiques No. 3. Quebec, Quebec. 634 pp.

Gauthier, R. and M.M. Grandtner. 1975. Etude phytosociologique des tourbieres du Bas Saint-Laurent, Quebec. Naturaliste Canadien 102:109-153.

Gerardin, V., P. Grondin and M. Lebel. 1984. Les tourbieres de la Moyenne-et-Basse-Cote-Nord: description et distribution. Service des inventaires ecologiques, Quebec Ministry of Environment, Inventaire du Capital-Nature Series No. 4. Quebec, Quebec. 155 pp.

Golet, F.C. and J.S. Larson. 1974. Classification of freshwater wetlands in the glaciated northeast. USDI Fish and Wildl. Serv. Resource Publ. 116. 56 pp.

Gore, A.J.P. 1983. Introduction. P. 1-34. IN A.J.P. Gore (ed.). Ecosystems of the World 4A. Mires: Swamp, Bog, Fen and Moor. General Studies. Elsevier Scientific Publ. Co., Amsterdam. 440 pp.

Gosselink, J.G. and R.E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems. P. 63-78. IN R.E. Good, D.F. Whigham and R.L. Simpson (eds.). Freshwater Wetlands: Ecological Processes and Management Potential. Academic Press, New York. 378 pp.

Gray, L.C., O.E. Baker, F.J. Marschner, B.O. Weitz, W.R. Chapline, W. Shepard and R. Zon. 1923. The utilization of our lands for crops, pasture, and forest. USDA, Wash., DC. Agric. Yearbook 1923.

Gresham, C.A. 1989. A literature review of effects of developing pocosins. P. 44-50. IN D.D. Hook and R. Lea (eds.). Proc. of the Symposium: the Forested Wetlands of the Southern United States. July 12-14, 1988, Orlando, FL. USDA For. Serv., SE For. Expt. Sta., Asheville, NC. Gen. Tech. Rep. SE-50. 168 pp.

Grigg, D. 1967. Regions, models, and classes. P. 461-509. IN R.J. Chorley and P. Hagget (eds.). Models in Geography. Methuen and Co., Ltd., London.

Grondin, P. and J. Ouzilleau. 1980. Les tourbieres du sud de la Jamesie. Geographie Physique et Quaternaire 34:267-299.

Haarlaa, R. and R. Asserstahl. 1972. The inter-nordic forest terrain classification project in 1969-1972. Dept. of Logging and Utilization of Forest Products, University of Helsinki, Helsinki. Res. Notes No. 20.

Hassan, A.E. 1979. Research methods applied to terrain classification - planting machine systems. Proc. IUFRO Symposium on Stand Establishment Techniques and Technology. September 3-8, 1979 at Moscow and Riga, USSR. 41 pp.

Heinselman, M.L. 1970. Landscape evaluation, peatland types, and their environment in Lake Agassiz Peatlands Natural Area, Minnesota. Ecol. Monogr. 40:235-261.

Heinselman, M.L. 1963. Forest sites, bog processes and peatland types in the glacial Lake Agassiz region, Minnesota. Ecol. Monogr. 33:327-374.

Hills, G.A. 1960. Regional site research. For. Chron. 36:401-423.

Hirsch, A., C.T. Cushwa, K.W. Flach and W.E. Frayer. 1978. Land classification - where do we go from here? J. For. 76:672-673.

Hodgkins, E.J. 1965. Southeastern forest habitat regions based on physiography. Alabama Agric. Exp. Sta., Auburn University, Auburn, AL. Forestry Dept. Series No. 2. 10 pp.

Hodgkins, E.J., T.K. Cannon and W.F. Miller. 1976. Forest habitat regions from satellite imagery: States of Alabama and Mississippi. Supplement to So. Coop. Series Bull. 210. Alabama Agric. Expt. Sta., Auburn. AL. and Mississippi Forestry Expt. Sta., Mississippi State, MS.

Hodgkins, E.J., M.S. Golden and W.F. Miller. 1979. Forest habitat regions and types on a photomorphic - physiographic basis: a guide to forest site classification. Alabama Agric. Expt. Sta., Auburn University, Auburn, AL. So. Coop. Series No. 210. 64 pp.

Hofstetter, R.H. 1983. Wetlands in the United States. P. 201-244. IN A.J.P. Gore (ed.). Ecosystems of the World 4B. Mires: Swamp, Bog, Fen and Moor. Regional Studies. Elsevier Scientific Publishing Co., Amsterdam. 479 pp.

Hosner, J.F. 1962. The southern bottomland region. P. 296-333. IN J.W. Barrett (ed.). Regional Silviculture of the United States. Ronald Press Co., New York.

Huffman, R.T. and S.W. Forsythe. 1981. Bottomland hardwood forest communities and their relation to anaerobic soil conditions. P. 187-196. IN J.R. Clark and J. Benforado (eds.). Wetlands of Bottomland Hardwood Forests. Proceedings of a Workshop on Bottomland Hardwood Forest Wetlands of the Southeastern United States held at Lake Lanier, GA, June 1-5, 1980. Elsevier Scientific Publ. Co., Amsterdam. 401 pp.

Hunt, C.B. 1967. Physiography of the United States. W. H. Freeman and Co., San Francisco. 480 pp.

Hunt, C.B. 1974. Natural Regions of the United States and Canada. W.H. Freeman and Co., San Francisco. 725 pp.

Isachenko, A.G. 1973. Principles of landscape science and physical-geographic regionalization. Melbourne Univ. Press, Carlton, Victoria, Australia. 311 pp.

Jaques, D. and C. Hamel. 1982. Systeme de classification des terres humides du Quebec. Laboratory for Aquatic Macrophytes Studies, Department of Biological Sciences, University of Quebec at Montreal for the Wildlife Directorate, Quebec Ministry of Recreation, Hunting, and Fishing, Quebec, Quebec. 131 pp.

Jeglum, J.K., A.N. Boissoneau and V.F. Haavisto. 1974. Toward a wetland classification for Ontario. Canadian Forestry Service, Environment Canada. Information Report O-X-215. Sault Ste Marie, Ontario. 54 pp.

Jones, R.K. 1988. Site classification in Ontario: review, evaluation and opportunities for integration with process models. P. 1-27. IN T.M. Williams and C.A. Gresham (eds.). Predicting Consequences of Intensive Forest Harvesting on Long-term Productivity by Site Classification. IAE / BE Project A3, Rep. No. 6. Baruch Forest Science Institute of Clemson University, Georgetown, SC. 180 pp.

Jones, S.M., D.H. Van Lear and S.K. Cox. 1984. A vegetation-landform classification of forest sites within the upper Coastal Plain of South Carolina. Bull. Torrey Bot. Club 111:349-360.

Jurdant, M., J.L. Belair, V. Gerardin and R. Wells. 1979. Ecological land Survey. P. 23-30. IN M.J. Romaine and G.R. Ironside (eds.). Canada's Northlands. Proc. of a Technical Workshop - to develop an Integrated Approach to Base Data Inventories for Canada's Northlands, April 17-19 1974, Toronto, Ontario. Lands Directorate, Environment Canada. Ecological Land Classification Series No. 0. 124 pp.

Kellison, R.C., D.J. Frederick and W.E. Gardner. 1981. A guide for regenerating and managing natural stands of southern hardwoods. North Carolina State University, Raleigh, NC. N.C. Agric. Expt. Sta. Bull. 463. 24 pp.

Kellison, R.C., J.P. Martin, G.D. Hansen and R. Lea. 1988. Regenerating and managing natural stands of bottomland hardwoods. Bottomland Hardwood Management Task Force, Southeast Technical Division, American Pulpwood Association, Inc., Wash., DC. APA 88- A-6. 26 pp.

Ketcheson, D.E. and J.K. Jeglum. 1972. Estimates of black spruce and peatland areas in Ontario. Canadian Forestry Service, Environment Canada, Sault Ste Marie, Ontario. Information Report O-X-172. 29 pp.

Kilian, W. 1981. Site classification systems used in forestry. P. 134-151. IN P. Laban (ed.). Proc. of the Workshop on Land Evaluation and Forestry. International Workshop of the IUFRO/ISSS. November 10-14, 1980, Wageningen, The Netherlands. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 355 pp.

Klingebiel, A.A. and P.H. Montgomery. 1961. Land capability handbook. U.S. Government Printing Off., Wash., DC. USDA Agric. Hdbk. 210. 21 pp.

Klinka, K. 1988. Biogeoclimatic ecosystem classification in British Columbia: the system, relationship to forest productivity, and application. P. 51-71. IN T.M. Williams and C.A. Gresham (eds.). Predicting Consequences of Intensive Forest Harvesting on Long-term Productivity by Site Classification. IAE / BE Project A3, Rep. No. 6. Baruch Forest Science Institute of Clemson University, Georgetown, SC. 180 pp.

Kologiski, R.L. 1977. The phytosociology of the Green Swamp, North Carolina. NC Agric. Exp. Stn. Bull. 250. 101 pp.

Kotar, J. 1986. Soil-habitat type relationships in Michigan and Wisconsin. J. Soil Water Conserv. 41:348-350.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States [map and manual]. Am. Geog. Soc. Spec. Publ. 36. 116 pp.

Kuenzler, E.J. 1974. Mangrove swamp systems. P. 346-371 IN H.T. Odum, B.J. Copeland, and E.A. McMahan (eds.). Coastal Ecological Systems of the United States. Vol. 1. The Conservation Foundation, Washington, D.C.

Kulczynski, S. 1949. Peat bogs of Polesie. Memoires de l'Academie polonais de sciences et lettres, Serie 15. Cracovie, Poland. 356 pp.

Lacate, D.S. 1969. Guidelines for bio-physical land classification. Can. Dept. Fish. Forest., Can. Forest Serv., Publ. No. 1264.

Lacate, D.S. and M.J. Romaine. 1978. Canada's Land Capability Inventory Program. J. For. 76:669-671.

Larson, K.N. and E.F. Schlatterer. 1984. Forest land classification - Forest Service perspective. P. 11-17. IN J.G. Bockheim (ed.). Forest Land Classification: Experiences, Problems, Perspectives. Proc. of a Symp. held at the University of Wisconsin at Madison on March 18-20, 1984. Dept. of Soil Science, University of Wisconsin, Madison. 276 pp.

Lea, R. 1988. Management of Eastern United States bottomland hardwood forests. P. 185-194. IN D.D. Hook [and others] (eds.). The Ecology and Management of Wetlands. Vol. 2: Management, Use and Value of Wetlands. Timber Press, Portland, OR. 394 pp.

Lebel, C. 1986. La vegetation des tourbieres de la region Mistassini-Sainte-Marguerite-Marie, Lac-Saint-Jean, Quebec. M.Sc. Thesis, Faculty of Arts, University of Sherbrooke, Sherbrooke, Quebec. 94 pp.

Leitch, W.G. 1966. Historical and ecological factors in wetland inventory. Trans. North Am. Wildl. Nat. Resour. Conf. 31:88-96.

Lugo, A.E., S. Brown and M.M. Brinson. 1988. Forested wetlands in freshwater and salt-water environments. Limnol. Oceanogr. 33:894- 909.

MacFarlane, I.C. 1958. Guide to a field description of muskeg. National Research Council of Canada. Tech. Memorandum 44. 36 pp.

Mabbut, J.A. 1968. Review of concepts of land classification. P. 11-28. IN G.A. Stewart (ed.) Land Evaluation. MacMillan Company of Melborne, Australia.

Mader, S.F. 1985. Preliminary physiognomic-ecological vegetation classification, vegetation units 1-190, Rodman's Neck, Pelham Bay Park, Bronx, New York. NYC Parks and Recreation Natural Resources Group, New York. 6 pp.

Martin, A.C., N. Hotchkiss, F.M. Uhlr and W.S. Bourn. 1953. Classification of wetlands of the United States. USDI Fish and Wildl. Serv., Spec. Sci. Rep. Wildl. 20. 14 pp.

Mattoon, W.R. 1915. The southern cypress. USDA, Wash., DC. Bull. 272. 74 pp.

McCormack, D.E., R.E. Hartung and K.N. Larson. 1981. Evaluations of forest lands in the United States. P. 167-179. IN P. Laban (ed.). Proc. of the Workshop on Land Evaluation and Forestry. International Workshop of the IUFRO/ISSS. November 10-14, 1980, Wageningen, The Netherlands. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 355 pp.

McCormack, R.J. 1967. Land capability classification for forestry. Canada Land Inventory, Dept. of the Environment, Ottawa. Rep. No. 4, 26 pp.

Mellgren, P.G. 1980. Terrain classification for Canadian forestry. Canadian Pulp and Paper Association, Montreal. 13 pp.

Messina, M.G., S.T. Gower, D.J. Frederick, A. Clark, III and D.R. Phillips. 1983. Biomass, nutrient and energy content of southeastern wetland hardwood forests. School of Forest Resources, North Carolina State University, Raleigh. Hardwood Research Cooperative Series No. 2. 28 pp.

Millar, J.B. 1976. Wetland classification in western Canada: a guide to marshes and shallow open water wetlands in the grasslands and parklands of the Prairie Provinces. Canadian Wildlife Service, Environment Canada, Saskatoon, Saskatchewan. Rep. Series No. 37. 38 pp.

Mitchell, C. 1973. Terrain Evaluation. Longman Group LTD., London. 221 pp.

Mitchell, C. 1979. Terrain evaluation. P. 159-180. IN B. Goodall and A. Kirby (eds.). Resources and Planning. Pergamon Press, New York.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Co., New York. 539 pp.

Monk, C.D. 1966. An ecological study of hardwood swamps in north-central Florida. Ecol. 47:649-654.

Moon, D.E. 1979. A comparison of four levels of soil and ecological mapping in forested watersheds. P. 331-334. IN C.D.A. Rubec (ed.). Applications of Ecological (Biophysical) Land Classification in Canada. Proc. 2nd Mtg. Canada Committee on Ecological (Biophysical) Land Classification, April 4-7, 1978, Victoria, British Columbia. Lands Directorate, Environment Canada. Ecological Land Classification Series No. 7. 396 pp.

Moore, P.D. and D.J. Bellamy. 1974. Peatlands: a guide to marshes and shallow open water wetlands in the grasslands and parklands of the prairie provinces. Springer-Verlag Inc., New York. 221 pp.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, Inc., New York. 547 pp.

Muir, T. 1989. Personal communication. U.S. Environmental Protection Agency, Wash., DC.

Myers, R.K., R. Zahner and S.M. Jones. 1986. Forest habitat regions of South Carolina. Coll. of Forestry and Recreation Resources, Clemson University, Clemson, SC. For. Res. Series No. 42. 31 pp.

National Wetlands Working Group. 1988. Wetlands of Canada. Sustainable Development Branch, Environment Canada, Ottawa, Ontario, and Polyscience Publications Inc., Montreal, Quebec. Ecological Land Classification Series No. 24. 452 pp.

Nelson, J.B. 1986. The natural communities of South Carolina, Initial classification and description. South Carolina Wildl. and Marine Resources Dept., Columbia, SC.

Nilsson, G. and S. Berg. 1979. Terrangtypsschema for skogsvard. Forskningsstiftelsen Skogsarbeten, Ekonomi Report No. 12.

North Carolina Department of Environment, Health, and Natural Resources. 1990. Best management practices for forestry in the wetlands of North Carolina. Raleigh, NC. 28 pp.

North Carolina Division of Forest Resources. 1989. Best management practices for forested wetlands in North Carolina (unpublished draft). Raleigh, NC. 42 pp.

Odum, H.T. 1974. Tropical marine meadows. P. 442-487 IN H.T. Odum, B.J. Copeland, and E.A. McMahan (eds.). Coastal Ecological Systems of the United States. Vol. 1. The Conservation Foundation, Washington, D.C.

Odum, H.T. 1984. Summary: cypress swamps and their regional role. P. 416-444. IN K.C. Ewel and H.T. Odum (eds.). Cypress Swamps. University Presses of Florida, Gainesville. 472 pp.

Odum, H.T., B.J. Copeland and E.A. McMahan (eds.). 1974. Coastal ecological systems of the United States, 4 vols. Conservation Foundation, Wash., DC.

Olson, R.A. 1981. Wetland vegetation, environmental factors, and their interaction in strip mine ponds, stockdams, and natural wetlands. USDA For. Serv., Rocky Mountain Forest and Range Expt. Sta., Fort Collins, CO. Gen. Tech. Rep. RM-85. 19 pp.

Omernik, J.M. 1987. Ecoregions of the United States. U.S. Environmental Protection Agency, Environmental Research Lab., Corvallis, OR. [map].

Oregon Department of Forestry. 1987. Riparian protection. Forest Practices Section, Oregon Department of Forestry, Salem, OR. Forest Practices Notes No. 6. 4 pp.

Osvald, H. 1925. Die Hochmoortypen Europas. Veroff. Geobot. Inst. Eidg. Tech. Hochsch. Stift. 3:707-723.

Pehl, C.E. and R.L. Brim. 1985. Forest habitat regions of Georgia, Landsat IV imagery. The Georgia Agric. Expt. Sta., Coll. of Agric., The University of Georgia. Special Publ. 31. 12 pp.

Penfound, W.T. 1952. Southern swamps and marshes. Bot. Rev. 18:413-446.

Perret, N.G. 1976. Canadian Wildlife Service. P. 131-141. IN J.H. Sather (ed.). Proc. of the National Wetland Classification and Inventory Workshop. USDI Fish and Wildl. Serv., Off. of Biol. Serv., Wash., DC. 248 pp.

Pestrong, R. 1965. The development of drainage patterns on tidal marshes. Stanford Univ. Publ. Geol. Sci. 10:1-87.

Pfister, R.D. 1976. Land capability assessment by habitat types. P. 312-325. IN America's Renewable Resource Potential - 1975: The Turning Point. Proc. 1975 Nat. Conv. Soc. Am. For., Wash., DC. 503 pp.

Pfister, R.D. 1984. Forest habitat classification in the western United States. P. 149-162. IN IUFRO. Site Productivity of Fast Growing Plantations, Vol. 1. Proc. of a Symp. held in Pretoria and Pietermaritzburg, South Africa. IUFRO.

Pfister, R.D. 1988. Site classification and productivity in the western United States. P. 81-91. IN T.M. Williams and C.A. Gresham (eds.). Predicting Consequences of Intensive Forest Harvesting on Long-term Productivity by Site Classification. Baruch Forest Science Institute of Clemson University, Georgetown, SC. IEA/BE Project A3 Rep. No. 6. 180 pp.

Pfister, R.D. and S.F. Arno. 1980. Classifying forest habitat types based on potential climax vegetation. For. Sci. 26:52-70.

Pfister, R.D., B.L. Kovalchik, S.F. Arno and R.C. Presby. 1977. Forest habitat types of Montana. USDA For. Serv. Intermountain Forest and Range Experiment Station, Ogden, UT. 174 pp.

Phillips, R.C. 1974. Temperate grass flats. P. 244-314 IN H.T. Odum, B.J. Copeland, and E.A. McMahan (eds.). Coastal Ecological Systems of the United States. Vol. 2. The Conservation Foundation, Washington, D.C.

Pierpoint, G. 1984. Forest land classification - rationale and overview. P. 6-10. IN J.G. Bockheim (ed.). Forest Land Classification: Experiences, Problems, Perspectives. Proc. of a Symp. held at the University of Wisconsin at Madison on March 18- 20, 1984. Dept. of Soil Science, University of Wisconsin, Madison. 276 pp.

Putkisto, K. 1947. Vanerikoivujen kasaamisisesta II. Tyoajan menekk iin vaikuttavien tekijoiden huomioon ottaminen palkkaperusteissa. Summary: Investigations concerning the logging of veneer birches. Metsateho tied. 28.

Putnam, J.A. 1951. Management of bottomland hardwoods. USDA For. Serv., So. For. Expt. Sta., New Orleans. Occas. Pap. 116. 60 pp.

Putnam, J.A. and H. Bull. 1932. The trees of the bottomlands of the Mississippi River Delta region. USDA For. Serv. So. For. Expt. Sta., New Orleans. Occas. Pap. 27. 207 pp.

Putman, J.A., G.M. Furnival and J.S. McKnight. 1960. Management and inventory of southern hardwoods. Government Printing Office, Wash., DC. USDA Agric. Hdbk. 181. 102 pp.

Radforth, N.W. 1952. Suggested classification of muskeg for the engineer. Engineering Journal 35:1199-1210.

Radforth, N.W. 1969a. Classification of muskeg. P. 31-52. IN I.C. MacFarlane (ed.). Muskeg Engineering Handbook. University of Toronto Press, Toronto, Ontario.

Radforth, N.W. 1969b. Airphoto interpretation of muskeg. P. 53- 77. IN I.C. MacFarlane (ed.). Muskeg Engineering Handbook. University of Toronto Press, Toronto, Ontario.

Rainville, A. 1983. Etude de la vegetation des tourbieres de Natashquan. Memoire de fin d'etudes., Faculty of Forestry and Geodesy, Laval University, Quebec, Quebec. 72 pp.

Raunkiaer, C. 1934. The Life Forms of Plants and Statistical Plant Geography. Clarendon, Oxford. 632 pp.

Redfield, A.C. 1972. Development of a New England salt marsh. Ecol. Monogr. 42:201-237.

Rolston, K.S. 1968. Terrain classification. American Pulpwood Association Tech. Release 68-R-11. 8 pp.

Rowan, A. 1974. A review of classification of terrain and operational systems. TIM/EFC/WP. 1, Geneva. 9 pp.

Rowan, A.A. 1977. Terrain classification. HMSO Forestry Commission, London. Forest Record 114. 22 pp.

Rowe, J.S. 1971. Why classify forest land? For. Chron. 47:144- 148.

Rowe, J.S. 1972. Forest regions of Canada. Can. For. Serv., Ottawa. Publ. 1300. 172 pp.

Rowe, J.S. 1978. Revised working paper on methodology/philosophy of ecological land classification in Canada. P. 23-30. IN C.D.A. Rubec (ed.). Application of Ecological (Biophysical) Land Classification in Canada. Proc. 2nd Mtg. Canada Committee on Ecological (Biophysical) Land Classification, April 4-7, 1978, Victoria, British Columbia. Lands Directorate, Environment Canada. Ecological Land Classification Series No. 7. 396 pp.

Rowe, J.S. 1984. Forestland classification: limitations of the use of vegetation. P. 132-147. IN J.G. Bockheim (ed.). Forest Land Classification: Experiences, Problems, Perspectives. Proc. of a Symp. held at the University of Wisconsin at Madison on March 18-20, 1984. Dept. of Soil Science, University of Wisconsin, Madison. 276 pp.

Samset, I. 1975. The accessibility of forest terrain and its influence on forestry conditions in Norway. The Norwegian Forest Research Institute Rep. 32.1. 92 pp.

Segebaden, G., R. Stromnes and M.I. Winer. 1967. Proposal for international terrain classification. P. 756-764. IN Proc. from XIV IUFRO Congress, Munich.

Shaler, N.S. 1885. Seacoast swamps of the eastern United States. U.S. Geol. Survey, Ann. Rep. 6:353-398.

Shaler, N.S. 1890. Fresh-water morasses of the United States. U.S. Geol. Survey Ann. Rep. 10:261-339.

Shaw, S.P. and C.G. Fredine. 1956. Wetlands of the United States. USDI Fish and Wildl. Serv. Circ. 39. 67 pp.

Sjors, H. 1950. On the relation between vegetation and electrolytes in north Swedish mire waters. Oikos 2:241-258.

Sjors, H. 1961. Surface patterns in boreal peatlands. Endeavour 20:217-224.

Sjors, H. 1963. Bogs and fens on Attawapiskat River, northern Ontario. P. 45-133. IN National Museums of Canada, Ottawa, Ontario. Bull. No. 186

Sjors, H. 1969. Bogs and fens in the Hudson Bay lowlands. Arctic 12:3-19.

Skogsarbeten (Anon.). 1969. Terrangtypsschema for svenskt skogsbruk. Forskningsstiftelsen Skogsarbeten, Redogorelse Report No. 9.

Smalley, G.W. 1979. Classification and evaluation of forest sites on the Southern Cumberland Plateau. USDA For. Serv., So. For. Expt. Sta., New Orleans. Gen. Tech. Rep. SO-23. 59 pp.

Smith, D.W. and N.E. Linnartz. 1980. The southern hardwood region. P. 145-230. IN J.W. Barrett (ed.). Regional Silviculture of the United States. 2nd ed. John Wiley and Sons, New York. 551 pp.

South Carolina Forestry Commission. 1988. Best management practices for South Carolina's forest wetlands. South Carolina Forestry Commission. 20 pp.

Society of American Foresters. 1954. Forest Cover Types of North America. 4th ed. Society of American Foresters, Wash., DC. 67 pp.

Speight, J.G. 1977. Landform pattern description from aerial photographs. Photogrammetria 32:161-182.

Stegman, J.L. 1976. U.S. Fish and Wildlife Service. P. 102-120. IN J.H. Sather (ed.). Proc. of the National Wetland Classification and Inventory Workshop. July 20-23, 1975 at College Park, MD. USDI Fish and Wildl. Serv., Off. of Biol. Serv., Wash., DC. FWS/OBS-76/09. 110 pp.

Stewart, R.E. 1962. Waterfowl populations in the upper Chesapeake Region. U.S. Fish and Wildlife Service, Special Science Rept. Wildl. 65. 208 pp.

Stewart, R.E. and H.A. Kantrud. 1971. Classification of natural ponds and lakes in the Glaciated Prairie Region. U.S. Bur. Sport Fish. Wildl. Resour. Publ. 92. 57 pp.

Stewart, R.E. and H.A. Kantrud. 1972. Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors. IN Hydrology of Prairie Potholes in North Dakota. U.S. Geol. Survey, Wash., DC. Prof. Pap. 585-D. 36 pp.

Stubbs, J. 1973. Atlantic oak-gum-cypress. P. 89-93. IN Silvicultural Systems for the Major Forest Types of the United States. USDA For. Serv., Wash., DC. Agric. Hdbk. 445.

Swank, G.W. 1985. Streamside management units in the Pacific Northwest. P. 435-438. IN Proc. Riparian Ecosystems and their Management, Reconciling Conflicting Uses, April 16-18, 1985, Tucson, AZ.

Szaro, R.C. 1989. Riparian forest and scrubland community types of Arizona and New Mexico. Desert Plants 9:69-138.

Tansey, J. 1989. Unpublished communication. USDA For. Serv. Renewable Resources Evaluation Unit, Asheville, NC.

Tansley, A.G. 1911. Types of British vegetation. Cambridge University Press, Cambridge, UK. 416 pp.

Tarnocai, C. 1970. Classification of peat landforms in Manitoba. Can. Dept. Agric., Res. Sta. Pedol. Unit, Winnipeg, Manitoba. 45 pp.

Tarnocai, C. 1980. Canadian wetland registry. P. 9-39. IN C.D.A. Rubec and F.C. Pollet (eds.). Proc., Workshop on Canadian Wetlands. Lands Directorate, Environment Canada, Ottawa, Ontario. Ecological Land Classification Series No. 12.

The Conservation Foundation. 1988. Protecting America's Wetlands: An Action Agenda. The Final Report of the National Wetlands Policy Forum. The Conservation Foundation, Wash., DC. 69 pp.

Thie, J. and G. Ironside. 1977. Ecological (biophysical) land classification in Canada. Proc. of the 1st meeting, Canada Committee on Ecological (Biophysical) Land Classification May 25-28, 1976, Petawawa, Ontario. Ecological Land Classification Series No. 1. 269 pp.

Thornbury, W.D. 1965. Regional Geomorphology of the United States. John Wiley and Sons, Inc., New York. 609 pp.

Tiner, R.W., Jr. 1984. Wetlands of the United States: Current Status and Recent Trends. USDI Fish and Wildl. Serv., National Wetlands Inventory, Wash., DC. 59 pp.

Tiner, R.W., Jr. 1989. A clarification of the U.S. Fish and Wildlife Service's wetland definition. National Wetlands Newsletter May-June:6-7.

Turner, R.E., S.W. Forsythe and N.J. Craig. 1981. Bottomland hardwood forest land resources of the southeastern United States. P. 13-28. IN J.R. Clark and J. Benforado (eds.). Wetlands of Bottomland Hardwood Forests, Proc. of a Workshop on Bottomland Hardwood Forest Wetlands of the Southeastern United States held at Lake Lanier, Georgia June 1-5, 1980. Elsevier Sci. Publ. Co., New York. Developments in Agricultural and Managed-forest Ecology 11. 401 pp.

Ungar, I.A. 1974. Inland halophytes of the United States. P. 235-305 IN R.J. Reimold and W.H. Queen (eds.). Ecology of Halophytes. Academic Press, New York. 605 pp.

UNESCO. 1973. International classification and mapping of vegetation, Series 6, Ecology and Conservation. UNESCO, Paris. 93 pp.

U.S. Dept. of the Interior. 1976. Existing state and local wetland surveys (1965-1975). II. Narrative. USDI Fish and Wildl. Serv., Wash., DC. 453 pp.

U.S. Forest Service. 1967. National Forest Survey Handbook. USDA For. Serv., Wash., DC.

U.S. Forest Service. 1968. Forest Regions of the United States. U.S. Government Printing Off., Wash., DC. [map].

U.S. Forest Service. 1976. Land system inventory guide. USDA For. Serv., Northern Region, Missoula, MT. RI-76-20. 69 pp.

U.S. Forest Service. 1985. Southeastern forest survey field manual. USDA For. Serv., SE For. Expt. Sta., Asheville, NC.

U.S. Forest Service. 1988. The South's fourth forest: alternatives for the future. USDA For. Serv., Wash., DC. Forest Resource Rep. 24. 512 pp.

U.S. Soil Conservation Service. 1975. Soil Taxonomy. U.S. Government Printing Office, Wash., DC. Agric. Hdbk. 436. 754 pp.

U.S. Soil Conservation Service. 1981. Land resource regions and major land resource areas of the United States. USDA Soil Conserv. Serv., Wash., DC. Agric. Hdbk. 296. 156 pp.

U.S. Soil Conservation Service. 1987. Hydric soils of the United States 1985. USDA Soil Conserv. Serv. in cooperation with the National Technical Committee for Hydric Soils, Wash., DC.

Virginia Department of Forestry. 1988. Forestry best management practices for water quality in Virginia. Richmond, VA. 80 pp.

Walsh, G.E. 1974. Mangroves: a review. P. 51-174 IN R.J. Reimold and W.H. Queen (eds.). Ecology of Halophytes. Academic Press, New York. 605 pp.

Walter, H. and H. Leith. 1966. Klimadiagramm-Weltatlas. Gustav Fischer-Verlag, Jena.

Walmsley, M.E. 1976. Biophysical land classification in British Columbia: the philosophy, techniques, and application. P. 3-26. IN J. Thie and G. Ironside (eds.). Ecological (Biophysical) Land Classification in Canada. Proc. 1st Mtg. Can. Comm. on Ecological (Bio-physical) Land Class. May 25-28, 1976, Petawawa, Ontario. Ecological Land Classification Series No. 1. 269 pp.

Walters, M.A., R.O. Teskey and T.M. Hinckley. 1980. Impact of water level changes on woody riparian and wetland communities. VIII. Pacific Northwest and Rocky Mountains Regions. USDI Fish and Wildl. Serv., Wash., DC. FWS/OBS-78/94. 47 pp.

Washington State Forest Practices Board. 1988. Washington Forest Practices Rules and Regulations. Seatlle, WA. 54 pp.

Weaver, J.E. 1960. Floodplain vegetation of the central Missouri valley and contacts of woodland with prairie. Ecol. Monogr. 30:37- 64.

Wells, E.D. 1981. Peatlands of eastern Newfoundland: distribution, morphology, vegetation, and nutrient status. Can. J. Bot. 59:1978-1997.

Wertz, W.A. and J.F. Arnold. 1973. Land systems inventory. USDA For. Serv., Intermountain Region, Ogden, UT.

Wertz, W.A. and J.F. Arnold. 1975. Land stratification for land use planning. P. 617-629. IN B. Bernier and C.H. Winget (eds.). Forest Soils and Forest Land Management. Les Presses de L'Universite Laval, Quebec.

Wharton, C.H., W.M. Kitchens, E.C. Pendleton and T.W. Sipe. 1982. The ecology of bottomland hardwood swamps of the Southeast: a community profile. USDI Fish and Wildl. Serv., Wash., DC. FWS/OBS- 81/37. 133 pp.

Wharton, C.H., H.T. Odum, K. Ewel, M. Duever, A. Lugo, R. Boyt, J. Bartholomew, E. DeBellevue, S. Brown, M. Brown and L. Duever. 1976. Forested Wetlands of Florida - Their Management and Use. Center for Wetlands, University of Florida, Gainesville. 421 pp.

Whittaker, R.H. 1975. Communities and Ecosystems. 2nd Ed. MacMillan Publ. Co., New York. 385 pp.

Wiken, E.B. and G. Ironside. 1977. The development of ecological (biophysical) land classification in Canada. Landscape Planning 4:273-275.

Williams, T.M., S.M. Jones, R. Zahner and N. Comerford. 1988. Forest site classification in the Southeastern United States. P. 153-163. IN T.M. Williams and C.A. Gresham (eds.). Predicting Consequences of Intensive Forest Harvesting on Long-term Productivity by Site Classification. IAE / BE Project A3, Rep. No. 6. Baruch Forest Science Institute of Clemson University, Georgetown, SC. 180 pp.

Zoltai, S.C. and F.C. Pollett. 1983. Wetlands in Canada: their classification, distribution, and use. P. 245-268. IN A.J.P. Gore (ed.). Ecosystems of the World 4B. Mires: Swamp, Bog, Fen and Moor. Regional Studies. Elsevier Scientific Publ. Co., Amsterdam. 479 pp.

Zoltai, S.C., F.C. Pollet, J.K. Jeglum and G.D. Adams. 1975. Developing a wetland classification for Canada. P. 497-511. IN B. Bernier and C.H. Winget (eds.). Proc., 4th North Am. Forest Soils Conf. Laval University Press, Quebec, Quebec.

Zonneveld, I.S. 1981. The role of single land attributes in forest evaluation. P. 76-94. IN P. Laban (ed.). Proc. of the Workshop on Land Evaluation and Forestry. International Workshop of the IUFRO/ISSS. November 10-14, 1980, Wageningen, The Netherlands. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands. 355 pp.