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Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin: A Working Map and Classification

Dennis A. Albert

The Upper Great Lakes Biodiversity Committee is a group of individuals representing wide interests who have come together to promote cooperation in maintaining and restoring biological diversity on a regional scale. Committee members include people from state and federal agencies, private industries, colleges and universities, Native American groups, and conservation organizations. By exchanging information and coordinating activities, we hope to play a positive role in resource management in Michigan, Wisconsin, and Minnesota.

North Central Forest Experiment Station
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Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin: A Working Map and Classification (Fourth Revision: July 1994)

Dennis A. Albert, Ecologist

Michigan Natural Features Inventory

By request of the Upper Great Lakes Biodiversity Committee

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Contributors and reviewers:
John Almendinger, *Minnesota Department of Natural Resources (DNR), Natural Heritage Program*
Roger C. Anderson, *Ecologist, Illinois State University*
Jeff Asfoor, *Minnesota DNR, Division of Forestry (Planning)*
John Attig, *Glacial Geologist, Wisconsin Geological and Natural History Survey*
Michael Austin, *GIS Mapping, Michigan Natural Features Inventory*
Janet Ball, *Ecological Classification System (ECS) Mapping and Soil Scientist, Hiawatha National Forest*
Burton V. Barnes, *Forest Ecologist, University of Michigan*
Bill Botti, *Silviculturalist, Michigan DNR*
Kim Chapman, *The Nature Conservancy, Minnesota Field Office*
Lee Clayton, *Glacial Geologist, Wisconsin Geological and Natural History Survey*
Patrick Comer, *Ecologist, Michigan Natural Features Inventory*
Carmen Converse, *Minnesota DNR, Natural Heritage Program*
Robert T. Coupland, *Grassland Ecologist, University of Saskatchewan*
Tom Crow, *Project Leader, North Central Forest Experiment Station, USDA Forest Service*
Henk Dahlberg, *Minnesota DNR, Division of Minerals*
Robert Dana, *Minnesota DNR, Natural Heritage Program*
Margaret Davis, *Ecologist, University of Minnesota*

David Diamond, *Coordinator, Texas Heritage Program*
Hannah Dunevitz, *Minnesota DNR, Natural Heritage Program*
Eric Epstein, *Wisconsin DNR, Endangered Resources, Natural Heritage Program*
David Ewert, *Director of Science and Stewardship, Michigan Field Office of The Nature Conservancy*
Don Faber-Langendoen, *Regional Ecologist, The Nature Conservancy*
Clifford Germain, *Wisconsin Natural Areas Program (retired)*
David F. Grigal, *Professor of Soil Science, University of Minnesota*
Dan Hanson, *Minnesota DNR, Division of Forestry (Soils)*
Bryan C. Hargrave, *Minnesota DNR, Division of Forestry (Soils)*
Jay R. Harman, *Climatologist, Michigan State University*
James (Bud) Hart, *Soil Scientist, Michigan State University*
Bonnie Heidel, *Ecologist, North Dakota Heritage Program*
Randy Hoffman, *Wisconsin DNR, Endangered Resources, Natural Heritage Program*
Francis D. Hole, *Soil Scientist, University of Wisconsin*
David Hoppe, *ECS and Soil Scientist, Nicolet National Forest*
George Host, *Forest Ecologist, Natural Resources Research Institute*
James K. Jordan, *ECS and Soil Scientist, Ottawa National Forest*
Lenny Kempf, *ECS and Soil Scientist, Chequamegon National Forest*
Pam Naber Knox, *State Climatologist, Wisconsin Geological and Natural History Survey*
J. D. Lehr, *Minnesota DNR, Division of Minerals*
Teresa Leibfreid, *GIS Mapping, Michigan Natural Features Inventory*
Barbara Leuelling, *ECS and Soil Scientist, Superior National Forest*
Fred Madison, *State Soil Scientist, Wisconsin*
Charamy Marcellus, *Administrative Assistant, Michigan Natural Features Inventory*
Jim Meeker, *Wildlife Biologist, Great Lakes Indian Fish and Wildlife Commission*
David Mickelson, *Glacial Geologist, University of Wisconsin*
Leah D. Minc, *Anthropologist, University of Michigan*
Jon R. Nelson, *Minnesota DNR, Division of Forestry*
Tim Nigh, *Ecologist, Missouri Natural Heritage Inventory*
Dave Ode, *Ecologist, South Dakota Natural Heritage Program*
Lewis F. Ohmann, *Principal Ecologist (retired), North Central Forest Experiment Station*
Garrett Ous, *Clearwater County Land Commissioner, Minnesota*
Eunice A. Padley, *Soils and Landscape Ecologist, Hiawatha National Forest*
Michael Penskar, *Botanist, Michigan Natural Features Inventory*
John Pearson, *Ecologist, Iowa Heritage Program*
Kirt Pregitzer, *Forest Ecologist, Michigan State University*
Mary Rabe, *Zoologist, Michigan Natural Features Inventory*
Robert E. Redman, *Grassland Ecologist, University of Saskatchewan*
Sue Ridge, *Administrative Assistant, Michigan Natural Features Inventory*
Walt Russell, *Ecosystems Team, Eastern Region, USDA Forest Service*
Kurt Rusterholz, *Minnesota DNR, Natural Heritage Program*
Nancy Sather, *Minnesota DNR, Natural Heritage Program*
Lyn Scrimger, *Data Manager, Michigan Natural Features Inventory*
John E. Schwegman, *Ecologist, Illinois Heritage Program*
Barbara Scudder, *U.S. Geological Survey, Madison, Wisconsin*
Dave Shadis, *ECS, Chippewa National Forest*
Terry Sharik, *Forest Ecologist, Michigan Technological University*
Forest Stearns, *Forest Ecologist, North Central Forest Experiment Station*
Philip Stuart, *Forest Ecologist, University of Michigan*
Wayne M. Wendland, *Illinois State Climatologist*
Keith Wendt, *Minnesota DNR, Planning*
Daniel S. Wovcha, *Minnesota DNR, Natural Heritage Program*
James Zandlo, *Climatologist, Minnesota DNR*
Dave Zumeta, *Minnesota DNR, Division of Forestry*

INTRODUCTION

The aim of landscape ecosystem classification and mapping is to distinguish appropriately sized ecosystems—useful and functional land units that differ significantly from one another in abiotic characteristics as well as in their related biotic components. The subdivision of a large area into distinctive landscape ecosystems provides a much-needed framework for integrated resource management and planning; for biological conservation; and for comparsion of differences in composition, occurrence, interactions, and productivity of plants and animals among ecosystems.

This publication provides such a regional landscape ecosystem classification for Michigan, Wisconsin, and Minnesota. Based on differences in climate, bedrock geology, glacial landform, and soils, this classification delineates and describes map units at the Section, Subsection, and Sub-subsection levels that represent areas with distinctive natural conditions affecting species composition and productivity. Macroclimate and physiography were the major components used to distinguish sections and subsections; differences in local physiography and soil were used primarily to delineate sub-subsections. Vegetation was used wherever possible to validate climatic and geomorphological boundaries. Further, by drawing on the expertise of numerous members of the scientific and conservation communities, I have incorporated specific information on rare species distributions, adequacy of existing preserves, and management concerns relative to the ecosystem mapping units delineated. The result is a product that expresses the interactive character of landscape ecosystems and their components of climate, geological parent material, physiography (landform and waterform), soil, plants, and animals that will prove useful for resource management, conservation, and study.

This project is a direct outgrowth of the earlier *Regional Landscape Ecosystems of Michigan* (Albert *et al.* 1986), and the units described here are the equivalent of the terms Region, District, and Subdistrict previously defined in that work. These two ecosystem classifications share a conceptual and methodological approach that can be characterized as **multifactor** and **multilevel** in orientation. A key aspect of the multifactor approach is the delineation of map units based on the evaluation of multiple abiotic factors (including bedrock geology, glacial landform, soils, hydrology, and regional climatic regimes). Because these abiotic factors represent the more constant and enduring features of the natural landscape, the mapping of ecosystems based on abiotic characteristics establishes a relatively stable framework for understanding and managing biological diversity. The three-State map and classification, by identifying significant environmental differences among areas along multiple abiotic dimensions, provides a basis for understanding patterns of species distribution, natural disturbance regimes, and human land use, as well as the natural processes responsible for these patterns.

A second distinguishing feature of the classification approach is the use of a multilevel spatial hierarchy. Following Rowe and Sheard (1981), the landscape is conceived here as a series of ecosystems, large and small, nested within one another in a hierarchy of spatial sizes. A hierarchical classification reflects the degree of relatedness or similarity among adjacent units and allows scientists and managers to move between larger or more local scales by working at higher or lower levels of the classification hierarchy. Because natural processes occur at various levels, from continent-wide to site-specific, ecosystems need to be delineated at a scale (regional or local) that is appropriate to the management intensity.

The three-level classification of Michigan, Wisconsin, and Minnesota is expressly hierarchical in organization. The largest units (sections) delineated here fit within macrolevel units defined by continent-wide classifications; at the other extreme, local delineation of ecosystem types or ecosystem components (such as landform, soil, vegetation, and/or animals) may proceed within the lower hierarchical levels as needed by different users.

Conceptual Approach

Ecosystems are the natural holistic units of the landscape that can be identified and mapped over wide areas or locally (from large regional geographic units such as outwash plains or till plains to small units such as rocky knobs or marsh-filled depressions). Each ecosystem, of whatever size, can be conceptualized as a layered

volumetric segment of the biosphere (Rowe 1984b), consisting of an air layer over a landform or water layer, with organisms sandwiched near the sun-energized interface. The largely invisible climatic and hydrologic dimension, imposed on the various Earth surface substrates, produces the land's ecological mosaics (Rowe and Sheard 1981). The perceived abiotic and biotic components, in dynamic interaction with one another, are illustrated in the diagram below (fig. 1).

Figure 1.—*Diagrammatic illustration of the biotic and abiotic components of the landscape ecosystem. The dynamic interactions among components are not shown. (Courtesy of B.V. Barnes.)*

Ecosystems clearly have a geographic dimension as well. Rowe (1961) stresses this geographic nature in his definition of an ecosystem as: "...a topographic unit, a volume of land and air plus organic contents extended areally over a particular part of the earth's surface for a certain time." It is this spatial component of ecosystems that provides the hierarchical context for the three-State classification developed here:

> "The Ecosphere is the largest system of immediate interest and nested within it, composing it, are the *macro-level* ecosystems that we distinguish as seas and continents. Within the continents, regional *meso-level* ecosystems constitute a lower sub-set of systems, while still lower are local *micro-level* ecosystems such as three-dimensional tracts of forest land" (Rowe 1992).

Within the macrolevel of the North American Continent, the three-State classification is part of the regional mesolevel of landscape ecosystems. Bailey's (1976, 1980; Bailey and Cushwa 1981) categories of Domain, Division, and Province provide the upper hierarchical levels, and the sections, subsections, and sub-subsections presented here provide the lower levels for the three-State geographic area. Below the subsection or sub-subsection levels is the mosaic of microlevel ecosystems—the local three-dimensional tracts of land that natural resource professionals seek to manage and conserve.

Factors in the Hierarchy

In the study, the ecosystem components used to distinguish major landscapes are macroclimate, physiography, soil, and vegetation. Climate and physiography strongly influence the regimes of energy and moisture that affect soil development and largely determine the structure and composition of vegetation and the occurrence of animal communities.

In Michigan, long-term climatic records were a primary component in delineating the larger hierarchical units — sections and subsections. Physiography was used in conjunction with climatic data to refine section and subsection boundaries because of its significant influence on the climatic regime. At the sub-subsection level, the primary determinants of boundaries were physiography (because it controls fluxes of radiation and moisture and thereby strongly determines the pattern of soil, microclimate, and vegetation [Rowe 1984b]) and soil conditions. In Minnesota and Wisconsin, climatic data were not analyzed in detail, but were taken from published climatic studies of the two States and the Midwest.

I must stress, however, that the hierarchy developed for this study is a flexible one based on several abiotic factors rather than a rigid hierarchy. In the complex glaciated landscape of Michigan, Minnesota, and Wisconsin, for a given mapping scale, different factors may be important within adjacent map units. For example, at the subsection level of the hierarchy, differences in landform are typically important, but the presence and type of large bedrock exposures may be equally important elsewhere.

Hierarchical Levels: Section, Subsection, Sub-subsection

The hierarchical levels of the section and subsection are recognized by the USDA Forest Service in

the *National Hierarchical Framework of Ecological Units* (ECOMAP 1993), along with broader mapping units (Domain, Division, and Province) and finer mapping units (Landtype Association, Landtype, and Landtype Phase) (table 1). As can be seen from the general size range presented in table 1, the scales of section, subsection, and landtype association are broadly defined, and may overlap. For example, the scale of tens of square miles of the subsections overlaps with the scale of thousands of acres for the landtype association.

In this study, the sub-subsection has been introduced as an additional hierarchical level where it is necessary to divide a subsection, but where treatment as a landtype association (LTA) is not adequate. For example, Subsection VII.2 in Michigan is a high, sandy plateau, which has been subdivided into Sub-subsection VII.2.1, an area of sandy ridges; Sub-subsection VII.2.2, an area of extensive sand outwash plain, and Sub-subsection VII.2.3, another area of steep, sand ridges. The sub-subsection level is needed here to show the relatedness of the three units as subdivisions of the high, sandy plateau (Subsection VII.2) long-recognized as an important physiographic feature in Michigan (Veatch 1953). Treating all three sub-subsections as unrelated subsections would result in the loss of important ecological information. Nor is treatment as LTA's an appropriate alternative in this case for several reasons. First, the scale of the LTA is generally much smaller than the sizes of these units, usually thousands or hundreds of acres compared with the several thousand square miles encompassed by Sub-sections VII.2.1-VII.2.3. Accordingly, the LTA is defined as a unit for "project and management area planning," **not** "forest or area-wide planning" (table 1) as needed here. Second, the LTA has been used by the Forest Service for mapping individual landforms or groups of repeated landforms, such as drumlins in a drumlin field (but not the adjacent outwash deposits, which would be another LTA), rather than for mapping a **mosaic** of interdigi-

Table 1.—*National Hierarchy of Ecological Units*[1]

Planning and Analysis Scale	Ecological Units	Purpose, Objectives, and General Use	GENERAL SIZE RANGE
Ecoregion Global Continental Regional	Domain Division Province	Broad applicability for modeling and sampling. Strategic planning and assessment. International planning.	Millions to tens of thousands of square miles.
Subregion	Section Subsection	Strategic; multi-forest, statewide and multi-agency analysis and assessment.	Thousands to tens of square miles.
Landscape	Landtype Association	Forest or area-wide planning, and water-shed analysis.	Thousands to hundreds of acres.
Land Unit	Landtype Landtype Phase	Project and management area planning and analysis.	Hundreds to less than 10 acres.

[1]From ECOMAP, USDA Forest Service (1993).

tated landforms, such as **both** the drumlins and surrounding outwash deposits of a drumlin field. In contrast, the sub-subsection level allows for the identification of several "mosaics of similar landforms" within a larger subsection.

The amount of detail included in the three-State map varies geographically, depending on available information. In both Michigan and Wisconsin, prior regional mapping was done to the level of the sub-subsection, and all three hierarchical levels (section, subsection, and sub-subsection) were identified on existing maps. As a result, sub-subsections are typically described here for Michigan and Wisconsin. In contrast, prior work in Minnesota was restricted primarily to section and subsection levels. Accordingly, only a few subsections were divided here into sub-subsections, because information was inadequate or because contributors strongly disagreed on the need for further subdivisions or on the locations of proposed boundaries. However, sub-subsections are now being delineated for the entire State.

Further, because the nature of the landscape of a geographic area dictates the size and number of hierarchical levels, subsections do not always have natural sub-subsection divisions. The landscape must speak for itself; a neat, tidy, completely orthogonal classification with exactly the same number of units and levels in each hierarchy is not possible.

Maps Units as Hypotheses for Testing

The regional ecosystems delineated here are hypotheses developed from ecological theory and knowledge of what is ecologically important to the landscape. By delineating climatic and structural differences in the landscapes of Michigan, Minnesota, and Wisconsin, I hope to identify units that are functionally different in important and useful ways. The units are hypotheses for testing: similar local ecosystems within a given subsection or sub-subsection should respond to natural disturbances and to management in similar ways.

Relationship to Other Approaches and Other Regional Ecosystem Maps

The methodology employed in developing the three-State map and classification is modeled after the multifactor, multilevel integrated field approach to understanding ecosystem structure and function pioneered in the southwestern German state of Baden-Württemberg (Schlenker 1964, Spurr and Barnes 1980, and Barnes 1984). Their approach and regional level classification, in turn, stem from the ideas and publications of G.A. Krauss and R. Gradman, who were noted for their early 20th century contributions in landscape ecology and biogeography. The approach of integrating multiple ecosystem components to generate regional and local ecosystem classifications and maps has been the basis of their integrated resource management for more than 50 years. The integrated ecosystem approach used here is also similar in holistic concept to that of the forest ecosystem region (site region) and total site methods pioneered by Hills (1960) in Ontario. Rowe's (1979) ecological land classification for Canada similarly stresses the integrated approach and four hierarchical levels.

Some of the major ecological maps used in developing this map and classification are discussed below. These maps were used as the starting point for this study, but other publications and data were studied and incorporated, resulting in modifications of the original ecological maps.

Regional Landscape Ecosystems of Michigan

This map and classification developed by Albert, Denton, and Barnes (1986) provided the basis for the Michigan part of this study. Modifications of the initial Michigan map were based on further field work (especially in the wetlands of the State), recent geological and climatic publications, and ongoing ecological classification work on Michigan's National Forests. The Michigan Heritage Program data base provided additional information on rare plant and animal distribution as well as interpretation of the original vegetation of the State. The hierarchical approach developed for Michigan was extended to Minnesota and Wisconsin, where natural division maps did not use a multilevel hierarchical approach.

Natural Division Maps of Minnesota and Wisconsin

The present publication is based partially on modifications of the natural division maps of Minnesota (Kratz and Jensen 1983) and Wiscon-

sin (Hole and Germain 1994). Because the Minnesota map was not hierarchical, it was necessary to determine hierarchial relationships among map units. In addition, some of the new map units were also introduced. Most of the natural divisions that were eliminated will be mapped on more detailed maps of Minnesota. For Wisconsin, I subdivided recognized natural divisions of the State into smaller map units. I further developed the hierarchy in portions of Wisconsin, but have also eliminated some of the smaller mapping units, which were too detailed to include at the scale of the three States.

Bailey's Climatic Ecoregion Map

Bailey's (1976, 1980; Bailey and Cushwa 1981) ecoregions map of North America, a part of which is reproduced in figure 2, delineates large geographic ecosystems at the scale of 1:7,500,000. Bailey's map is based on distinctive climates (following Köppen 1931), potential natural vegetation (after Küchler 1964), and soils (according to the classification of Crowley 1967). Bailey uses a hierarchical classification: *domains* describe subcontinental areas of broad climatic similarity; *divisions* describe subdivisions of the domain that are determined by isolating areas of differing vegetation and regional climates; and *provinces* are broad vegetation regions that have uniform regional climate and the same type or types of zonal soils).

According to Bailey's treatment, all of Minnesota, Wisconsin, and Michigan fall within the Humid Temperate Domain (unit 200 in figure 2). At the next lower hierarchical level, three divisions are represented in the three-State area: the Humid Warm-Summer Continental Division (210) (including the Laurentian Mixed Forest Province (211)); the Humid Hot-Summer Continental Division (220) (including the Eastern Deciduous Forest Province (221)); and the Subhumid Prairie Division (250) (including the Tall-grass Prairie Province (253) and the Aspen Parkland Province (254)).

In my treatment of the three-State area, each of Bailey's provinces is further subdivided into two or more sections, except for Bailey's Aspen Parkland Province, which is treated as a single section. The sections represent a further climatic subdivision of the province. Although each section generally has climatic conditions that differ distinctly from those of adjacent sections, a major change in bedrock, landform, or elevation may be at least partially responsible for the climatic change.

Although Bailey's ecoregion maps were not used to develop this three-State map and classification, the map boundaries of the two studies agree relatively well at the province/section level; and Bailey's corresponding classification units (province, division, and domain) are cited in the descriptions of the sections delineated in this study.[1] A comparison of Bailey's ecoregion map (fig. 2) and the Michigan-Minnesota-Wisconsin landscape ecosystem map demonstrates this close correspondence between the boundaries of the two classifications at the province/section level. Because of the differences in scale, however, a province-level boundary may correspond to the boundaries of more than one section. For example, the southern boundary of Bailey's Laurentian Mixed Forest Province is the southern boundary of Sections VII, VIII, IX and X.

Methods

In Michigan, boundaries of the regional ecosystems were determined from analyses of meteorological data recorded by the National Weather Service network of first order and cooperative weather stations, field surveys, and existing publications of geology, physiography, and soil. In Minnesota and Wisconsin, boundaries were based largely on existing publications on climate, geology, physiography, and soil, and on modified natural division maps of Minnesota (Kratz and Jensen 1983) and Wisconsin (Hole and Germain 1994).

To develop the climatic boundaries in Michigan, daily weather data for 1951 to 1980 were obtained for 125 weather stations (Albert *et al.* 1986, Denton 1985). Analytical methods were chosen to minimize the effect of understated microclimatic and measurement idiosyncracies

[1] *Recent publication of an eco-subregion map by the USDA Forest Service (Bailey* et al. *1994, McNab and Avers 1994), part of an ongoing Forest Service project to delineate subregions throughout the United States, have modified Bailey's province boundaries to correspond to those deliniated in earlier drafts of this publication (Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin). The eco-subregion map and its concept of hierarchy are not widely incorporated into this classification.*

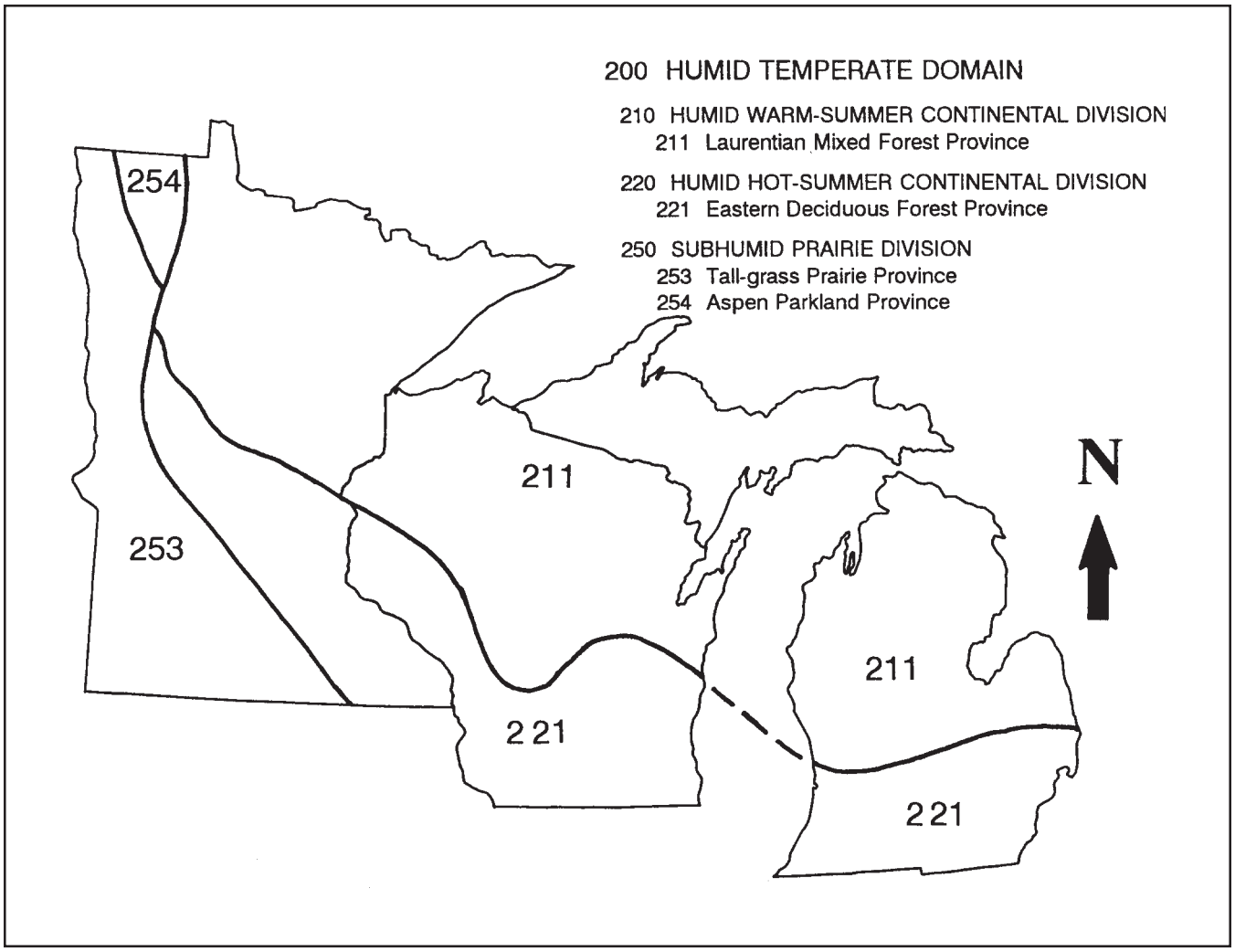


Figure 2.—*A portion of Bailey and Cushwa's (1981) map of ecoregions of North America.*

(Denton 1985; Denton and Barnes 1987, 1988). These data were used to compute a large number of statistics describing weather in Michigan; and principal component analyses were used to summarize most of the statistics into a smaller number that were used as variables in subsequent analytic comparisons of regions, districts, and subdistricts (sections, subsections, and subsubsections). Contour maps were drawn for each major climatic statistic. Cluster analyses were used to classify weather stations into groups with similar climatic patterns. The contour maps, classifications, and major physiographic features in Michigan were used to identify climatically distinctive sections and subsections, and discriminant analyses were used to confirm the final classification. In the present publication, climatic maps from *The Climatic Atlas of Michigan* (Eichenlaub *et al.* 1990) were used to provide climatic statistics of Michigan; more detailed data from Shirley Denton's work (Denton 1985; Denton and Barnes 1987, 1988) are also included where they provide additional insights.

For Minnesota and Wisconsin, climatic data were not analyzed in detail, as in Michigan. Instead, published State (University of Minnesota 1969, 1971, 1973, 1977, 1979, 1980a-c, 1981a,b; Wisconsin Statistical Reporting Service 1967; Wisconsin Agricultural Statistics Service 1987, 1989) and midwestern climatic studies (Müller 1982, Wendland *et al.* 1992, Reinke *et al.* 1993) were examined to compare adjacent map units. Climatic statistics included in this study are growing season length, extreme minimum temperatures, average annual precipitation, and average annual snowfall.

For all three States, information from topographic maps, geological maps and publications, and soil maps and surveys was integrated to provide a preliminary physiographic and soil classification at section and subsection levels. In Michigan, to assess the accuracy and applicability of each map, forest vegetation and soils were sampled, and topographic data and notes on wetland vegetation were recorded. In Minnesota and Wisconsin, no field sampling was conducted. Instead, the presettlement vegetation maps were used to assist in developing and evaluating map boundaries, and scientists and managers from both States were asked to comment on the appropriateness of map boundaries.

Geologic variables of primary importance were bedrock type, landforms, glacial drift thickness, and hydrology. The many geologic references consulted are cited within the text. Also used were maps of bedrock geology, Quaternary geology, and glacial drift thickness.

Soils maps used include national maps of soil Orders, Suborders, and Great Groups (USDA Soil Conservation Service 1967), soil association maps of all three States, and numerous soil surveys from all three States. Information on soil texture, drainage class, topographic-soil relationships, and land use was available from these sources.

Topographic maps (scales 1:250,000; 1:62,500; and 1:24,000) were used to characterize the size and pattern of landforms, slope, and drainage class. The 1:250,000 maps were useful for recognizing topographically distinct areas at the section and subsection levels. The 1:62,500 and 1:24,000 maps were used more extensively to delineate more exact physiographic boundaries at the subsection and sub-subsection levels.

Integration of Climatic and Physiographic Classifications

In Michigan, although separate classifications of climate and physiography were made, an integrated classification and map were planned from the outset. Boundaries of the climatic map units were purposely placed along physiographic boundaries so that a minimum of change would be necessary when the physiographic classification was completed. When both classifications and maps were ready, the differences between them were carefully examined and boundaries were adjusted as necessary. For further discussion of the integration of the climatic and physiographic classifications, see *Regional Landscape Ecosystems of Michigan* (Albert *et al.* 1986).

In Minnesota and Wisconsin, climatic data were not directly used to generate section boundaries; instead, a combination of bedrock features, glacial landform, soils, and the response of vegetation to these abiotic factors was more important for delineating section boundaries, but climatic boundaries proved to be recognizable and important as well. For example, a strong precipitation gradient forms the boundary between Sections IX and X.

Validation

Vegetation played a varying but critical role in validating climatic-physiographic boundaries. In Michigan, pre-European settlement vegetation had not been adequately mapped for large portions of the State; accordingly, this information was not used initially for developing or validating boundaries. In contrast, both Minnesota and Wisconsin have presettlement vegetation maps (Marschner 1974, Finley 1976) that provided useful insights into boundary delineation. The General Land Office (GLO) surveyor's notes are now being interpreted for Michigan by Michigan Natural Features Inventory (Comer *et al.* 1993a, 1993b, 1994, and work in progress) and are the source for the detailed description of presettlement vegetation found within this text.

For further detail on the theory and practice of regional and local ecosystem classification, consult papers by Rowe (1971, 1979, 1984a, 1984b, 1992), Rowe and Sheard (1981), Bailey (1983, 1985), Barnes *et al.* 1982, and Barnes (1986, 1993).

GENERAL SETTING

Climate

The climate of the three States is a product of latitude, position on the North American continent, and position relative to the Great Lakes. On a global scale, the mid-latitudes are areas where southern air masses moving northward from subtropical regions meet northern air masses moving southward from high latitude regions. Movement of these air masses (anticy-

clones or high pressure systems) is deflected toward the east by the Coriolis force, which is caused by rotation of the Earth. The boundary (front) between unlike air masses is characterized by low pressure, unstable atmospheric conditions, waves, and storms (cyclones). The jet stream is a high-altitude feature of this boundary.

The weather of the three States is controlled by three major air masses, the **Continental Polar**, **Maritime Tropical**, and the **Maritime Polar** (Eichenlaub 1979). The Continental Polar air mass, forming over land in the Arctic, brings cold, dry weather in the winter and cool conditions in the summer. The Maritime Tropical, forming over the waters of the Gulf of Mexico to the south, brings warm, moist winter weather and hot, humid summer conditions. The Maritime Polar air mass originates in the northern Pacific Ocean; although it originally carries large amounts of moisture, much of this is lost on the western slope of the Rocky Mountains. The air warms as it descends from the mountains. The Maritime Polar air mass brings mild weather with little precipitation to the Midwest.

The Great Lakes are another major control on climate for Michigan and parts of northern Wisconsin, but much less so for Minnesota. These effects increase the intensity of storms over and adjacent to the lakes during the winter; they also decrease the intensity of storms and increase the stability of air masses over the lakes during the spring and summer. Overall, lacustrine (lake) effects are important regulators of regional and local climate in the three-State area.

Elevation differences and physiographic features in the States are too small to have much influence on the movement of air masses. However, in Michigan, they do influence the degree to which lake effects penetrate the land and the intensity of lake-effect precipitation. Areas where elevation increases rapidly near lakes receive the most lake-effect precipitation.

Climate is responsible for major differences in both soils and vegetation, and climatic differences are the primary basis for separating sections within this study. In Michigan, Wisconsin, and Minnesota, the most distinctive difference in vegetation is between prairie (Sections I and II) and savanna or forest (Sections III through XI). The prairie is partially the product of the dry, cold rain shadow from the Rocky Mountains. This rain shadow becomes weaker to the east, where the impacts of the Maritime Tropical air mass from the Gulf, and to some degree, the arctic Continental Polar air mass begin to outweigh those of the Pacific Maritime Polar air mass.

Latitudinal climatic differences, largely length of growing season and annual input of solar energy, separate Sections II through VI (southern sections with longer growing seasons) from Sections I and VII-XI (northern sections). The far northern parts of Minnesota (Section X) and possibly Wisconsin and Michigan are near the transition to boreal forest, a transition resulting from further reduced growing season and extreme winter temperatures.

Sections I-V, X, and XI, and most of Section IX have more continental climates than Sections VI-VIII, which have climates influenced by the Great Lakes. Areas with continental climates tend to be hotter in the summer and cooler in the winter than areas with a lake-moderate climate. Along the Great Lakes, the air near the coast warms more slowly in the spring and cools more slowly in the fall than in the sections with a continental climate; both native vegetation and human land use reflect this lake-effect climate.

Bedrock Geology

The continental interior of North America, including all of Michigan, Minnesota, and Wisconsin, is known as the *Central Stable Region* or *craton*, an area that was relatively stable during the Paleozoic (Dorr and Eschman 1984). The northern portion of the craton, in the northern United States and parts of Canada, where old Precambrian rocks are now exposed at the surface, is called the *Canadian Shield*. Within the stable craton, there were active areas of uplift where erosion occurred and areas that were sagging down to form local basins (*intracratonic basins*) in which sediments were accumulating. Much of the Great Lakes Region was an intracratonic basin, now called the Michigan basin.

During the Paleozoic, from Cambrian to Pennsyl-

vanian times, the southern portion of the craton, including Michigan, Minnesota, and Wisconsin, was intermittently submerged beneath shallow seas. Marine and near shore sediments, including limestone, dolomite, evaporites, sandstone, and shale, were deposited over Precambrian bedrock. Thus, the major bedrock distinction in the three States is between Proterozoic (Precambrian) igneous and metamorphic bedrock and younger Paleozoic sedimentary bedrock. Mesozoic sedimentary bedrock is very localized in Minnesota. Soils derived from much of the Precambrian crystalline bedrock are generally acidic, resulting in less productive agricultural lands. The soils derived from marine deposits, including shale and marine limestone, dolomite, and evaporites, are typically more calcareous (less acidic), more nutrient- and moisture-rich loams and clays; they are generally the soils most utilized for agriculture.

Physiography

All of Michigan, and much of Minnesota and Wisconsin, were covered by ice during the Wisconsinan Glaciation of the Pleistocene Epoch. Modern physiography and soils are the result of postglacial erosion and soil formation processes acting on glacial deposits. Erosion of bedrock and unconsolidated materials occurred beneath the advancing glacier. The advancing ice scoured the bedrock uplands, producing rounded knobs. Rocks and soil materials were carried on top of and in the glacial ice. They were later redeposited and formed diverse features, including moraines, drumlins, eskers, kames, and outwash plains. Lakes and depressions are now common in the glacial landscape. Many lakes formed when large blocks of ice were surrounded by outwash sands as the glacier melted. When these ice blocks melted, deep depressions, kettles, remained as lakes. Lakes also formed in linear depressions that had been scoured out by the glacier. Swamps and marshes occur where vegetation colonized shallow depressions.

The Driftless Area in southwestern Wisconsin and southeastern Minnesota shows no sign of having ever been glaciated and the “Coteau” in southwestern Minnesota was not glaciated during the Wisconsinan Glaciation. Compared to the more recently glaciated parts of the three States, both of these areas are characterized by much more highly dissected topography and more highly weathered sediments, the result of several hundred thousand years of erosion and weathering.

The land surface of the glaciated portions of the three States is composed of several different glacial landforms, each with characteristic slopes, substrate and soils, and drainage conditions, and as a result of these physical factors, different vegetation. The map units described in this study (sections, subsections, and sub-subsections) are an attempt to subdivide the three States into smaller, more uniform areas for ecological study, inventory, and management. The greatest homogeneity in soil, landform, climate, and biota is found at the sub-subsection level of the classification. However, as in any glaciated area, there can be tremendous variability in landform, soils, and drainage class within even a relatively small area.

Vegetation

The present-day vegetation of Michigan, Minnesota, and Wisconsin is a result of the physical environment, post-Pleistocene species migration patterns (Bernabo and Webb 1977, Davis 1981, Delcourt and Delcourt 1988), and human alteration of lands and plant communities. Many publications describe the presettlement and present vegetation. Nature preserves include representative examples of many characteristic ecosystems and have been listed in this publication for that reason.

Disturbances such as logging, agriculture, drainage, fire, and fire exclusion have significantly altered plant cover and composition. Many shade intolerant, early successional species, such as paper birch, bigtooth and trembling aspens, and black cherry, have greatly increased in relative abundance. Because of the complexity of local disturbances, I have not attempted to present the specific occurrences of early successional species.

USING THE REGIONAL LANDSCAPE ECOSYSTEM MAP

The regional ecosystem map is designed to be widely used for scientific studies, for resource inventories of all kinds on an ecological basis,

and for a broad range of management activities. It is also useful for comparing the distribution of plant and animal species and their productivity among sections, subsections, and sub-subsections.

Natural landscape features, as well as endangered and rare species, can also be located, designated, and compared on this map. Insect and disease pests may be monitored by section, subsection, and sub-subsection; and the incidence and severity of damage can be compiled by these units and related to the climatic variables. The map may also be used as guide for collecting seeds and for correlating the performance of the progeny with the climatic and soil variables of sections, subsections, and sub-subsections. The incidence and severity of acid deposition can be plotted and compared among ecosystems. The areas of old-growth forests or potential old-growth forests can be identified and compared among sections, subsections, and sub-subsections.

The regional framework can be useful even in the management of local ecosystems. Local tracts exist within and are directly influenced by the ecological conditions (especially climate) of the subsection or sub-subsection in which they occur. Thus, the regional framework is indispensable in planning for the allocation of local ecosystems and can be critical in resolving issues such as old growth and prescribed burning. The sub-subsection (or subsection) units, with their relatively homogeneous macroclimate, provide the framework for further subdivision into local ecosystem units characterized by local landform, microclimate, soil, and vegetation. The marked physiographic and soil differences within each subsection or sub-subsection are discussed in the descriptions below. Such differences (for example, wetlands vs. uplands and clay lake plain vs. sandy lake plain) are the bases for determining local ecosystems at a level desired by the user.

Finally, I want to remind users that the original title for this publication included the word ***draft*** to emphasize that this was a first attempt at regionalizing the three-State area and that boundaries would be changing as new information became available. After the fourth revision, I decided that the term *draft* did not convey the level of research, evaluation, and input from resource professionals that have gone into this publication. The title was changed to **Regional Landscape Ecosystems of Michigan, Minnesota, and Wisconsin: A Working Map and Classification (Fourth Revision: July 1994)**. I hope the original understanding—that this is a working map and classification that may undergo modification—will remain clear to users.

GUIDE TO DESCRIPTIONS

For each map unit, including sections, subsections, and sub-subsections, descriptions are provided under the following headings: **DISCUSSION, ELEVATION, AREA, STATES, CLIMATE, BEDROCK GEOLOGY, LANDFORMS, LAKES AND STREAMS, SOILS, PRESETTLEMENT VEGETATION, NATURAL DISTURBANCE, PRESENT VEGETATION AND LAND USE, RARE PLANT COMMUNITIES, RARE PLANTS, RARE ANIMALS, NATURAL AREAS, PUBLIC LAND MANAGERS, CONSERVATION CONCERNS,** and **BOUNDARIES**. A brief explanation of the information included under each of these headings follows:

DISCUSSION: The DISCUSSION section provides a brief, general overview of the map unit, concentrating on the most distinctive characteristics of the map unit. In some cases, no DISCUSSION section is provided.

ELEVATION: The elevation is provided in both feet and meters, and is based on 1:24,000 topographic maps in most cases. Elevation can be an important factor for understanding biotic distribution. Elevation can be used to contrast adjacent map units. For example, a sub-subdistrict of lake plain will generally be very flat and poorly drained. A sub-subdistrict of end moraine will have steeper, more irregular topography, characterized by better drainage conditions.

AREA: Area is listed in acres and hectares.

STATES: The states in which the section, subsection, or sub-subsection occurs are listed here.

CLIMATE: Several climatic variables are described, including average annual precipitation, average annual snowfall, average growing season length, and extreme minimum temperature. Other climatic factors may be discussed in certain sections, subsections, or sub-subsections. The influence of specific climatic factors on the biota and land management may also be discussed when appropriate.

BEDROCK GEOLOGY: Predominant or common bedrock types are described, emphasizing the bedrock types closest to the surface. If bedrock is not exposed within the map unit, the depth of overlying glacial deposits is provided, where known. Important mineral deposits of economic importance are mentioned. The detail of bedrock maps differs greatly across the three States; this is reflected in map-unit descriptions.

LANDFORMS: Most of the landforms occurring in Michigan, Minnesota, and Wisconsin are glacial landforms. The major landforms are described, with some discussion of the size of the landform features, as well as the spatial relationship of neighboring landforms.

LAKES AND STREAMS: The number, size, and types of lakes and streams are described. Water chemistry and substrate are also discussed where appropriate. Consistently presented data bases for lakes and streams do not exist for all three states, but such data bases are being developed, and may soon allow for more consistent and detailed descriptions of both.

SOILS: Soils descriptions can include parent material, soil texture, slope class, and drainage class. Factors important for understanding forested landscapes often differ from those used for describing agricultural soils. Characteristic soil orders are listed for each mapping unit.

PRESETTLEMENT VEGETATION: Comments on the presettlement vegetation are based on maps by Marschner (1974) in Minnesota, Finley (1976) in Wisconsin, several published studies describing portions of Michigan, and an ongoing statewide mapping project in Michigan. Presettlement mapping provides a brief view of the vegetation at the time of the original land surveys, before intensive logging, farming, industrial development, and settlement in the 19th century by immigrants from outside of North America. Published maps, used for the descriptions of Minnesota and Wisconsin, provide generalized descriptions of the dominant vegetation, including wetlands, forests, and grasslands. The surveyors' notes, used for many of the Michigan descriptions, provide more detailed information on species composition of forests and natural disturbances.

NATURAL DISTURBANCE: The common natural disturbances that occur across the three-State area are listed and discussed. Many of these

were mentioned and mapped by the first land surveyors. Some of the more common disturbances referenced by the surveyors were forest fires, windthrown forests, flooding caused by beaver dams, and alterations of wetlands caused by fluctuations of Great Lakes water levels. Land use by Native Americans, including game management, foot trails, villages, and farming, were also mapped by the first land surveyors. Other natural disturbances that are critical for maintaining the natural biota of ecosystems were not mentioned by the land surveyors, but have been subsequently documented by researchers. Examples of these include widespread disturbance and modification of prairie soils by mammals, such as bison and prairie dogs, and insects, such as ants. Such disturbances are also discussed in this section.

PRESENT VEGETATION AND LAND USE: The full range of vegetation conditions and land uses will be discussed in this section, but not in great detail; obviously there are many more detailed studies of both present vegetation and land use available to the reader. Present vegetation includes natural vegetation, both in relatively intact and highly modified condition, and agricultural and plantation lands.

RARE PLANT COMMUNITIES: This section lists, and in some cases, discusses plant communities that are considered rare, based on scientific literature and the data bases of the Heritage Programs.

RARE PLANTS: This section contains both the common and scientific names of rare plants listed by the Heritage Programs of all three States. Included within this list are species listed as threatened and endangered by the State and Federal Governments, and as special concern by the states. The status of each of these species is periodically reviewed and revised on the basis of available scientific data.

RARE ANIMALS: This section contains both the common and scientific names of rare animals listed by the Heritage Programs of all three States. Included within this list are species listed as threatened and endangered by the State and Federal Governments, and as special concern by the States. The status of each of these species is periodically reviewed and revised on the basis of available scientific data.

NATURAL AREAS: These lists include both privately and publicly owned natural areas. All three States name and track their natural areas differently. County- and township-owned natural areas are more thoroughly tracked in Minnesota and Wisconsin than in Michigan.

PUBLIC LAND MANAGERS: Public lands are important areas for natural resource management. In this section, major public land ownerships are listed for each mapping unit. This section is based on information from published maps, Heritage Programs, and government agencies.

CONSERVATION CONCERNS: Concerns are based on comments from staff of Heritage Programs, conservation groups, university staff, and government agencies. The lists of concerns are often incomplete and may focus on the concerns of a single agency or organization. This document does not attempt to resolve these concerns.

BOUNDARIES: Boundary interpretations and questions are referenced or discussed here. Alternative interpretations of boundaries typically occur in areas where there has been earlier classification by government agencies. Different interpretations are often the result of mapping and classifying at different scales, especially when previous work has been done at a more local scale or only on lands under a single ownership. It is assumed that further studies may be required to resolve some of the boundary questions discussed here. Different boundaries will often result from studies either based on different data or conducted for different management purposes.

Figures 3 to 6

Figure 3.—*Regional Landscape Ecosystems of Minnesota.*

SECTION I. NORTHWESTERN MINNESOTA GRASSLAND (RED RIVER VALLEY)

SECTION II. SOUTHWESTERN MINNESOTA GRASSLAND
- SUBSECTION II.1. Upper Minnesota River Country
- SUBSECTION II.2. Coteau des Prairies
  - SUB-SUBSECTION II.2.1. Inner Coteau des Prairies
  - SUB-SUBSECTION II.2.2. Lake Benton-Adrian Coteau
  - SUB-SUBSECTION II.2.3. Ivanhoe-Worthington Coteau

SECTION III. SOUTHEASTERN MINNESOTA AND WEST-CENTRAL WISCONSIN SAVANNA
- SUBSECTION III.1. Hardwood Hills
  - SUB-SUBSECTION III.1.1. Leaf Hills
  - SUB-SUBSECTION III.1.2. Blue Hills
- SUBSECTION III.2. Big Woods
- SUBSECTION III.3. Anoka Sand Plain
- SUBSECTION III.4. Southern Oak Plains

SECTION IV. DRIFTLESS AREA
- SUBSECTION IV.1 Prairie du Chiens
- SUBSECTION IV.3. Maple-Basswood Forested River Ravines
  - SUB-SUBSECTION IV.3.3. Mississippi River Ravines

SECTION IX. NORTHERN CONTINENTAL MINNESOTA, WISCONSIN, AND MINNESOTA
- SUBSECTION IX.8. Lake Superior Lake Plain

SECTION X. NORTHERN MINNESOTA
- SUBSECTION X.1. Bayfield Barrens
- SUBSECTION X.2. Mille Lacs Uplands
- SUBSECTION X.3. Laurentian Highlands
- SUBSECTION X.4. Tamarack Lowlands
- SUBSECTION X.5. Pine Moraines and Outwash Plains
  - SUB-SUBSECTION X.5.1. Itasca, Alexandria, and St. Croix Moraines
  - SUB-SUBSECTION X.5.2. Park Rapids-Staples and Crow Wing Outwash Plains
- SUBSECTION X.6. Chippewa Plains
  - SUB-SUBSECTION X.6.1. Black Duck Till Plain
  - SUB-SUBSECTION X.6.2. Bemidji and Bagley Outwash Plains
- SUBSECTION X.7. St. Louis Moraines
- SUBSECTION X.8. Nashwauk Uplands
- SUBSECTION X.9. North Shore (Lake Superior) Highlands
- SUBSECTION X.10. Border Lakes
- SUBSECTION X.11. Littlefork-Vermilion Uplands
- SUBSECTION X.12. Agassiz Lowlands

SECTION XI. ASPEN PARKLAND

Figure 4.—*Regional Landscape Ecosystems of Wisconsin.*

SECTION III. SOUTHEASTERN MINNESOTA AND WEST-CENTRAL WISCONSIN SAVANNA
- SUBSECTION III.4. Southern Oak Plains

SECTION IV. DRIFTLESS AREA
- SUBSECTION IV.1 Prairie du Chiens
- SUBSECTION IV.2. Eau Claire
- SUBSECTION IV.3. Maple-Basswood Forested River Ravines
  - SUB-SUBSECTION IV.3.1. Kickapoo-Wisconsin River Ravines
  - SUB-SUBSECTION IV.3.2. Chippewa River Ravines

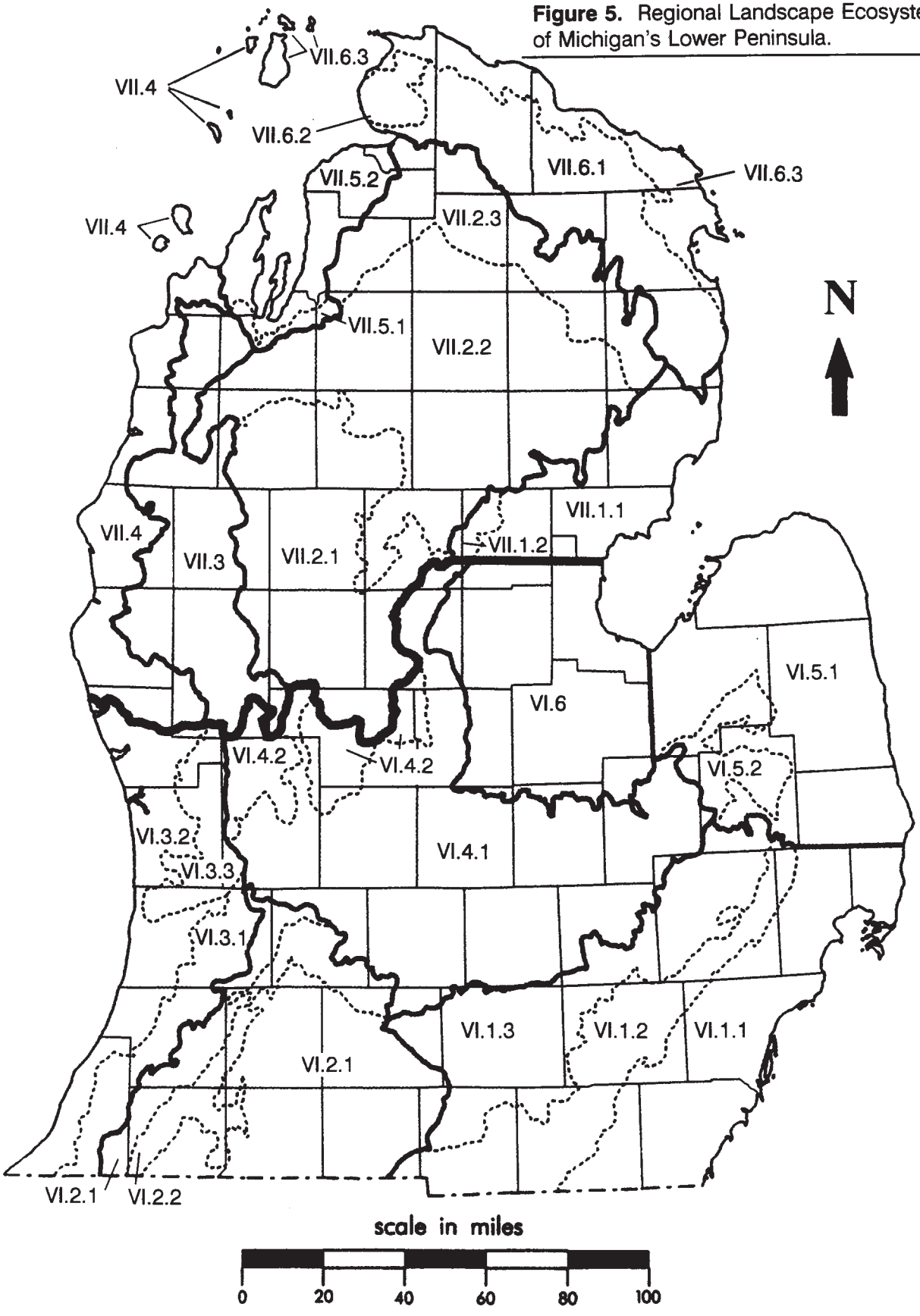
SECTION V. SOUTHEASTERN WISCONSIN SAVANNA
- SUBSECTION V.1. Central Wisconsin Sand Plain
  - SUB-SUBSECTION V.1.1. Black River Falls
  - SUB-SUBSECTION V.1.2. Camp Douglas
  - SUB-SUBSECTION V.1.3. Stevens Point
  - SUB-SUBSECTION V.1.4. Waupaca
- SUBSECTION V.2. Southeastern Wisconsin Till Plain
  - SUB-SUBSECTION V.2.1. Milwaukee
  - SUB-SUBSECTION V.2.2. Madison
  - SUB-SUBSECTION V.2.3. Galena-Platteville
  - SUB-SUBSECTION V.2.4. Kettle Moraine
- SUBSECTION V.3. Lake Winnebago Clay Plain
- SUBSECTION V.4. Rock River Hill Country

SECTION VIII. NORTHERN LACUSTRINE-INFLUENCED UPPER MICHIGAN AND WISCONSIN
- SUBSECTION VIII.1. Niagaran Escarpment and Lake Plain
  - SUB-SUBSECTION VIII.1.3. Escanaba/Door Peninsula
  - SUB-SUBSECTION VIII.1.4. Green Bay Till Plain and Lake Plain
- SUBSECTION VIII.3. Dickinson
  - SUB-SUBSECTION VIII.3.1. Northern Lake Michigan (Hermanville) Till Plain

SECTION IX. NORTHERN CONTINENTAL MICHIGAN, WISCONSIN, AND MINNESOTA
- SUBSECTION IX.1. Spread Eagle-Dunbar Barrens
- SUBSECTION IX.3. Upper Wisconsin/Michigan Moraines
  - SUB-SUBSECTION IX.3.1. Brule and Paint Rivers
  - SUB-SUBSECTION IX.3.2. Winegar Moraine
  - SUB-SUBSECTION IX.3.3. Central Wisconsin Loess Plains
  - SUB-SUBSECTION IX.3.4. Chippewa-Green Bay Lobes
- SUBSECTION IX.4. Lincoln Formation Till Plain
  - SUB-SUBSECTION IX.4.1. Marshfield
  - SUB-SUBSECTION IX.4.2. Rib Mountain
  - SUB-SUBSECTION IX.4.3. Neillsville Sandstone Plateau
- SUBSECTION IX.5. Lac Veaux Desert Outwash Plain
- SUBSECTION IX.6. Bergland
  - SUB-SUBSECTION IX.6.1. Gogebic-Penokee Iron Range
- SUBSECTION IX.8. Lake Superior Lake Plain

SECTION X. NORTHERN MINNESOTA
- SUBSECTION X.1. Bayfield Barrens
- SUBSECTION X.2. Mille Lacs Uplands

Figure 5. Regional Landscape Ecosystems of Michigan's Lower Peninsula.



Scale 1 : 2,000,000

Figure 5.—*Landscape Ecosystems of Michigan's Lower Peninsula.*

SECTION VI. SOUTHERN LOWER MICHIGAN
- SUBSECTION VI.1. Washtenaw
  - SUB-SUBSECTION VI.1.1. Maumee Lake Plain
  - SUB-SUBSECTION VI.1.2. Ann Arbor Moraines
  - SUB-SUBSECTION VI.1.3. Jackson Interlobate
- SUBSECTION VI.2. Kalamazoo Interlobate
  - SUB-SUBSECTION VI.2.1. Battle Creek Outwash Plain
  - SUB-SUBSECTION VI.2.2. Cassopolis Ice-Contact Ridges
- SUBSECTION VI.3. Allegan
  - SUB-SUBSECTION VI.3.1. Berrien Springs
  - SUB-SUBSECTION VI.3.2. Southern Lake Michigan Lake Plain
  - SUB-SUBSECTION VI.3.3. Jamestown
- SUBSECTION VI.4. Ionia
  - SUB-SUBSECTION VI.4.1. Lansing
  - SUB-SUBSECTION VI.4.2. Greenville
- SUBSECTION VI.5. Huron
  - SUB-SUBSECTION VI.5.1. Sandusky Lake Plain
  - SUB-SUBSECTION VI.5.2. Lum Interlobate
- SUBSECTION VI.6. Saginaw Bay Lake Plain

SECTION VII. NORTHERN LACUSTRINE-INFLUENCED LOWER MICHIGAN
- SUBSECTION VII.1. Arenac
  - SUB-SUBSECTION VII.1.1. Standish
  - SUB-SUBSECTION VII.1.2. Wiggins Lake
- SUBSECTION VII.2. Highplains
  - SUB-SUBSECTION VII.2.1. Cadillac
  - SUB-SUBSECTION VII.2.2. Grayling Outwash Plain
  - SUB-SUBSECTION VII.2.3. Vanderbilt Moraines
- SUBSECTION VII.3. Newaygo Outwash Plain
- SUBSECTION VII.4. Manistee
- SUBSECTION VII.5. Leelanau and Grand Traverse Peninsula
  - SUB-SUBSECTION VII.5.1. Williamsburg
  - SUB-SUBSECTION VII.5.2. Traverse City
- SUBSECTION VII.6. Presque Isle
  - SUB-SUBSECTION VII.6.1. Onaway
  - SUB-SUBSECTION VII.6.2. Stutsmanville
  - SUB-SUBSECTION VII.6.3. Cheboygan

Figure 6. Regional Landscape Ecosystems of Michigan's Upper Peninsula.

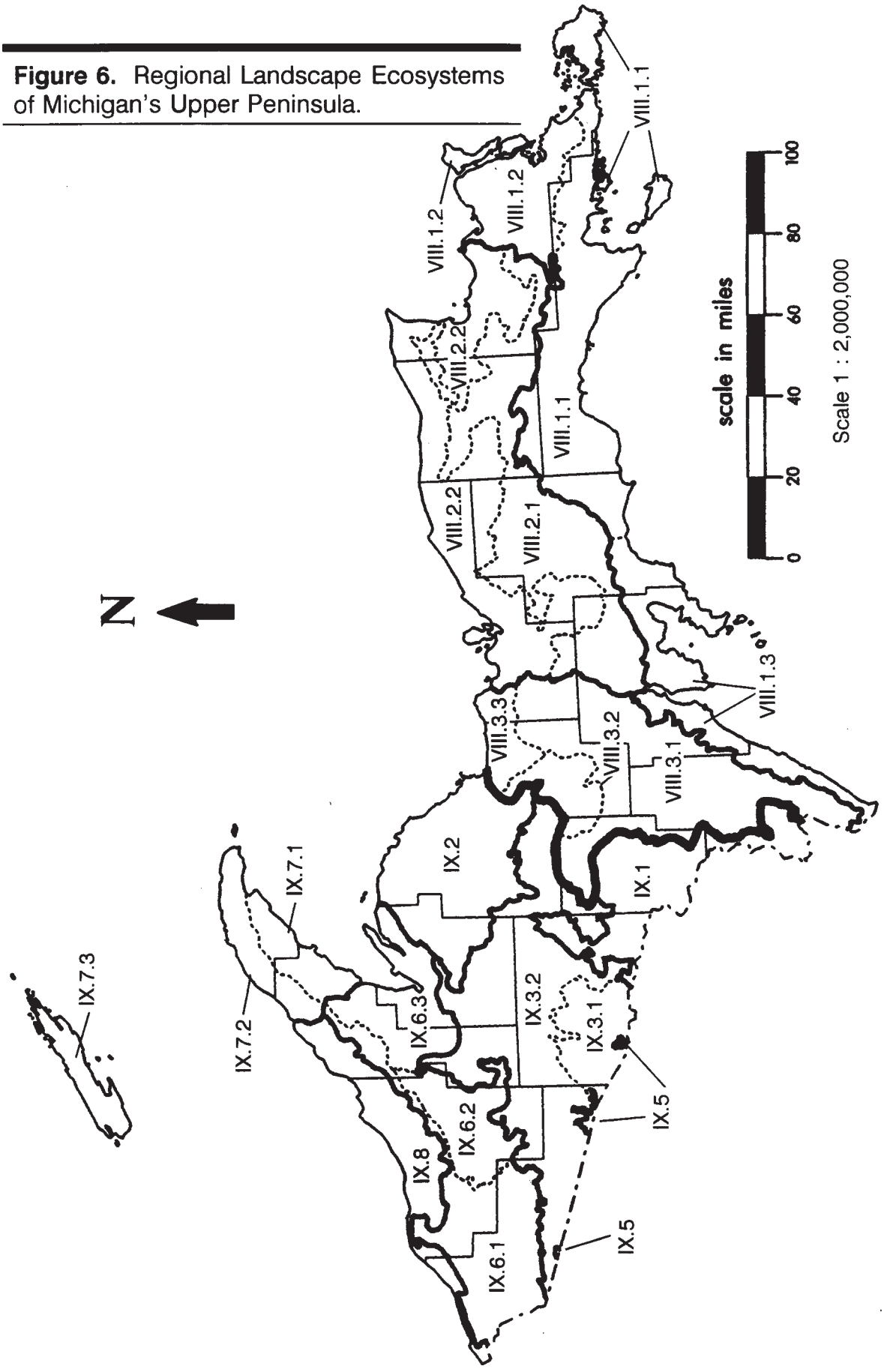


Figure 6.—*Landscape Ecosystems of Michigan's Upper Peninsula.*

SECTION VIII. NORTHERN LACUSTRINE-INFLUENCED UPPER MICHIGAN AND WISCONSIN
- SUBSECTION VIII.1. Niagaran Escarpment and Lake Plain
  - SUB-SUBSECTION VIII.1.1. St. Ignace
  - SUB-SUBSECTION VIII.1.2. Rudyard
  - SUB-SUBSECTION VIII.1.3. Escanaba/Door Peninsula
- SUBSECTION VIII.2. Luce
  - SUB-SUBSECTION VIII.2.1. Seney Sand Lake Plain
  - SUB-SUBSECTION VIII.2.2. Grand Marais Sandy End Moraine and Outwash
- SUBSECTION VIII.3. Dickinson
  - SUB-SUBSECTION VIII.3.1. Northern Lake Michigan (Hermanville) Till Plain
  - SUB-SUBSECTION VIII.3.2. Gwinn
  - SUB-SUBSECTION VIII.3.3. Deerton

SECTION IX. NORTHERN CONTINENTAL MICHIGAN, WISCONSIN, AND MINNESOTA
- SUBSECTION IX.1. Spread Eagle-Dunbar Barrens
- SUBSECTION IX.2. Michigamme Highland
- SUBSECTION IX.3. Upper Wisconsin/Michigan Moraines
  - SUB-SUBSECTION IX.3.1. Brule and Paint Rivers
  - SUB-SUBSECTION IX.3.2. Winegar Moraine
- SUBSECTION IX.5. Lac Veaux Desert Outwash Plain
- SUBSECTION IX.6. Bergland
  - SUB-SUBSECTION IX.6.1. Gogebic-Penokee Iron Range
  - SUB-SUBSECTION IX.6.2. Ewen
  - SUB-SUBSECTION IX.6.3. Baraga
- SUBSECTION IX.7. Keweenaw
  - SUB-SUBSECTION IX.7.1. Gay
  - SUB-SUBSECTION IX.7.2. Calumet
  - SUB-SUBSECTION IX.7.3. Isle Royale
- SUBSECTION IX.8. Lake Superior Lake Plain

SECTION I. NORTHWESTERN MINNESOTA GRASSLAND **(Red River Valley); part of Bailey and Cushwa's (1981) Humid Temperate Domain, Subhumid Prairie Division, Tall-grass Prairie Province; southern Glacial Lake Agassiz and Erskine ground moraine; tallgrass prairie.**

DISCUSSION: Section I, once dominated by tallgrass prairie, is concentrated in western Minnesota, but continues into adjacent North Dakota and South Dakota. Like other prairie areas of the U.S., this section is characterized by geomorphic features of low relief, which allow the spread of fires over long distances (Rumney 1968, Gleason 1913). The fertile soils of the section have been intensively farmed mostly for grains, potatoes, and sugar beets, almost completely eliminating the original prairie vegetation.

Section I has no subsections.

ELEVATION: 825 to 1,150 feet (252 to 351 m).

AREA: 7,096 square miles (18,378 sq km).

STATES: Minnesota.

CLIMATE: Continental, with great differences between winter and summer temperature. The section is strongly influenced by the Maritime Polar (dry, mild) air mass, but is also influenced by Maritime Tropical (moist, warm) and Continental Polar (dry, cold) air masses. Polar air masses have more regular impact upon this section than does the Gulf air mass (Critchfield 1974).

Growing season ranges from 111 days in the north to 151 days in the south. Annual snowfall averages 40 inches; total precipitation ranges from 20 to 23 inches, with roughly 40 percent occurring during the growing season (Wendland *et al.* 1992, Hargrave 1992). Although the total precipitation is not significantly less than that in parts of the forested sections to the east, the timing of precipitation is probably an important influence on the vegetation; only 11 percent of the annual precipitation arrives during November through February (based on Wendland *et al.* 1992). In contrast, savanna-dominated Section III receives 16 to 23 percent of its precipitation in this same period, and conifer-dominated Section X receives 14 to 29 percent. The combination of low levels of winter precipitation and strong desiccating winds increases the potential for spring fires. Drought conditions also occur relatively often during the growing season (Weaver 1954, Weaver and Albertson 1956). Tree growth is limited under these climatic conditions.

BEDROCK GEOLOGY: Bedrock of the entire section is overlain by 200 to 400 feet of glacial drift (Olsen and Mossler 1982). Glacial drift in the eastern part is underlain by Precambrian bedrock, including middle to late Archean and early Proterozoic gneiss, amphibolite, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks. The western portion is underlain by Cretaceous marine shale, sandstone, and variegated shale; Ordovician carbonates, sandstone, siltstone, and shale; and Jurassic dolomitic shale, cherty dolomite, and gypsum (Morey *et al.* 1982).

LANDFORMS: Glacial lake plain, beach ridges, sand dunes, water-reworked till, and small areas of ground moraine. The section is a lowland with clay- and silt-rich soils deposited in Glacial Lake Agassiz (Wright 1972, Kratz and Jensen 1983). Wheeler *et al.* (1992a) describe it as a nearly featureless plain except to the east, in the interbeach zone, where there is a series of narrow beach ridges and wavecut scarps. Flat topography and clay soils combine to create poorly drained soils. As the lake levels of Glacial Lake Agassiz fell, ridges of sand and gravel formed along the shoreline; these are concentrated along the eastern edge of the lake plain and are known as the Lake Agassiz interbeach zone. Included within Section I is a large area of ground moraine, part of the Erskine moraine of the Des Moines lobe (Hobbs and Goebel 1982). The sediments of this lobe are also fine textured, and the topography is flat.

LAKES AND STREAMS: A few shallow lakes (Hargrave 1992). Drainage is to the north via the Red River and its tributaries. The larger tributaries, the Buffalo, Marsh, Ottertail, and Wild Rice Rivers, originate on the upland moraines to the

east and flow across the lake plain as winding, sluggish streams (Wheeler *et al.* 1992a).

SOILS: Poorly drained lacustrine clays, sands, and gravels, primarily Mollisols. Cummins and Grigal (1981) map most of these soils as Aquolls, and Borolls are also common. Almost all clay- or silt-rich soils have been ditched and plowed for agricultural use. Saline soils are locally present.

PRESETTLEMENT VEGETATION: At the time of settlement, almost the entire section was tallgrass prairie. Marschner (1974) indicates two vegetation types: upland prairie (primarily tallgrass prairie) and prairie wetland (wet prairie) (see figures 7 and 8 on pages 56 and 57). Narrow, forested floodplains were originally present along larger streams. Broader zones of woodland or brushland often occurred along "fire shadows" of streams; size and configuration depended on prevailing wind and stream alignment.

The vegetation zone just to the west of Section I's tallgrass prairie (and outside the area of this study)—the short grass prairie or steppe—occupies a long, narrow, north-south trending zone almost completely within the rainshadow of the Rocky Mountains (Rumney 1968, Küchler 1964). These shortgrass prairies, also called the transitional grassland zone (wheatgrass-bluestem-needlegrass) by Küchler (1964), occur less than 30 miles to the west of Section I at the western margin of the Glacial Lake Agassiz basin (Barker and Whitman 1988, as cited in Wheeler *et al.* 1992a).

Recent botanical studies have broken the prairies of the section into three major types: tallgrass prairie, wet prairie, gravel prairie. Calcareous fens occur along the slopes of beach ridges or some of the moraines at the eastern margin of the lake plain (Wheeler *et al.* 1992a); these artesian seepages occur along the downslope sides (west) of the shorelines.

The Minnesota Natural Heritage Program (1993) states that wet prairie was especially common on broad, poorly drained flats of the Agassiz lake plain; locally, high salt concentrations (sulfates of calcium and magnesium) influence the species composition of the wet prairie community.

The more northern fescue prairie begins just north of Minnesota in the Canadian Province of Manitoba (Wright and Bailey 1980; Küchler 1964; Bird 1961; Coupland 1950, 1961; Moss 1932).

NATURAL DISTURBANCE: Fire, drought, and annual inundation were important. Bison grazing and ant activity caused important fauna modifications of the vegetation and soils, respectively.

PRESENT VEGETATION AND LAND USE: The lake plain has been intensively ditched for agriculture. Native flora persists in fragments (though some of moderate size) east of the beach ridges and in the interbeach zone.

The interbeach zone of Glacial Lake Agassiz contains some of the largest remaining tracts of native prairie vegetation, primarily due to a combination of locally steep dunes, gravelly beach ridges, and poorly drained interbeach areas. The vegetation of the interbeach zone changes to aspen or oak woodlands. West of the interbeach zone, virtually no native vegetation remains, except on railroad and highway rights of way. Wheeler *et al.* (1992b) found upland prairie species to be common in parts of the section (based on herbarium records).

The interbeach zone of Glacial Lake Agassiz supports wet prairie in the interbeach areas, with bands of drier "gravel prairie" along the beach ridges and dunes. Gravel prairie, which is drier than tallgrass prairie, is dominated by *Schizachyrium scoparius* (little bluestem), *Koeleria macrantha* (June grass), *Sporobolus heterolepis* (prairie dropseed), and several other short grasses. The drier prairies are similar to those found further to the west in the Dakotas.

RARE PLANT COMMUNITIES: Although once dominant in the section, all prairie types are now rare. Rare prairie and wetland communities include dry prairie, glacial till hill prairie, mesic prairie, wet prairie, and calcareous seepage fen (Minnesota Natural Heritage Program 1993).

RARE PLANTS: Almost all rare plants in the section are considered prairie plants (Coffin and Pfannmuller 1988). *Androsace septentrionalis* var. *puberulenta* (northern androsace), *Antennaria aprica* (small-leaved pussytoes), *Astragalus neglectus* (Cooper's milk-vetch), *Botrychium gallicomontanum* (prairie moonwort), *Carex garberi* (Garber's sedge), *Carex hallii* (Hall's

sedge), *Carex obtusata* (blunt sedge), *Carex scirpiformis* (sedge), *Carex sterilis* (sterile sedge), *Carex xerantica* (dry sedge), *Chamaerhodos nuttallii* (Nuttall's ground-rose), *Cladium mariscoides* (twig-rush), *Cypripedium candidum* (small white lady's-slipper), *Eleocharis pauciflora* (few-flowered spike rush), *Gentiana affinis* (northern gentian), *Helianthus nuttallii* (Nuttall's sunflower), *Lygodesmia rostrata* (annual skeletonweed), *Orobanche fasciculata* (clustered broomrape), *Orobanche ludoviciana* (Louisiana broomrape), *Platanthera praeclara* (western prairie fringed orchid), *Rhynchospora capillacea* (hairlike beak-rush), *Salicornia rubra* (red saltwort), *Spartina gracilis* (alkali cord-grass), *Stellaria longipes* (long-stalked chickweed), *Tofieldia glutinosa* (false asphodel), *Triglochin palustris* (marsh arrow-grass).

RARE ANIMALS: Most of the rare fauna is strongly associated with prairies. Mammals: *Bison bison* (bison), *Canis lupis* (gray wolf (plains subspecies)), *Cervus elaphus* (elk), *Felis concolor* (mountain lion), *Microtus ochragaster* (prairie vole), *Thomomys talpoides* (northern pocket gopher); Birds: *Ammodramus bairdii* (Baird's sparrow), *Ammodramus caudacutus* (sharp-tailed sparrow), *Anthus spragueii* (Sprague's pipit), *Athene cunicularia* (burrowing owl), *Asio flammeus* (short-eared owl), *Bartramia longicauda* (upland sandpiper), *Calcarius ornatus* (chestnut-collared longspur), *Coturnicops noveboracensis* (yellow rail), *Grus canadensis* (sandhill crane), *Lanius ludovicianus* (loggerhead shrike), *Limosa fedoa* (marbled godwit), *Phalaropus tricolor* (Wilson's phalarope), *Tympanuchus cupido* (greater prairie-chicken); Reptiles: *Heterodon nasicus* (western hognose snake); Insects: *Cicindela limbata nympha* (tiger beetle), *Cicindela scutellaris criddlei* (tiger beetle), *Hesperia assiniboia* (Assiniboia skipper), *Hesperia dacotae* (Dakota skipper), *Oarisma poweshiek* (Poweshiek skipper), *Oeneis uhleri varuna* (Uhler's arctic).

NATURAL AREAS: State Natural Areas: Bicentennial Prairie, Bluestem Prairie, Felton Prairie, Frenchman's Bluff, Malmberg Prairie, Ottertail Prairie, Pembina Trail Preserve, Prairie Smoke Dunes, Richard M. and Mathilde Rice Elliot Prairie, Sandpiper Prairie, Santee Prairie, Twin Valley Prairie, Verlyn Marth Memorial Prairie, Western Prairie South; The Nature Conservancy Preserves: Felton Prairie Complex (Bluestem Prairie and Blazing Star Prairie), Western Prairie North, Malmberg Prairie; Others: Anna Gronseth Prairie, Audubon Prairie, Bluestem Prairie, Foxhome Prairie, Kettledrummer Prairie, Miller Prairie East, Pankratz Prairie North, Pankratz Prairie South, Town Hall Prairie.

PUBLIC LAND MANAGERS: Wildlife Management Areas: Agassiz-Nelson, Agassiz-Olson, Alberta, Andrea, Atherton, Bejou, Belgium, Bjorson, Burnham, Chicog, Clay County, Cromwell, Cupido, Dalby, Dittmer, Dugdale, Faith, Felton, Gruhl, Highland Grove, Hitterdal, Janssen, Jeral, Joe River, Kertsonville, Kube-Swift, Lake Ida, Liberty, Magnusson, Maple Meadows, Marcoux, Moccasin, Neal, Ogema Springs, Onstad, Orwell, Rothsay, Rush Lake, Shypoke, Spring Creek, Stipa, Syre, Tilden, Trail, Twin Valley, Tympanuchus, Ulen, Vangsness, Wambach, Waubun; Waterfowl Production Areas: Agassiz Beachline, Bellmore, Brown, Buchl, Chief Lake, Damaree, Eide, Flickertail Prairie, Foss South, Fuglie, Geyer, Haggman, Hanneman, Haugrud-Sillerud, Hellickson, Hoykens, Kloos, Lofgren, Marks, Melvin Slough, Nelson Prairie, Pepperton, Ruona, Squirrel Lake, Swede Grove Lake, Wildung; Others: Buffalo River State Park.

CONSERVATION CONCERNS: Some of the major resource management issues are (1) gravel mining and its destruction of prairie, (2) degradation of prairies, including rare prairie bird habitat, by present grazing practices, (3) loss of wet prairies of the interbeach zone due to invasion by woodlands of trembling aspen as a result of fire suppression (Wheeler *et al.* 1992a), and (4) the conversion of prairie to crop land and the impacts of altered water regime on fens at the base of beach ridges. The cumulative effects of increased timber harvesting activities upon forest biodiversity within this section are being evaluated by the Minnesota Department of Natural Resources.

Privately owned prairies are being managed as part of the Prairie Bank program. Some prairie lands are under county management, but many of these have no formal protection.

Virtually nothing remains of the extensive landscape of tallgrass prairie and wet prairie that occupied this section before settlement. Prairie preserves, as seen at Malmberg Prairie, are

threatened by the effects of surrounding agriculture, notably by the accumulation of soil blowing from fields and being caught by vegetation, thus stimulating invasion by exotic plant species.

BOUNDARIES: I chose to take this section to the southern limit of the reworked till instead of stopping at the boundary between reworked till and clay lake plain. This is a decision based on the presence of extensive areas of wet prairie on both the clay lake plain and reworked till. The prairies on the reworked till have been reported to be more similar floristically to prairies further to the south in Subsection II.1 (Upper Minnesota River Country). Although rainfall and minimum temperatures differ significantly from the southern to northern edges of the section, investigations of the prairie flora in Minnesota and adjacent eastern North Dakota have not noted any major floristic changes to justify further subdivision of the section from north to south (Wright and Bailey 1980, Redmann 1972, Cosby 1965, Küchler 1964, Buell and Facey 1960, Rudd 1951).

SECTION II. SOUTHWESTERN MINNESOTA GRASSLAND**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Subhumid Prairie Division, Tall-grass Prairie Province; till plains of pre-Illinoian, Illinoian, and Wisconsinan age; tallgrass prairie.**

DISCUSSION: The section, once dominated by tallgrass prairie, is concentrated in western Minnesota, but continues into adjacent South Dakota and Iowa. Like other prairie areas of U.S., this section is characterized by geomorphic features of low relief, which allow the spread of fires over long distances (Rumney 1968, Gleason 1913). The fertile soils of the section have been intensively farmed mostly for grains, potatoes, and sugar beets, almost completely eliminating the original prairie vegetation.

Section II is further divided into two subsections and three sub-subsections based on soils and landform differences. (See pages 58-66.)

ELEVATION: 750 to 1,995 feet (229 to 608 m).

AREA: 16,278 square miles (42,160 sq km).

STATES: Minnesota.

CLIMATE: Continental, with great differences between winter and summer temperature. The section is strongly influenced by the Maritime Polar (dry, mild) air mass and also influenced by Maritime Tropical (moist, warm) and Continental Polar (dry, cold) air masses. Annual average temperatures range from 44˚F in the south to 39˚F in the north (Wheeler *et al.* 1992a). Average annual precipitation ranges from approximately 24 inches in the northwest to approximately 30 inches in the southeast (Wendland *et al.* 1992). Mean annual snowfall is about 40 inches.

Although the total precipitation is not significantly less than that in portions of the forested sections to the east, the timing of precipitation is probably an important influence on the vegetation; only 11 percent of the annual precipitation arrives during November through February (based on Wendland *et al.* 1992). In contrast, savanna-dominated Section III receives 16 to 23 percent of its precipitation in this same period, while conifer-dominated Section X receives 14 to 29 percent. The combination of low levels of winter precipitation and strong desiccating winds increases the potential for spring fires. Drought conditions also occur relatively often during the growing season (Weaver 1954, Weaver and Albertson 1956). Tree growth is limited under these climatic conditions.

BEDROCK GEOLOGY: Bedrock within most of the section is blanketed with a thick layer of glacial drift that ranges from 100 to 600 feet in depth (Olsen and Mossler 1982). Bedrock, locally exposed here, includes Precambrian granitic bedrock along large stretches of the Minnesota River (Matsch and Wright 1967); Cambrian sandstone and Ordovician dolomite and sandstone along the Minnesota River near Mankato (Sims *et al.* 1966, Morey 1981); and numerous outcrops of Precambrian quartzite on the Coteau des Prairies and elsewhere (Wright 1972).

The glacial drift is underlain by several types of bedrock. Cretaceous shale, sandstone, and clay are the most common, but there are also Ordovician dolomite, sandstone, and shale; Jurassic shale, dolomite, and gypsum; and Precambrian quartzite, gneiss, amphibolite, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks and quartzite (Morey *et al.* 1982).

LANDFORMS: Gently sloping ground moraines and water-reworked moraines characterize the greatest area, but there are also some areas of glacial lake plain. The Coteau des Prairies has deeply incised, loess-covered ridges underlain by pre-Illinoian tills. End-moraine ridges, including stagnation moraines, occupy only a small percentage of the section's surface. Broad terraces and alluvial deposits are associated with the Minnesota River and its tributaries, as well as numerous narrow outwash channels.

SOILS: Calcareous glacial and lacustrine deposits of late Wisconsinan age are parent material of the Upper Minnesota River Country (Wheeler *et al.* 1992a). The silt- and clay-rich soils have thick, organic-rich surface horizons typically

associated with prairies. The soils are classed primarily as Mollisols (Aquolls, Borolls, Ustolls, and Udolls) by Cummins and Grigal (1981) and the Minnesota Soil Survey Staff (1983).

PRESETTLEMENT VEGETATION: The original vegetation was almost entirely prairie and prairie wetland (Marschner 1974). Outliers of woodland occurred along the eastern margin, primarily bur oak openings and aspen-oak woodlands (Wheeler *et al.* 1992a). Woodlands formed narrow borders along major streams; oak openings occurred on dissected bluffs such as those above Big Stone Lake and Lake Traverse in extreme southwestern Minnesota.

Recent studies have further subdivided Marschner's prairies into several prairie types, including tallgrass prairie, wet prairie, brush prairie, and gravel prairie. See subsections or sub-subsections.

The vegetation zone immediately west of Section II's tallgrass prairie (less than 30 miles outside the area of this study to the west)—the short grass prairie or steppe—occupies a long, narrow, north-south-trending zone almost completely within the rainshadow of the Rocky Mountains (Rumney 1968, Küchler 1964). These shortgrass prairies are also called the transitional grassland zone (wheatgrass-bluestem-needlegrass) by Küchler (1964).

NATURAL DISTURBANCE: Fire and drought were once major disturbance factors, but many depressions in the ground moraine and lake plain within the section were also regularly flooded, resulting in periodic tree and shrub mortality. Bison grazing was important for exposing mineral soil and limiting woody vegetation along the prairie/woodland border (Bird 1961). The Native American practice of hunting buffalo with fire over the last 3,000 to 4,000 years, probably contributed to maintaining the prairie. Grazing by other large mammals, insect infestations, and ant activities in the soil all had impacts on vegetation structure and establishment.

PRESENT VEGETATION AND LAND USE: The primary land use is now agriculture, either cultivation of row crops or livestock grazing. Human manipulation of drainage has allowed large areas of poorly drained soils to be farmed. Over most of the section, grassland vegetation is dominated by exotic and native weedy species (Wheeler *et al.* 1992a). Native prairie vegetation survives primarily on poor agricultural sites, such as steep slopes, poorly drained sites, and on droughty, infertile soils. Small fragments of wet prairies remain, and mesic prairie vegetation persists as even smaller remnants within either wet or dry prairie.

RARE PLANT COMMUNITIES: All prairie types are now rare.

RARE PLANTS: Several plants associated with prairies are now rare. See subsections and sub-subsections.

RARE ANIMALS: Several animals of the prairie are now either rare or extirpated. See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: See subsections and sub-subsections.

CONSERVATION CONCERNS: Landscape management teams in Minnesota have identified maintenance of river and stream corridors within the section as a high priority; riparian habitat provides continuous cover and travel corridors for many species. Streamside vegetation controls sedimentation and other nonpoint-source pollution of streams. Oxbows are of historic, ecological, and wildlife value. Limiting grazing, road construction, and surface mineral extraction within the riparian zone has been recommended, as has maintenance and restoration of mixed-species forests in riparian areas.

BOUNDARY JUSTIFICATION: The change from dominance by grasses in Section II to dominance by woodland or forest in Sections III to XI is primarily the product of more extreme drought conditions in the prairies of Section II. The prairie-forest ecotone has been related to mid-tropospheric flow patterns during the summer (Harman and Braud 1975, Harrington and Harman 1985).

The actual boundary of the grasslands with woodlands is generally located at or just east of a fire barrier, such as a series of lakes in a stagnation moraine, a series of glacial beach ridges and swales, a large moraine ridge, or a broad flood

plain. The present boundary is similar to that drawn by Kratz and Jensen (1983), which corresponds reasonably well with the boundary of continuous prairie vegetation (Marschner 1974) and continuous prairie soils (Cummins and Grigal 1981).

Farther to the east, prairie exists in a broken mosaic, indicating either past conditions that allowed the prairie to expand there, or anthropomorphic expansion of the prairie through burn management. Pollen records indicate such a past expansion of the prairies and savannas approximately 5,000 to 7,000 years ago due to climatic fluctuations (Delacourt and Delacourt 1981). The importance of Indian occupation and management with fire is recognized in many areas where prairie occurred within a mosaic of forest and savanna (Anderson 1990).

The boundary between Section II and Section III is located along the west edge of parts of the Big Stone, Alexandria, and Altamont moraines. The correspondence of continuous prairie to this boundary is only approximate because the characteristics of a given section of boundary, i.e., the size of water bodies or ridges, determine the sharpness of the prairie/woodland boundary.

SECTION III. SOUTHEASTERN MINNESOTA AND WEST-CENTRAL WISCONSIN SAVANNA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest Province; Des Moines lobe (late Wisconsinan age) glacial features and pre-Illinoian glacial features; savanna prevalent, also tallgrass prairie, sugar maple-basswood forest.**

DISCUSSION: A large part of the section is characterized by gently sloping ground moraine and end and lateral moraine ridges, with calcareous soils. The relatively long growing season, coupled with fertile soils, has resulted in heavy agricultural use of the land.

Section III has four subsections. (See pages 67-79.)

ELEVATION: 650 to 1,600 feet (198 to 488 m).

AREA: 16,208 square miles (41,989 sq km).

STATES: Minnesota, Wisconsin.

CLIMATE: Continental, with great differences between summer and winter temperatures. The section is influenced by three air masses: the Maritime Polar (dry, mild), Maritime Tropical (moist, warm), and Continental Polar (dry, cold). Total annual precipitation ranges from 24 to 32 inches across the section, and precipitation increases from west to east (Wendland *et al.* 1992). Annual snowfall averages 44 to 48 inches. This relatively light winter precipitation may partially account for stress on many tree species and may increase the potential for spring fires, which are important for maintaining prairie and savanna conditions. The section receives more precipitation in the form of snow than Section VII to the north. This snow comes in the form of moisture-carrying storms from the southwest. In contrast, Section VII receives dry, cold air from the northwest (Wisconsin Statistical Reporting Service 1967).

BEDROCK GEOLOGY: Glacial drift thickness is quite variable, ranging from less than 100 feet of drift in the east, with local exposures of bedrock along the St. Croix River, to 500 feet of glacial drift in parts of the western portion of the section (Olsen and Mossler 1982). Bedrock underlying the section is diverse; in the southwest are Cretaceous shale, sandstone, and clay; lower Precambrian granite; metasedimentary and metaigneous gneiss, schist, and migmatite; and amphibolite and granulite (Morey 1976). In the northwest are metasedimentary rocks; iron formation; greenstone; and metavolcanic rocks, including basalt, andesite, pillow lava, tuff, and ultramafic and rhyolitic rocks. Farther east, the underlying bedrocks are Ordovician and Cambrian sandstone, shale, and dolomite to the south and Cretaceous shale, sandstone, and clay to the north. At the extreme eastern edge of the section, Ordovician and Devonian dolomite, with some limestone, sandstone, and shale, are locally exposed, especially in the dissected stream valleys.

LANDFORMS: Section III has surface sediments and landforms from the most recent Wisconsin Glaciation. End moraine, ground moraine, and outwash are the most common landforms; a loess cap (wind-deposited silt) covers much of the section. The Anoka Sand Plain (III.3) has been historically interpreted as an outwash plain, but is now considered to be partially a lacustrine feature (Keen and Shane 1990, Lehr 1992, Meyer *et al.* 1993, Meyer 1993, Meyer and Hobbs 1993).

SOILS: Soils are generally fine textured, either derived from glacial till or aeolian silt (loess) deposits (Cummins and Grigal 1981). The till often contains abundant clasts of sedimentary bedrock. Loess deposits are up to 16 feet deep. The soils are primarily Alfisols (Udalfs), Mollisols (including Udolls and Aquolls), and some Psamments (USDA Soil Conservation Service 1967, Cummins and Grigal 1981). The soils of the Anoka Sand Plain are sands.

PRESETTLEMENT VEGETATION: Bur oak savannas (openings) and oak forest were the characteristic vegetation of the section. Tallgrass prairie occupied the least dissected, rolling parts of the section; prairie grasses dominated the groundcover of the open savannas, which often occupied slightly more irregular, rolling to moderately hilly topography. Sugar maple-basswood forest occupied the steepest, most fire-protected sites.

NATURAL DISTURBANCE: Fire occurred regularly in the savannas and prairies. Fire frequency was largely controlled by climatic fluctuations (Kline and Cottam 1979, Grimm 1984). Windthrow was not commonly referenced by GLO surveyors, but was probably important in the forests.

PRESENT VEGETATION AND LAND USE: Most of the level to hilly topography is farmed, except for parts of the Anoka Sand Plain and major river corridors; primarily the steepest and most dissected topography remains in natural vegetation.

RARE PLANT COMMUNITIES: Both tallgrass prairie and oak savanna, originally the dominant vegetation, have become rare because of fire exclusion and agricultural development.

RARE PLANTS: See subsections and sub-subsections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: See subsections and sub-subsections.

CONSERVATION CONCERNS: Minnesota is attempting to maintain the oak component in the section's forests, as well as the native prairies, prairie chicken habitat, and sedge-dominated wetlands. Many of the native prairies in the section are in danger of being mined for gravel. Forests need to be managed as larger tracts, with increased amounts of old-growth forest.

BOUNDARY JUSTIFICATION: The boundary between Sections II and III is based on the predominance of savanna in Section III and prairie in Section II. As already discussed in Section II, savanna becomes more common than prairie as intensity of fire decreases and the interval between fires lengthens; these conditions typically result from increased topographic relief. Prairie was scattered throughout Section III, primarily on relatively flat topography and on some alluvial soils. The boundary between Sections III and Section IV is based on a major physiographic boundary: Section III consists of rolling to hilly ground moraine and end moraine; Section IV consists of the highly dissected, steep topography of the Driftless Area, also called the Paleozoic Plateau or Blufflands in Minnesota.

SECTION IV. DRIFTLESS AREA **(Paleozoic Plateau or Blufflands); part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest Province; highly dissected, loess-capped unglaciated landscape, including some glacial features of pre-Illinioan age; oak savanna, tallgrass prairie, midgrass prairie, sugar maple-basswood forest.**

DISCUSSION: Section IV is a highly eroded, unglaciated landscape, with some till deposits of pre-Wisconsinan age near the margins of the section. It has been called the Driftless Area in Wisconsin (Curtis 1959) and Blufflands (Kratz and Jensen 1983) or Paleozoic Plateau (Hargrave 1992) in Minnesota; the section continues south into Iowa and Illinois.

Section IV has three subsections. (See pages 79-85.)

ELEVATION: 603 to 1,450 feet (184 to 442 m).

AREA: 16,203 square miles (41,986 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: Continental. Annual average precipitation ranges from 29 inches in the west to 34 inches in the southeast (Hargrave 1992, Wendland *et al.* 1992). Annual average snowfall ranges from 32 inches in the south to approximately 50 inches in the north (Wendland *et al.* 1992). Growing season precipitation ranges roughly from 11 to 16 inches, and growing season length ranges from 129 to 170 days. Extreme minimum temperature ranges from -30˚F in the south to below -40˚F in the north (Wendland *et al.* 1992).

BEDROCK GEOLOGY: Large exposures of bedrock occur in the steep ravines. These exposures are primarily Ordovician dolomite, limestone, and sandstone in Minnesota, with Cambrian sandstone, shale, and dolomite exposed along the valley walls of the Mississippi River (Morey 1981, Sims *et al.* 1966). Devonian dolomite and limestone are more locally exposed along the western edge, in Minnesota. In Wisconsin, Ordovician dolomites have the greatest exposures (Ostrom 1981).

LANDFORMS: A loess-capped plateau, deeply dissected by river valleys. The greatest amount of relief—as much as 600 feet—occurs along the Mississippi River. In Wisconsin, much of the section was never glaciated. Parts of the section, as mapped, are considered to have been blanketed with pre-Illinoian-age till, most of which was probably removed before the area was covered with Wisconsinan-age loess. In eastern Minnesota, loess lies directly upon bedrock. Paleozoic sedimentary rocks crop out in the valley walls, but are generally mantled with colluvium or loess.

Along the western edge of the section, where glacial drift is several feet thick, topography is controlled by the underlying glacial till; further east, where glacial drift is thin, topography is largely bedrock controlled (University of Minnesota *et al.* 1973). In most of the section, there is no sign of past glaciation. In these areas, beneath the surface deposit of loess is a layer of limestone residuum, underlain by bedrock.

LAKES AND STREAMS: Few natural lakes except for some in the northern part of Subsubsection IV.2, all on old glacial drift. Water tables are commonly deeper than 20 feet (University of Minnesota *et al.* 1973). Sinkholes are common in the southwest. Several major rivers flow through the section, forming steep ravines and, on some of the streams, broad alluvial plains. These rivers include the Mississippi, Wisconsin, Kickapoo, Chippewa, Black, Root, Whitewater, Zumbro, and Canon.

SOILS: Loess thickness is quite variable; in Minnesota, loess deposits range from 20 feet thick on broad ridgetops to less than a foot thick on valley walls (Hargrave 1992). In Wisconsin, loess deposits range from 16 feet thick along the Mississippi River to 2 to 4 feet thick and locally discontinuous at the eastern edge of the section (Hole 1976). The predominant soils are Udalfs, with localized Aquents along the flood plains of major rivers (Cummins and Grigal 1981). Cambrian siltstones, sandstones, and shales influence the soil properties.

PRESETTLEMENT VEGETATION: Major vegetation types were tallgrass prairie and bur oak savanna on ridge tops and dry upper slopes, sugar maple-basswood-oak forest on moister slopes, sugar maple-basswood forests in protected valleys and on north-facing slopes, wet prairies along the rivers, and some mesic prairie on the flood plain further back from the river (Finley 1976, Lange 1990). There were probably also oak forests that contained no sugar maple. Marsh and flood-plain forests were also common on river flood plains.

Prairie was restricted primarily to the broader ridge tops, which were unfavorable sites for trees due to thin soils, rapid drainage, and desiccating winds; all these conditions were also good for carrying fires across the landscape (Finley 1976). Prairies also occurred on steep slopes with south or southwest aspect.

Large areas dominated by maple-basswood forest are treated as Sub-subsections IV.3.1, IV.3.2, and IV.3.3. (See figure 3 and 4.)

NATURAL DISTURBANCE: Fire was important on the upland prairie and oak-dominated ecosystems; it also occurred in some lowlands, such as oak-dominated flood-plain forests and wet meadows (Finley 1976). Windthrows were recorded in the original GLO survey notes for Sauk County, including areas of 40 and 1,500 acres (Lange 1990). Recent records of tornados and ice storms indicate their local impact on forest vegetation.

PRESENT VEGETATION AND LAND USE: In Minnesota, Wheeler *et al.* (1992b) found abundant species characteristic of oak openings and barrens (based on herbarium collections), especially in the west, where a greater portion of the topography is relatively flat upland. Prairie species are also relatively common in the west, but rare elsewhere, where the land is in agriculture. In eastern Minnesota, where the most dissected topography with a greater percentage of lowland is present, both oak opening/barren and prairie flora are much less common.

Cliffs and associated flora and fauna are common within this section. Maple-basswood forest and mesic oak forests are present on east and north slopes; oak forest and woodland occur on south to west slopes. Relict pine forests are also common, especially at the southern edge of the section in Wisconsin. Hemlock is locally common in the southern half of the section, especially on northern and eastern sandstone exposures along the drainages of the Kickapoo and Baraboo Rivers. In Wisconsin, yellow birch, along with black ash, is characteristic of seepages on the lower, steep slopes. Hemlock, yellow birch, and black ash are much rarer in Minnesota than in Wisconsin.

In Minnesota, the western part of the section is heavily farmed, with approximately 90 percent in crops and pasture and the remainder in woodland. Farther east in Minnesota and Wisconsin, along the steep coulees, bluffs, and ridges above the Mississippi River, Wisconsin River, and other major streams, 50 to 60 percent is in crops and pasture and the remainder is in woodland (University of Minnesota *et al.* 1973, Hole 1976, Raile 1985).

Cottam (1949) found that prairie and savanna had been replaced by oak forest after fire suppression. Hix (1988) found steepness of slope and aspect, as well as soil depth and texture, to be important factors determining the forest composition along the Kickapoo River. Many of the remaining areas of prairie in Minnesota and Wisconsin are dry-mesic prairie on droughty sites, often steep slopes.

A recent study of Sauk County and portions of Columbia County, Wisconsin (Lange 1990), documents land use since European settlement within part of the section. Most prairies and savannas were farmed. Forests dominated by oak and sugar maple were used for fueling lime kilns and creating charcoal for smelting; oak was used for barrels and railroad ties. Fires were common, even after European settlement, and were documented as occurring frequently both in uplands and wetlands.

RARE PLANT COMMUNITIES: A rare natural community, algific talus slope, is found only along the steep bluffs of tributaries of the Mississippi River within this section. Prairies and savannas, once common on the flat ridge tops and slopes, are now rare, but examples of bluff prairie, dry oak savanna, dry prairie (bedrock bluff subtype) persist locally. High-quality

examples of calcareous seepage fen, dry cliff, flood-plain forest, maple-basswood forest, moist cliff, oak forest, and white pine-hardwood forest also occur in the section.

RARE PLANTS: Rare plants (and animals) reflect several different but characteristic landscapes of the section. Many are associated with the prairies and savannas on ridge tops and steep slopes, others with forests with a relict northern flora, and still others with bedrock cliffs. See subsections and sub-subsections.

RARE ANIMALS: See comments for rare plants. The fauna also reflects the isolated, relict watersheds of the section, which have rich fish and mussel faunas, as well as dragonflies and mayflies with restricted distribution. The southern half of the section contains many significant bat hibernacula. See subsections and sub-subsections.

NATURAL AREAS: This section has more natural areas than any other in the three States, reflecting the large number of rare plants and animals found here, as well as the unique topography. Natural Areas are listed under subsections and sub-subsections.

PUBLIC LAND MANAGERS: See subsections and sub-subsections.

CONSERVATION CONCERNS: Grazing is common in woodlots in both Minnesota and Wisconsin. Logging pressure on oak saw logs is high due to the depressed farm economy and strong timber market, and there is a concern about future logging on federally managed floodplain forests. Development pressure is increasing on the blufflands, especially on the Mississippi and lower Wisconsin Rivers. Mesic prairie has been almost eliminated. In Wisconsin, bluff prairies are being lost due to woody species encroachment and lack of fire.

BOUNDARIES: Section IV is bounded on all sides by more rolling topography.

SECTION V. SOUTHEASTERN WISCONSIN SAVANNA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest Province; glaciated landscape of late Wisconsinan age; savanna (most common), tallgrass prairie, deciduous forest.**

DISCUSSION: A large part of Section V is characterized by gently sloping ground moraine and end moraine ridges, with calcareous soils. There are also areas of lacustrine sand and clay in the north. The relatively long growing season, coupled with fertile soils, has resulted in heavy agricultural use of the land.

Section V has four subsections. (See pages 86-100.)

ELEVATION: 580 to 1,535 feet (177 to 468 m).

AREA: 13,544 square miles (35,089 sq km).

STATES: Wisconsin.

CLIMATE: Continental, with great differences between summer and winter temperatures. Section V is influenced by three air masses: the Maritime Polar (dry, mild), Maritime Tropical (moist, warm), and Continental Polar (dry, cold). Total annual precipitation, which ranges from 28 to 33 inches across the section, is intermediate between that of Section IV to the west and Section VI to the east; precipitation increases from west to east (Wisconsin Statistical Reporting Service 1967). About 23 percent of precipitation falls during winter; this relatively low amount may partially account for stress on many tree species and may increase the potential for spring fires, which are important for maintaining prairie and savanna conditions.

BEDROCK GEOLOGY: Cambrian, Ordovician, and Silurian sedimentary rocks underlie most of the section; Silurian and Devonian marine sedimentary rocks are exposed along sections of the Lake Michigan shoreline (Ostrom 1981, Morey *et al.* 1982). At the northern edge of the section, Cambrian sandstone is locally exposed as buttes (Martin 1965, Hole 1968, Germain and Hole 1994). Precambrian-age (Archean) gneiss and amphibolite also occur at the northern edge (Morey *et al.* 1982). Granitic rock of the Wolf River batholith (Precambrian age) occurs in the northeast. Underlying bedrock is responsible for general topographic relief in this section. For example, several of the broad plains here are underlain by resistant limestone or dolomite cuestas, such as the Niagaran upland along Lake Michigan and the Prairie du Chien cuestas farther to the west (Hole 1976, Martin 1965).

LANDFORMS: Section has surface sediments and landforms from the most recent Wisconsin Glaciation. End moraine, ground moraine, and outwash are the most common landforms; a loess cap (wind-deposited silt) covers much of the section.

SOILS: Soils are generally fine textured, either derived from glacial till or aeolian silt (loess) deposits. Loess deposits are up to 16 feet deep (Hole 1976). Soils are primarily Alfisols (Udalfs) and Mollisols (USDA Soil Conservation Service 1967). The soils of the Central Wisconsin Sand Plain (Subsection V.1) are sands.

PRESETTLEMENT VEGETATION: Bur oak savannas (openings) and oak forest can be considered the characteristic vegetation of flatter portions of the section. Tallgrass prairie occupied the least dissected, rolling parts of the section; prairie grasses dominated the groundcover of the open savannas, which often occupied slightly more irregular, rolling to moderately hilly topography. Sugar maple-basswood forest occupied the steepest most fire-protected sites, as well as those areas protected from fire by either wetlands or lakes.

NATURAL DISTURBANCE: Fire occurred regularly in the savannas and prairies. Fire frequency was largely controlled by climatic fluctuations (Kline and Cottam 1979). Windthrow was not commonly referenced, but was probably important in the forests.

PRESENT VEGETATION AND LAND USE: Most of the level to hilly topography is farmed, except for parts of the Central Wisconsin Sand Plain

and major river corridors. Primarily the steep, dissected topography and the large wetlands remain in natural vegetation.

RARE PLANT COMMUNITIES: Both tallgrass prairie and oak savanna, originally the dominant vegetation, have became rare because of fire exclusion and agricultural development.

RARE PLANTS: See subsections and sub-sub-sections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: See subsections and sub-subsections.

CONSERVATION CONCERNS:

BOUNDARY JUSTIFICATION: The boundary between Section IV, the Driftless Area, and Section V is based on differences in topography, with steeper slopes and more dissected topography in the Driftless Area. Lake Michigan forms the eastern boundary of Section V. Section VI begins along the eastern shore of Lake Michigan (in Michigan); it is characterized by moister, cooler summers and warmer winters (less continental conditions) than Section V because of winds off Lake Michigan. Sections VIII and IX have cooler temperatures than Section V because of higher latitude and prevailing winds from the northwest.

SECTION VI. SOUTHERN LOWER MICHIGAN**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest; Great Lakes-moderated climate (Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990); glaciated landscape of late Wisconsinan-age, underlain by Paleozoic bedrock; white oak-black oak savannas and forests, beech-sugar maple forest.**

DISCUSSION: This section of rolling hills and flat lake plains has been greatly modified by agricultural and urban development. The Great Lakes have moderated the climate and provided fertile lacustrine soils along the east and west edges of the section.

Section VI has six subsections. (See pages 101-129.)

ELEVATION: 572 to 1,280 feet (175 to 390 m).

AREA: 24,248 square miles (62,821 sq km).

STATES: Michigan.

CLIMATE: The climate of the section is strongly influenced by the Maritime Tropical air mass, with some lake-effect snows and moderation of temperature from Lake Michigan (Albert *et al.* 1986, Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990). Compared to the rest of the study area, the southern Lower Peninsula of Michigan has more warm humid air masses from the Gulf of Mexico and fewer cold dry air masses of continental origin. Winter precipitation is higher (7 to 10 inches; 23 to 26 percent of annual precipitation) and more of it falls as rain than in Wisconsin's Section V to the west or Michigan's Section VII to the north. The growing season is longer and warmer than that of Sections VII to XI and similar to that of Sections I to V.

BEDROCK GEOLOGY: Section is underlain by Paleozoic bedrock deposited in marine and nearshore environments, including sandstone, shale, limestone, and dolomite (Dorr and Eschman 1984). This Paleozoic bedrock was deposited in an intercratonic basin, known as the Michigan basin, which was occupied by marine waters from the Silurian through Pennsylvanian Periods. Mississippian and Devonian bedrocks are nearest the surface in the south and along the Great Lakes shorelines; Pennsylvanian bedrock is near the surface in the north (at the center of the Michigan basin). Bedrock exposures are few and small. At the eastern edge of the section near Lake Erie, Devonian limestone bedrock is often within 5 feet of the surface and is locally exposed along streams. Local exposures of Mississippian shale, sandstone, and limestone are near Saginaw Bay of Lake Huron, but glacial lacustrine deposits can be as deep as 300 feet on the inland portions of the lake plain.

Over the rest of the section, 100 to 400 feet of loamy glacial drift cover bedrock (Akers 1938). Very localized outcrops of Pennsylvanian sandstone occur along the Grand River and its tributaries (Dorr and Eschman 1984).

LANDFORMS: Wisconsinan-age glacial and postglacial landforms cover the entire land surface of the section. Landforms include lake plain, outwash, ground moraine (till plain), and end moraine. Broad lacustrine plains occur along all of the Great Lakes; these plains extend more than 20 miles inland along Lake Michigan and more than 50 miles inland along the Lake Huron shoreline at Saginaw Bay. Sand dunes form a 1- to 5-mile band along much of the Lake Michigan shoreline. The interior of the section consists of a relatively low plain of ground and end moraines, with narrow outwash channels throughout. A broad interlobate outwash plain occupies the southern half of the section.

SOILS: Most of the soils are calcareous and loamy, derived from underlying limestone, shale, and sandstone. Till deposits are primarily loams, silt loams, and clay loams. Lacustrine soils are silt- and clay-rich; lacustrine sands are often banded with silt or clay. The outwash plains of the interlobate are sands, often containing abundant gravel. Most of the soils are classified as Alfisols, including Aqualfs and Udalfs, but there are also Aquepts, Aquolls, and Psamments (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Almost the entire section was forested. Oak savanna was

probably the most prevalent, followed by oak-hickory forest and beech-sugar maple forest. This is the only section of Michigan that originally supported large areas of tallgrass prairie, which was concentrated in the sandy interlobate area in the southwestern part of the section. There were also large areas of wet prairie on the lake plains of Lake Erie, Lake St. Clair, and Lake Huron. Wetlands included extensive marshes, fens, and swamp forests (Comer *et al.* 1993a, 1993b).

NATURAL DISTURBANCE: Fire was important for maintaining oak savannas and tallgrass prairie. Large windthrows were documented in the GLO surveys of the glacial lake plains along Lake Huron and Lake St. Clair.

PRESENT VEGETATION AND LAND USE: Most of the section is farmed for row crops; it is the most heavily farmed section in Michigan. Almost all the original tallgrass and wet prairies have been converted to farmland. The oak savannas have become forests as a result of fire suppression. The heaviest urban, industrial, and residential development has occurred in this section, especially along the Great Lakes shoreline.

RARE PLANT COMMUNITIES: Savannas (oak openings), once common on rolling ground moraine and glacial lake beds, have become rare due to fire suppression. Similarly, prairies on both flat glacial lake beds and outwash plains have become rare due to agriculture. Inland salt marshes are the rarest plant community in Michigan. Coastal plain marshes, containing disjunct plants from the Atlantic Coastal Plain, are locally common in sandy depressions in outwash plains and glacial lake beds.

RARE PLANTS: See subsections and sub-subsections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: See subsections and sub-subsections.

CONSERVATION CONCERNS: Most of the forests and savannas have been nearly eliminated by farming or greatly altered by fire exclusion. Restoration will probably be required if large, functional examples of these are to persist. The savannas provided important habitat for several invertebrates, including the federally threatened Karner blue butterfly; restoration efforts are presently underway on State lands.

The marshes and wetlands along Great Lakes shorelines are critical for maintaining migratory waterfowl, shore birds, and the Great Lakes fisheries. Restoring and expanding these coastal wetlands are high priorities within the section and the State.

BOUNDARY JUSTIFICATIONS: Lake Michigan creates the western boundary of the section; Section V, west of Lake Michigan, has a more continental climate, with more impact from dry Maritime Polar air masses; Section VI is more greatly influenced by the Maritime Tropical air mass. The boundary between this section and Section VII to the north is based on 1) analysis of climatic data (Denton 1985), 2) the topographic boundary between a low plain to the south and a prominent upland plateau to the north (Albert *et al.* 1986), and 3) a long-recognized floristic boundary (Potzger 1948, McCahn 1979).

SECTION VII. NORTHERN LACUSTRINE-INFLUENCED LOWER MICHIGAN**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; Great Lakes-moderated climate (Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990); late Wisconsinan-age glaciated landscape underlain by Paleozoic bedrock; northern hardwoods forest, jack pine barrens, white pine-red pine forest, conifer swamp, bog.**

DISCUSSION: The section has some of the highest elevations, up to 1,725 feet near Cadillac in Sub-subsection VII.2.1, and the largest end moraine features in the Lower Peninsula of Michigan.

Section VII has six subsections. (See pages 130-156.)

ELEVATION: 580 to 1,725 feet (177 to 526 m).

AREA: 17,109 square miles (44,323 sq km).

STATES: Michigan.

CLIMATE: Most air masses cross the Great Lakes before entering this section, resulting in reduced continentality. Compared to areas of equivalent latitude in Section IX of Wisconsin and Minnesota, the section is warmer in winter and cooler in summer. Lake effect snow characterizes portions of the section within 20 to 30 miles of the Great Lakes shorelines. The Highplains (Subsection VII.2), the part of the section most distant from the Great Lakes and also the highest elevation above them, has the most continental climatic conditions within the section: more summer precipitation, the greatest summer and winter temperature extremes, the shortest growing season, and the greatest risk of spring freeze (Denton 1985).

Of annual precipitation, 26 to 28 percent occurs during November through February; 36 to 40 percent falls during the growing season (interpreted from Wendland *et al.* 1992).

BEDROCK GEOLOGY: This section, similar to Section VI to the south, is underlain by Paleozoic bedrock deposited in marine and near-shore environments, including sandstone, shale, limestone, and dolomite (Dorr and Eschman 1984, Milstein 1987). These Paleozoic bedrocks are deposited in an intercratonic basin, known as the Michigan basin, which was occupied by marine waters from the Silurian through Pennsylvanian Periods. Locally there are also Jurassic marine and near-shore deposits. The Jurassic and Pennsylvanian bedrocks are nearest the surface at the south end of the section, while Mississippian and Devonian bedrocks are nearest in the north.

Limestone bedrock is locally exposed along the Lake Huron and Lake Michigan shorelines. However, the sandy glacial deposits over most of the section are generally thick, up 600 to 1,100 feet thick near Cadillac and Grayling (Akers 1938).

LANDFORMS: The entire section was covered during late Wisconsin Glaciation; common glacial landforms include lake plain, outwash plain, end moraine, and ground moraine. Glacial landforms are the major factor upon which most of the subsection and sub-subsection boundaries here are defined. See subsections and sub-subsections for more details.

SOILS: Soils in the section range from sand to clay. Most soils are sands, loamy sands, and sandy loams, with sands by far the most prevalent (USDA Soil Conservation Service 1981, Albert 1990). Almost all the soils are forest soils. Soils are classified primarily as Spodosols, primarily Orthods, but also including Boralfs and Psamments (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The common forest types included northern hardwoods forest, jack pine barrens, white pine-red pine forest, hardwood-conifer swamp, and conifer swamp. Northern hardwoods were common on the end and ground moraines. Jack pine, along with northern pin oak, dominated the flat, droughty outwash plains, which occupy large portions of the section. Forests of white pine and red pine

were located in narrow outwash channels and on the moraines at the edges of the outwash plains, where fires were relatively common, but less intense than on the outwash plains themselves. Conifer and hardwood-conifer swamps covered large parts of the lake plains, but also occurred along drainages throughout the section. See subsections and sub-subsections.

NATURAL DISTURBANCE: Windthrow was common on both upland hardwood and conifer forests. Fire was important in the jack pine-, red pine-, and white pine-dominated forests, but it also occurred infrequently in hardwood forests.

PRESENT VEGETATION AND LAND USE: Most of the section remains forested. Intensive logging for white pine occurred in the latter half of the 19th century, causing major changes in forest composition. Eastern hemlock was also logged for the tannin industry, and northern hardwoods were harvested for many uses.

Following logging, farming was attempted on a broad range of soil types within the section. It failed on most of the sandy soils, but row crops are grown locally on some of the loamy soils. Some pasturing is also done, especially on the loamy moraines.

Orchards and vineyards are numerous along the Lake Michigan shoreline, where microclimatic conditions extend the growing season and reduce frost damage to fruit crops. Loamy soils are also preferred for the orchards and vineyards.

RARE PLANT COMMUNITIES: Northern grasslands associated with jack pine barrens are rare as a result of conversion to red pine or jack pine.

RARE PLANTS: See subsections and sub-subsections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: Huron-Manistee National Forests; Camp Grayling Military Reserve; Mackinaw and Pere Marquette State Forests; Kirtland Warbler Management Area.

CONSERVATION CONCERNS: Timber management is important throughout the section, which contains both state and national forests. These forest lands are important for diverse game and nongame plants and animals, including the federally threatened Kirtland's warbler. Oil and gas leases are common on State lands and continue to be environmental concerns, primarily because of the risk of ground-water contamination.

The Great Lakes shoreline is being rapidly developed for both recreation and residences. This development often conflicts with natural shoreline processes, such as erosion of shoreline bluffs and beach migration.

BOUNDARY JUSTIFICATIONS: See Section VI for discussion of the boundary between Section VI and Section VII. To the north, the boundary between Section VII and Section VIII is the boundary between Michigan's Lower and Upper Peninsula.

SECTION VIII. NORTHERN LACUSTRINE-INFLUENCED UPPER MICHIGAN AND WISCONSIN**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; Great Lakes-moderated climate (Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990); late Wisconsinan-age glaciated landscape; northern hardwoods forest, jack pine barrens, white pine-red pine forest, conifer swamp, bog.**

DISCUSSION: Most of this section is characterized by relatively flat topography, with large expanses of swamp forest and low productivity peatland. Most of the landscape remains forested, except for pasture lands on both clay lake plain and loamy ground moraine.

Section VIII has three subsections. (See pages 157-178.)

ELEVATION: 580 to 1,300 feet (177 to 396 m).

AREA: 13,168 square miles (34,105 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Most air masses cross the Great Lakes before entering this section, resulting in reduced continentality. The part of the section with the most continental climate is in northeastern Wisconsin, where prevailing winds are less often off the Great Lakes. Compared to areas of equivalent latitude in Section IX of Wisconsin and Michigan, the section is warmer in winter and cooler in summer. Lake-effect snow and rain characterize parts of the section near the Great Lakes shorelines, especially the Lake Superior shoreline. All the sections with climates influenced by the Great Lakes have rainfall more evenly distributed throughout the year than those with more continental climates (Sections I to IV and X and XI to the west).

BEDROCK GEOLOGY: Section is underlain by Cambrian-age sandstone and Paleozoic limestone, shale, and dolomite (Dorr and Eschman 1984). Sandstone is exposed along and near the Lake Superior shoreline and along the western edge of the section. Limestone and dolomite are exposed along the Lake Michigan shoreline and locally inland. In the interior of the region, thick glacial drift covers bedrock.

LANDFORMS: The entire section was covered by late Wisconsin Glaciation; common glacial landforms include lake plain, outwash plain, end moraine, and ground moraine. Glacial lake plain covers the largest part of the section; most of the lake plains are sandy, but a large area of clay lake plain is near the eastern edge of the section. On the sand lake plains, common landforms include transverse dunes, sand spits, beach ridges, and large deltas. Broad outwash plains are located along the entire northern edge of the proglacial lakes.

Ground moraine is extensive at the western edge of the section. End moraine is common along the northern edge of the section near Lake Superior.

SOILS: Soils of the sand and clay lake plain, which are quite extensive in the section, are largely poorly drained or very poorly drained, supporting extensive peatlands and swamp forests. Soils of the extensive outwash plains are generally excessively drained sands.

The sandy and loamy tills near the southern edge of the section are quite variable in drainage class and depth to underlying bedrock. At the northern edge near Lake Superior, there are sandy tills and outwash.

The most common soil orders within the section are Alfisols (Boralfs), Histosols, and Entisols (Aquepts), with some Orthods and Aquods (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Diverse forests (see subsections and sub-subsection). The original forests included northern hardwood forest, jack pine barrens, white pine-red pine forest, hardwood-conifer swamp, conifer swamp, and muskeg (Comer *et al.* 1994). Open bogs occurred on kettle lakes within end moraines and pitted outwash. Where bedrock was locally exposed or near the surface, grassland vegetation

was present. There were also extensive marshes along the Great Lakes shoreline. Northern hardwood forests, with sugar maple and beech as common dominants, were concentrated on end moraines, ground moraines, and drumlin fields. Jack pine forests grew on extensive outwash plains, along with red pine-white pine forests where fires were less severe.

The sandy lake plain supported open peatlands dominated by shrubby black spruce, tamarack, and occasionally jack pine (Comer *et al.* 1993a). Near the margins of the lake plain, there were also extensive swamps of northern white-cedar. On the clay lake plain, the forest was a diverse mix of hardwood and conifer species, including white spruce, balsam fir, white pine, eastern hemlock, trembling aspen, balsam poplar, and red maple.

NATURAL DISTURBANCE: Windthrow was common on both upland and wetland forests, especially on the flat topography of the glacial lake plains and along the windy shorelines of the Great Lakes. Fire was important on the jack pine plains and in the red pine-white pine forests.

PRESENT VEGETATION AND LAND USE: Most of the section remains forested, except the clay lake plains, which are used for pasture and forage crops. Intensive logging for white pine occurred in the latter half of the 19th century, causing major changes in forest composition. Eastern hemlock was also logged for the tannin industry, and northern hardwoods were harvested for many uses.

RARE PLANT COMMUNITIES: A globally rare plant community, Alvar, a grassland type found growing on thin soils over limestone or dolomite, is found only in this section.

RARE PLANTS: See subsections and sub-subsections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: Hiawatha National Forest, Seney National Wildlife Refuge, Lake Superior and Escanaba River State Forests.

CONSERVATION CONCERNS: Most the land surface is managed as either national or state forest, with large areas of private forest land. These forests are recognized as critical habitat for neotropical migratory songbirds.

Great Lakes shorelines are facing rapid developmental pressure, primarily for construction of second homes. The Nature Conservancy has a major Bioreserve Project underway along the northern Lake Huron shoreline, which includes Bois Blanc Island, Les Cheneaux Islands, Drummond Island, and the many small islands in the St. Marys River. Development pressures are also severe along the northern shore of Lake Michigan and on Wisconsin's Door Peninsula.

See subsections and sub-subsections.

BOUNDARY JUSTIFICATIONS: In Michigan, the boundary between Section VII and Section VIII is based on the analysis of climatic data (Denton 1985) and the boundary between the Upper and Lower Peninsulas of Michigan. To the west, the boundary between Section VIII and Section IX is defined roughly by the boundary between Paleozoic and Precambrian bedrocks in the center of Michigan's Upper Peninsula and eastern upper Wisconsin. The boundary with Section V in Wisconsin is determined by soil differences; a spodic horizon characterizes upland forest soils in Section VIII, but not those in Section V.

SECTION IX. NORTHERN CONTINENTAL MICHIGAN, WISCONSIN, AND MINNESOTA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; Precambrian Shield bedrock, late Wisconsinan-age glaciated landscape; northern hardwoods forest, white pine-red pine forest, jack pine barrens, hardwood-conifer and conifer swamp, bog.**

DISCUSSION: Section IX is underlain by highly resistant igneous and metamorphic bedrock of the Precambrian Shield. It has been overridden by continental glaciers many times; each time the glacier eroded some of the underlying bedrock and redeposited glacial drift upon the bedrock or older underlying glacial deposits. The result is a diverse landscape of glacially scoured bedrock ridges and irregularly overlain glacial features, including moraines, lake beds, and outwash channels and plains.

A combination of cold climate, resulting from both the high latitude and high continentality, and relatively nutrient-poor, rocky, acidic soils has resulted in minimal use of most of the section for agriculture. However, the silty soils of Sub-subsection IX.3.3 in north-central Wisconsin are used for farming. Most of the section is managed as either private or public forest. Mining was important here in the past, but has decreased significantly in recent years.

Section IX has eight subsections. (See pages 179-210.)

ELEVATION: 602 to 1,980 feet (184 to 604 m).

AREA: 31,320 square miles (81,118 sq km).

STATES: Michigan, Minnesota, and Wisconsin.

CLIMATE: Strongly continental, with only moderate influence from Lake Superior. Temperatures are extremely cold in the winter. Snowfall and rainfall are heavy adjacent to Lake Superior as a result of moisture-laden air from the lake being forced to rise rapidly over the bedrock uplands at the northern edge of the section (Eichenlaub *et al.* 1990, Eichenlaub 1979, Wisconsin Statistical Reporting Service 1967, Albert *et al.* 1986).

The winter precipitation is intermediate between that of Section X to the west and Section VIII to the east; 14 to 29 percent of the precipitation occurs between November and February, with the lower percentages to the south and west. This probably accounts for the reduced numbers of forest fires in the northern and eastern parts, along with the reduced dominance of upland conifers.

BEDROCK GEOLOGY: Large exposures of Precambrian bedrock are found throughout the northern part. Glacial drift thickness is quite variable; some drift is thicker than 200 feet (Doonan and Hendrickson 1968, Thwaites 1929). Large exposures of bedrock occur in the Michigamme subsection (IX.2), where the bedrock knobs consist primarily of granites and gneiss, but also contain the important Negaunee iron formation (Dorr and Eschman 1984, Reed and Daniels 1987). On the Keweenaw Peninsula (Sub-subsection IX.7.1 and IX.7.2), middle Precambrian volcanics, conglomerates, sandstones, and shales are exposed; middle Precambrian volcanics, conglomerates, and shales are also exposed on Isle Royale. Three iron mining ranges are in the section: the Marquette, Menominee, and Gogebic (Dorr and Eschman 1984). The iron formation is all of Huronian (middle Precambrian) age. Most iron mines are now inactive. Copper was mined from the Keweenawan (late Precambrian)-age lavas and conglomerates on the Keweenaw Peninsula.

At the southern edge of the section, Cambrian sandstone, with some dolomite and shale, underlies the glacial drift (Ostrom 1981). Locally, Cambrian sandstone is within a few feet of the surface (Hole and Germain 1994).

The bedrock here was abraded by continental glaciation and incorporated into the glacial drift, accounting for the red soils found in much of the section.

LANDFORMS: Exposed bedrock knobs occur commonly in the north. The most common features are ground- and end-moraine ridges,

which occur throughout. Clayey glacial lake plains occur near Lake Superior, extending as far as 30 miles inland. Several extensive outwash plains occur, including one near Lac Vieux Desert along the Wisconsin/Michigan boundary and another along the Michigamme River in Michigan.

SOILS: Stony, red, sandy loams are common on the moraines. One to two feet of wind-blown silt (loess) blanket large areas, creating a silt-loam surface soil (Hole and Germain 1994, Hole 1976, Albert 1990); this loess cap becomes thin and discontinuous in northern Wisconsin and Michigan. Both the sandy loam and silt loam soils tend to be acidic. Lacustrine deposits are generally silt- and clay-rich (Cummins and Grigal 1981, Hole 1976, Veatch 1953); these fine-textured soils are typically somewhat leached (Hole and Germain 1994). Outwash soils are acidic sand and gravels with little accumulation of organic material. Major soils are classified as Spodosols (Orthods), with some Boralfs, Ochrepts, Aquepts, and Psamments (USDA Soil Conservation Service 1967, Anderson and Grigal 1984).

PRESETTLEMENT VEGETATION: The original vegetation on the thick till soils was northern hardwood forests dominated by sugar maple, eastern hemlock, basswood, and yellow birch, with some white pine. This forest type persists over most of the section. Beech was absent, probably because of extremely low winter minimum temperatures. On thin soils and bedrock knobs, red pine, white pine, and red oak were common dominants. On some of the exposed bedrock knobs of the Keweenaw Peninsula, Porcupine Mountains, and Isle Royale, a dwarf "krummholz" forest of red oak occurred. Fire-tolerant jack pine and northern pin oak grew on the droughty, flat outwash plains.

The highly dissected lacustrine clay plain along Lake Superior supported a diverse hardwood-conifer forest, which included white pine, eastern hemlock, balsam fir, northern white-cedar, trembling aspen, balsam poplar, and paper birch (Comer *et al.* 1993a). Northern hardwoods and almost pure stands of hemlock or white pine occurred on some upland plateaus on the lake plain.

Wetlands were not extensive. However, numerous bogs occurred in the kettle depressions within the end moraines, and tamarack-black spruce swamps were in the broad valleys between broad ground-moraine ridges. Hardwood-conifer swamp occurred on the poorly drained portions of the lake plain. Larger flood plains were often dominated by American elm, green and black ashes, and occasionally silver maple. Smaller flood plains were more typically dominated by conifers, especially balsam fir.

NATURAL DISTURBANCE: Large windthrows were documented in the GLO surveys for hardwood-dominated end moraines and shallow-soiled bedrock ridges. Windthrow also appears to have been a common form of disturbance on large areas of ground moraine (my interpretation of Canham and Loucks (1984)). Fire was important on droughty outwash plains, bedrock ridges, and conifer-dominated wetlands; all of these are dominated by upland or wetland conifers.

PRESENT VEGETATION AND LAND USE: The primary land use is forestry. Logging of white and red pines for construction lumber began in the latter part of the 19th century and continued into the early 20th century. Logging of the pines was followed by logging of eastern hemlock for tannin from the bark and later logging of northern hardwoods for furniture and pulp. Damage caused by late 19th and early 20th century logging and subsequent slash fires is still much in evidence today; much of the land that was originally forested with northern hardwoods or pine was reforested with aspen-paper birch, species still prominent today. Logging of northern hardwoods, aspen, and jack pine for paper production continues.

Several iron formations were mined in the past in the Menominee, Penokee, Gogebic, and Michigamme Ranges of Michigan and Wisconsin. Copper was also mined on the Keweenaw Peninsula and near the Porcupine Mountains of Michigan. Mining resulted in rapid, early development of the section, including logging for mine timbers, housing, and fuel. However, in Wisconsin and Michigan, mining is no longer a major industry, and human populations and development have slowed or stopped in most mining areas.

RARE PLANT COMMUNITIES: Bedrock beach and balds, bedrock knobs with krummholz or boreal and western herbs and shrubs, are found on the lavas and conglomerates along Lake Superior.

RARE PLANTS: See subsections and sub-subsections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: Only the largest areas are listed here; see individual subsections and sub-subsections for others. **Michigan:** Isle Royale National Park, Porcupine Mountains State Wilderness Area and Park, McCormick Research Natural Area (Ottawa National Forest), Sylvania Wilderness Area (Ottawa NF), Huron Mountain Club. **Wisconsin:** Apostle Islands National Lakeshore. **Minnesota:** Jay Cooke State Park.

PUBLIC LAND MANAGERS: Michigan: Ottawa National Forest; Iron River, Copper Country, Escanaba River State Forests. **Wisconsin:** Nicolet and Chequamegon National Forests; Northern Highland State Forests. **Minnesota:** Nemadji State Forest.

CONSERVATION CONCERNS: The section makes up a large part of the deciduous hardwood forest in the Northeastern United States. Its forests have been recognized as the major breeding area for many migratory song bird species. Large portions are managed as state and national forest and contain large, unbroken tracts of forest. This land is a potential site for large-scale experimentation to determine the impacts upon biotic diversity of various spatially and temporally configured timber cuts and other timber management approaches, including use of fire.

Although the timber-resource inventory and the relationships of game wildlife to the timber resource are well documented, there is still a tremendous need for inventory of the understory flora and nongame fauna. Ecological Classification Systems (ECS) are better developed here than in any other part of the country, providing a framework for such biological inventories. Linking of biological inventories to ECS has begun on the Ottawa, Chequamegon, and Nicolet National Forests.

BOUNDARY JUSTIFICATIONS: The Precambrian Shield roughly defines the eastern boundary in Michigan and the southern boundary in Wisconsin. The boundary between Sections IX and X along the Wisconsin/Minnesota border is marked by a change in primary dominance by northern hardwoods on mesic sites in Section IX to dominance by conifers on similar mesic sites in Section X of Minnesota. This shift is probably related to more severe spring and summer drought in Section X. Rapid increase in relief and elevation and the general irregularity of topography are responsible for increased "orthographic" snowfall in Section IX.

SECTION X. NORTHERN MINNESOTA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; drought prone with low winter precipitation; Precambrian Shield bedrock, late Wisconsinan-age glaciated landscape; upland conifer forests, extensive paludified peatlands and conifer swamps.**

DISCUSSION: Section X is characterized by rolling to steep ground- and end-moraine ridges, low bedrock knobs, and vast peatlands on glacial lake plains. Topographically it is similar to Section IX to the east. However, from near the Wisconsin-Minnesota border, there is a major shift in upland vegetation from northern hardwoods in Section IX to fire-dependent pines and hardwoods to the west in Section X.

Ecoclimatic regions have been defined on the basis of forest vegetation by several authors. In Canada, Rowe (1972) treats the forests along the U.S.-Canadian border as the Great Lakes-St. Lawrence Forest Region, which contains sugar maple, yellow birch, white pine, and red pine. Bailey and Cushwa (1981) include Rowe's Great Lakes-St. Lawrence Forest Region and this section as the Laurentian Mixed Forest Province.

In an alternative treatment, *The Ecoclimatic Regions of Canada* (Ecoregions Working Group 1989) shows boreal forest extending into Minnesota in the Border Lakes (Boundary Waters), Lake Superior Highland, and Agassiz Peatlands subsections, thus subdividing the Great Lakes-St. Lawrence Forest Region or Laurentian Mixed Forest Province on the basis of climate. The Canadian climatic units, LBst (Subhumid Transitional Low Boreal Ecoclimatic Region) and LBx (Moist Low Boreal Ecoclimatic Region), are based on conifer dominance in both the uplands and lowlands. LBx, described as containing sugar maple and yellow birch, is shown as extending into the Border Lakes, but that subsection does not include either species in any number.

In this study, I use Bailey and Cushwa's and Rowe's treatments, with the realization that the northernmost subsections (Border Lakes, Agassiz Peatlands, and portions of the North Shore Highlands) may be transitional to the boreal forest. However, the presence of large areas of bedrock in the Border Lakes subsection and broad, poorly drained landscapes ideal for peatland development may also contribute to the greater conifer dominance, in addition to the more severe northerly (boreal) climatic conditions. Analysis of climatic data, now being conducted, should help resolve this question.

Section X has 12 subsections. (See pages 211-238.)

ELEVATION: 602 to 2,301 feet (184 to 701 m).

AREA: 40,108 square miles (103,903 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: Annual precipitation is slightly higher than in Sections I, III, and XI to the west, and lower than in Section IX to the southeast (especially where Section IX's topographic relief causes increased precipitation along the southern shore of Lake Superior). Average and extreme winter temperatures are lower than in Section IX, but similar to temperatures in the northern part of Section I, and in Section XI.

An important climatic factor influencing the vegetation is probably the low amounts of winter precipitation. Of the annual precipitation, 15 to 19 percent falls between November and February (interpolated from Wendland *et al.* 1992). Winter snowfall increases relatively sharply to the east in Section IX, partially as a result of increased snowfall near the Lake Superior shoreline. Light winter precipitation increases the potential for spring fires. Heinselman (1973) discusses the importance of spring fires for maintaining the conifer-dominated forests of parts of this section.

Heinselman (1973) and Frissel (1973) demonstrate the recurring pattern of severe droughts that occur in the section as often as two to three times a century. Major fires are associated with these periods of drought.

BEDROCK GEOLOGY: Precambrian igneous and metamorphic bedrock underlies the entire section (Morey 1976, Ostrom 1981). Thick

glacial drift up to 600 feet deep blankets much of the section (Olsen and Mossler 1982), but abundant Precambrian bedrock exposures occur along the Lake Superior shoreline and in the Border Lakes area (Morey 1981, Olsen and Mossler 1982). Small bedrock exposures occur throughout the entire eastern half of the section.

Iron mining in Minnesota has been concentrated within the Mesabi Range in this section. Early mining here was concentrated in local pockets of "soft" iron ore, but recent mining has been in unaltered iron formation, called taconite (Wright 1972). Mining has diminished greatly in recent years (Hargrave 1992).

The greatest amount of exposed bedrock occurs in the Border Lakes subsection, where several types of Precambrian bedrock are exposed, including slate, diabase, gabbro, and granite (Wright 1972). Each of these bedrock types is reflected in distinct patterns of lakes and drainages.

From Duluth to the Canadian border, the North Shore (Lake Superior) Highlands subsection is underlain by Keweenawan basalt and diabase, which dips sharply to the southeast. These volcanic bedrocks, part of the Lake Superior syncline, dip below Lake Superior and are exposed along the southeastern edge of the syncline from the Keweenaw Peninsula in Michigan to south of the Porcupine Mountains in northern Wisconsin. On the Highland Flutes of the Superior Highlands, bedrock is exposed on approximately 30 percent of the land surface (Hargrave 1992).

Even though most of the section is underlain by Precambrian bedrock, there are also Cambrian sandstone, shale, and dolomite at the extreme southeastern edge and Cretaceous shale, sandstone, and clay near the southwestern edge (Morey 1976).

LANDFORMS: The entire section is characterized by Wisconsinan-age glacial drift and landforms. The largest glacial feature within the section is a large part of Glacial Lake Agassiz; most of the Beltrami arm of Lake Agassiz (Wright 1972) is within the section. The fine-textured lacustrine sediments of the peatland are 100 to 200 feet thick along the western margin of the lake plain, but much shallower at the eastern edge, where there are local exposures of bedrock (Olsen and Mossler 1982). Smaller glacial lacustrine features are Glacial Lakes Upham and Aitkin.

Glacial erosion of bedrock, with only minimal deposition of till on the bedrock, characterizes the Border Lakes subsection of northeastern Minnesota (Wright 1972). Similar bedrock abrasion features are common in the Superior Highlands and locally within the eastern half of the section.

Ground- and end-moraine ridges cover large areas. The moraine features range from ice stagnation moraines with many lakes to distinct end- and ground-moraine ridges with few lakes. The till of these moraines is also quite variable, depending on the source material. Tills from the Des Moines lobe are typically calcareous and fine-textured; Wadena lobe tills are also calcareous, but often coarse-textured; Rainy lobe tills are non-calcareous and coarse-textured; and Superior lobe tills are non-calcareous and fine-textured. Stoniness of the till from the lobes is variable.

Sandy outwash plains and channels occur throughout. The Pine Moraines (Subsection X.5) contains several large outwash plains. Pitted outwash, with many small lakes and wetlands, is common in this subsection, as well as throughout the remainder of the section. Narrow outwash channels, often as wide as 2 to 3 miles, are also widespread.

SOILS: The soils are both upland and wetland forest soils developed under either conifers, hardwoods, or a mix of hardwood and conifers. The soils are developed on either glacial drift or bedrock. There are four major glacial lobes within the section, each with somewhat distinctive till, as well as lacustrine and fluvial deposits. As a result, the soils are quite variable in texture, chemistry, stoniness, and drainage conditions. Soils are classified as Alfisols (Boralfs), Entisols (Psamments and Orthents), and Histisols (Hemists), with some Borolls, Orthods, and Ochrepts (USDA Soil Conservation Service 1967, Anderson and Grigal 1984). See subsections and sub-subsections.

PRESETTLEMENT VEGETATION: Conifers dominated both upland and lowland forests, but

forests of northern hardwoods were also present. The prevalence of conifers on relatively mesic, upland soils distinguished the forests of the section from those of Section IX to the east, where hardwood dominance was more typical on mesic soils. Preliminary analyses showed northern hardwood dominance on only 10 to 25 percent of the mesic sites of the section, as opposed to 75 percent or more of the mesic sites of Section IX. Sugar maple and other northern hardwoods were nearly absent from the northern and northwestern portions of Section X, probably because of frequent and intense fires, late spring frosts, and poor drainage conditions in the peatlands. In the north, northern hardwoods persist on ridgetops and near large lakes, or on highly irregular, steep topography protected from both fire and frost.

On the uplands, jack pine dominated the droughty, fire-prone outwash plains, beach ridges, and thin soils on bedrock. White pine and red pine dominated pitted outwash and sandy moraines that burned less frequently and less intensely than the outwash plains. Marschner (1974) also mapped many areas of aspen-birch forest, a type he considered successional to red pine, white pine, white spruce, balsam fir, and paper birch. Aspen-birch occurred on a broad range of upland soils and landforms (Grigal and Kernik 1980).

The Agassiz, Upham, and Aitkin glacial lake plains all supported extensive areas of swamp and peatland. The extensive peatlands of Glacial Lake Agassiz supported swamp forests dominated by black spruce and tamarack, along with some northern white-cedar, balsam poplar, paper birch, and trembling aspen. Open bog and patterned peatlands were also extensive, as were numerous other wetland communities related to water flow and water chemistry (Heinselman 1963, 1970; Glaser *et al.* 1981; Glaser 1983).

Fairly extensive areas of northern hardwoods were in the southern half of the section, especially in Aitkin, Pine, and Mille Lacs Counties.

NATURAL DISTURBANCE: Fire was the most important form of natural disturbance, occurring in both uplands and wetlands. Fires occurred as frequently as every 10 years on many sites (Frissel 1973). Insect mortality was also important and partially responsible for the frequency and intensity of fires; spruce budworm was the most important cause of mortality for white and black spruce and balsam fir (Heinselman 1973).

PRESENT VEGETATION AND LAND USE: Red and white pine forests were heavily logged at the beginning of the 20th century, resulting in major changes in forest composition; on many lands, aspen increased greatly in dominance. Jack pine and red pine plantations are also quite extensive in some subsections. Many of the other forest types have not changed greatly in composition from those of the original forest.

Iron mining, although now reduced, continues to be an important industry in the Mesabi Range.

RARE PLANT COMMUNITIES: See subsections and sub-subsections.

RARE PLANTS: See subsections and sub-subsections.

RARE ANIMALS: See subsections and sub-subsections.

NATURAL AREAS: See subsections and sub-subsections.

PUBLIC LAND MANAGERS: Minnesota: National Forests: Chippewa and Superior; Wilderness Areas: Boundary Waters Canoe Area (Superior NF); National Parks: Voyageurs; National Wildlife Refuges: Rice Lake; State Forests: St. Croix, Snake River, Rum River, Savanna, Solana, Smokey Hills, White Earth, Huntersville, Crow Wing, Badoura, Foothills, Lyons, Paul Bunyan, Hill River, Land O'Lakes, Black Duck, Big Forks, Finland, Cloquet Valley, George Washington, and Nemadji; Wildlife Management Area: Mille Lacs; State Parks: Mille Lacs, Katheo, Jay Cooke, Savanna Portage, St. Croix, St. Croix Wild River. **Wisconsin:** National Forests: Chequamegon; State Forests: Brule River, Governor Knowles; National Scenic Rivers: St. Croix-Namekagon; County Forests: Douglas, Bayfield, Burnett, and Washburn Counties.

CONSERVATION CONCERNS: The Minnesota Environmental Quality Board is producing a Generic Environmental Impact study of the cumulative effects of increased timber harvesting

activities, with forest biodiversity a major issue.

BOUNDARY JUSTIFICATIONS: Section X has lower annual precipitation and more severe summer droughts than Section IX to the east. Compared to Section III, it has lower temperatures and more soils derived from igneous and metamorphic Precambrian bedrock. The boundary between Section XI and Section X may be the product of more extreme drought conditions in the aspen parkland and prairie of Sections XI and I to the west. Even though the prairie-forest ecotone has been related to mid-tropospheric flow patterns during the summer (Harman and Braud 1975, Harrington and Harman 1985), aspen woodland and brush prairie dominance in Section XI is at least partially the result of more irregular topography and increased areas of wetland rather than a sharp climatic transition.

SECTION XI. ASPEN PARKLAND**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Subhumid Prairie Division, Aspen Parkland Province; sand lake plain and water-reworked till on northern Glacial Lake Agassiz (late Wisconsinan age, Des Moines lobe glacial deposits); aspen parkland, tallgrass prairie, wet prairie, fen.**

DISCUSSION: Section XI gets its name from the vegetation, which is a mosaic of [trembling] aspen groves, prairies, and wetlands located between the extensive Lake Agassiz peatlands to the east and the agricultural lands of the flat clay plain to the west. This mosaic of vegetation probably occurs because drought and fire are frequent enough to prevent succession to forest but not frequent enough to eliminate trees. The section is a low-relief landscape of ground moraine further subdued from inundations by Glacial Lake Agassiz. Low dunes, beach ridges, and wet swales form the western edge and provide a barrier that reduces both fire frequency and intensity, resulting in increased dominance by shrubs, trembling aspen, and balsam poplar. Farther east, low ridges of water-reworked till are surrounded by herbaceous wetlands.

The section is transitional between flat agricultural lands to the west and extensive peatlands to the east. It is much more extensive to the north and west in the Canadian Provinces of Manitoba, Saskatchewan, and Alberta, where it is also viewed as transitional between tallgrass prairie to the south and boreal forest to the north.

Section XI has no subsections.

ELEVATION: 900 to 1,250 feet (274 to 381 m).

AREA: 4,052 square miles (10,500 sq km).

STATES: Minnesota.

CLIMATE: Similar to that of the northern edge of Section I to the west. Total annual precipitation is 20 to 22 inches; 40 percent of this falls during the growing season (Hargrave 1992). Only 11 to 14 percent of the annual precipitation falls from November through February (estimated from Wendland *et al.* 1992). Annual average snowfall is 40 to 44 inches (Wendland *et al.* 1992). This low amount of winter precipitation, combined with extreme cold and desiccating wind, probably accounts for both increased spring fires and severe stress on most shrub and tree species, resulting in the open woodland vegetation of the section. Growing season is approximately 120 days; last spring frosts are in late May, and first fall frosts are in mid-September. Extreme minimum temperatures are -40˚F to -45˚F (Reinke *et al.* 1993) or colder. Climate within the parklands has been generally stable for the last 2,000 years (Janssen 1992).

BEDROCK GEOLOGY: Bedrock is overlain by 100 to 400 feet of calcareous glacial drift. The glacial drift is underlain by several types of bedrock; in the western portion Ordovician dolomite, sandstone, and shale are the most common, along with Cretaceous shale, sandstone, and clay; and Jurassic shale, dolomite, and gypsum (Morey *et al.* 1982). East of these sedimentary rocks are Precambrian undifferentiated granites and metamorphosed mafic to intermediate volcanic rocks.

LANDFORMS: The section consists of two distinct parts: the sand lake plain to the west and the water-reworked moraines to the east. Portions of the sand lake plain are level, but there are also small dunes and series of low beach ridges and swales. The beach ridges can be gravelly, and the swales often contain abundant cobbles and boulders (Cummins and Grigal 1981). The reworked moraines generally have reduced relief resulting from the reworking by wave action of Glacial Lake Agassiz; the topography is that of an undulating plain broken by large areas of marsh, wet meadow, and shrub swamp.

LAKES AND STREAMS: Few Lakes. The major river is the Roseau, which flows north into Canada (Hargrave 1992). The drainage system is poorly developed. Rivers and streams meander extensively, and flooding occurs regularly on the flat topography.

SOILS: Soils of the sand lake plain range from sands to gravels. Calcareous and saline seeps occur at the bases of sand dunes and beach ridges, often resulting in interesting vegetation communities. Soils are classified as Entisols (Psamments and Aquents), Histosols (Hemists), and Mollisols (Aquolls) (USDA Soil Conservation Service 1967, Cummins and Grigal 1981). On the reworked moraines, soils are generally loamy. The till often contains large boulders that restrict land use (Cummins and Grigal 1981). The till is partially mantled with lacustrine sands, silts, and clays.

PRESETTLEMENT VEGETATION: Marschner (1974) mapped the vegetation as a mosaic of prairie, wet prairie (including marsh), brush prairie, and aspen-oak land (see figures 36 and 37 on page 239). The prairie was generally tallgrass prairie, with mixed-grass prairie on the drier beach ridges and dunes. Wet prairie occurred in the flats and swales between the beach ridges. On the till in the eastern part of the section, much of what was mapped as wet prairie was probably rich fen, dominated by sedges rather than by prairie grasses. Bearing tree data suggest a higher proportion of the landscape was dominated by shrubs rather than trees.

At present, willows are the predominant woody species. Common shrubs include *Betula glandulifera* (bog birch), *Potentilla fruticosa* (shrubby cinquefoil), *Corylus* spp. (hazel), and *Amelanchier* spp. (Saskatoon). Prairie species are those of the tallgrass prairie, *Andropogon gerardi* (big bluestem), *Sorghastrum nutans* (Indian grass), *Sporobolus heterolepis* (dropseed), *Calamagrostis* spp. (bluejoint), and *Agropyron trachycaulum* (slender wheatgrass), rather than those of the mixed-grass parklands of Canada, such as *Agropyron smithii* (western wheatgrass), *Koeleria macrantha* (Junegrass), and *Schizachyrium scoparium* (little bluestem).

Ewing's (1924) study on succession within the brush prairie of the aspen parkland was conducted south of Section XI, as presently delineated, and may not be applicable. At Ewing's study site, brush prairie was concentrated in areas of small wetlands and irregular topography, where fire frequency and intensity, as well as desiccation by strong winds, were reduced. Ewing considered brush prairie to be a successional community tending toward trembling-aspen-dominated forest or parkland.

Aspen-oak land, typically called aspen woodland or parkland, was dominated by trembling aspen, with scattered bur oak. The woodland was also concentrated where there was increased fire protection. Stream valleys and wetlands often provided the necessary fire protection for woodland establishment. Although most of the trembling aspen is found on ground moraine, the western boundary of the aspen is found on the sandy and gravelly beach ridges of the Red River Valley part of Glacial Lake Agassiz.

NATURAL DISTURBANCE: Fire was important for maintaining the open brush prairies and aspen woodlands here, as were the desiccating winds characteristic of the prairie. Buffalo destroyed trembling aspen by breaking the stems and rubbing the bark (Bird 1961); snowshow rabbits also girdled young aspen (Moss 1932). Buffalo also exposed bare soil by overgrazing and wallowing, which allowed shrubs to establish (Bird 1961). Burrowing mammals, such as ground squirrels, pocket gophers, badgers, fox, and coyote, exposed bare soils for shrub establishment. Sharp-tailed grouse, pine grosbeak, and other birds distributed shrub seeds.

PRESENT VEGETATION AND LAND USE: In the north, large areas have been drained and farmed. Grazing, gravel mining, and agriculture are the primary land uses. The remaining unfarmed lands have become much more dominated by shrubs or trees as the result of fire suppression.

Plant communities well represented in this section include: aspen brush prairie, aspen openings, dry prairie, lowland hardwood forest, mesic brush prairie, mesic prairie, wet brush prairie, wet prairie, wet meadow, calcareous seepage fen, and rich fen.

RARE PLANT COMMUNITIES: All prairie and fen communities listed in PRESENT VEGETATION AND LAND USE.

RARE PLANTS: *Androsace septentrionalis* var. *puberulenta* (northern androsace), *Astragalus neglectus* (Cooper's milk-vetch), *Platanthera*

praeclara (western prairie fringed orchid).

RARE ANIMALS: *Ammodramus caudacutus* (sharp-tailed sparrow), *Coturnicops noveboracensis* (yellow rail), *Grus canadensis* (sandhill crane), *Limosa fedoa* (marbled godwit).

NATURAL AREAS: State Natural Areas: Lake Bronson Prairie Parkland; Other: Halma Prairie, Norway Dunes.

PUBLIC LAND MANAGERS: Wildlife Management Area: Beaches, Belgium, Caribou, Crane, Devil's Playground, East Park, Eckvoll, Elm Lake, Emardville, Emerson, Erskine, Espelie, Florian, Gervais, Halma Swamp, Higginbothan, Huot, Jacksnipe, Larix, Marcoux, Nereson, Oriniak, Pelan, Pembina, Polk, Polonia, Roseau River, Skull Lake, Thief Lake, Twin Lakes; State Parks: Lake Bronson, Old Mill; Other: Agassiz National Wildlife Refuge.

CONSERVATION CONCERNS: Aspen has become much more prevalent since the time of settlement; fire suppression has allowed "brush prairie" to become aspen parklands. Prescribed burns or timber harvesting may be required to reduce aspen dominance, where this is desirable.

The dynamic association of wetland and upland plant communities found on the parklands is best maintained at a landscape level. Full representation of the parkland ecosystem can only be accomplished by protecting multiple patches of each community type at a scale dictated by the patch size of the constituent communities. A recent acquisition of 6,900 acres of parkland, combined with existing wildlife management areas, provides an opportunity for long-term management of large land blocks, essential for maintaining the dynamic flux of prairie and woodland.

BOUNDARY JUSTIFICATIONS: Section I to the west is flat clay lake plain and supports more tallgrass prairie than Section XI. Subsection X.12 to the east is very poorly drained peatland. Section III to the south has more irregular topography (largely end moraines) and a warmer climate.

DESCRIPTIONS OF SUBSECTIONS AND SUB-SUBSECTIONS

SECTION I. NORTHWESTERN MINNESOTA GRASSLAND **(Red River Valley); part of Bailey and Cushwa's (1981) Humid Temperate Domain, Subhumid Prairie Division, Tall-grass Prairie Province; southern Glacial Lake Agassiz and Erskine ground moraine; tallgrass prairie and wet prairie.**

Section I (see pages 26-29 for description) there are no subsections. The section is shown on the large three-State map (Plate I) and on figure 3 in the text.

Figure 7.—Section I: *Twin Valley Prairie Scientific and Natural Area, Norman County, Minnesota. Only small remnants remain of the once vast prairies of the flat clay plain of Glacial Lake Agassiz. Mesic tallgrass prairie, seen in the foreground, was much less extensive than wet prairie on the poorly drained clay plain. Drainage has allowed most of this landscape to be converted to agriculture. Minnesota Department of Natural Resources photo by D.S. Wovcha.*

Figure 8.—Section I: *Agassiz Dunes Scientific and Natural Area, Norman County, Minnesota. Sand dune formed in deltaic deposits at the margin of Glacial Lake Agassiz. Stunted bur oak and mixed grass prairie are characteristic vegetation on this landscape of small sand dunes. Minnesota Department of Natural Resources photo by D.S. Wovcha.*

SECTION II. SOUTHWESTERN MINNESOTA GRASSLAND**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Subhumid Prairie Division, Tall-grass Prairie Province; till plains of pre-Illinoian, Illinoian, and Wisconsinan age; tallgrass prairie.**

Section II (see pages 30-32 for description) contains two subsections: Upper Minnesota River Country, Coteau des Prairies. The section and subsections are shown on the large three-State map (Plate I).

SUBSECTION II.1. Upper Minnesota River Country **(Minnesota River prairie); portions of the Des Moines lobe till plains (Olivia and Blue Earth till plains) and the Minnesota River Valley; tallgrass prairie.**

DISCUSSION: Subsection consists of a 30-mile-wide area of calcareous ground moraine, located on both sides of the Minnesota River. It was originally vegetated with tallgrass prairie. The ground moraine was deposited by the Des Moines lobe (Hobbs and Goebel 1982). The Minnesota River occupies a broad channel created by Glacial River Warren, which drained Glacial Lake Agassiz. Two areas of silt- and clay-rich lacustrine deposits are located in the northwestern and southeastern parts; these areas contain large, unbroken areas of poorly drained soils (Cummins and Grigal 1981). Steep topography is restricted to the Big Stone moraine area at the extreme western edge of the subsection, to the sides of the river, and to the sides of abandoned river channels.

SUB-SUBSECTIONS: None.

ELEVATION: 750 to 1,300 feet (229 to 396 m).

AREA: 12,103 square miles (31,347 sq km).

STATES: Minnesota.

CLIMATE: Typical continental climate with extremes in temperature from summer to winter (Hargrave 1992). Annual precipitation ranges from 25 inches in the west to 30 inches in the east, with 11 to 13 inches of growing season precipitation. As in Section I, approximately 11 percent of the annual precipitation falls from November through February (Wendland *et al.* 1992), probably resulting in extreme desiccation of most woody plants and contributing to the dominance by prairie grasses. Growing season length is approximately 147 to 152 days.

BEDROCK GEOLOGY: Bedrock is covered with 100 to 400 feet of glacial drift for most of the subsection (Olsen and Mossler 1982). Most of the subsection is underlain by Cretaceous shale, sandstone, and clay; the extreme eastern edge is underlain by more resistant Ordovician dolomite (Morey 1976). This resistant dolomite also underlies the irregular topography of the Southern Oak Plains subsection (III.4) to the east. There is a major area of exposed granite bedrock scoured by Glacial River Warren near Ortonville, and also in the river valley just west of Morton (Wheeler *et al.* 1992a). Sporadic exposures of Sioux quartzite of the upper Precambrian occur in northeastern Cottonwood County and southwestern Brown County in the southeast (Morey 1981, Olsen and Mossler 1982).

LANDFORMS: Loamy ground moraine (till plain) is the predominant landform, but end moraine, outwash deposits, and sand and clay lake plains are also present. The ground moraine is relatively flat, but contains many more small lakes and ponds (potholes) than Glacial Lake Agassiz. The steepest topography of the subsection is the Big Stone moraine, which has both steep kames and broad slopes. There are also steep bluffs along the Minnesota River Valley.

LAKES AND STREAMS: More than 150 lakes are larger than 160 acres (University of Minnesota *et al.* 1969, 1979, 1981a). Major rivers include the Minnesota and Chippewa.

SOILS: Most of the soils are loams formed from calcareous glacial drift. Although some soils are clayey, and sandy and gravelly soils occur locally, these account for only a small percentage of the subsection (University of Minnesota *et al.* 1969, 1979, 1981a). Cummins and Grigal (1981) show most of the division as Udoll and Aquolls on relatively level topography, generally with 15 feet or less of local relief; dry prairie soils (primarily Ustolls) also occur on relatively level topography. A Minnesota Department of Natural Resources map of "probable original wetlands" shows a large percentage of poorly drained or wet mineral soils, but these soils are broken into much smaller topographic units than the soils of the Red River Valley as a result of the more dissected topography of the ground moraine.

PRESETTLEMENT VEGETATION: The presettlement vegetation of the division was primarily tallgrass prairie, with many islands of wet prairie (Kratz and Jensen 1983, Marschner 1974). Flood-plain forest of silver maple, elm, cottonwood, and willow occurred along the Minnesota River and other streams. On portions of the Big Stone moraine, both steep kames and the broad slopes along the coulees supported dry and dry-mesic prairie (Wheeler *et al.* 1992a). There were also dry gravel prairies on kames.

NATURAL DISTURBANCE: Fire was responsible for maintaining the prairie. Fire suppression has allowed woodlands to develop from what were originally oak openings or brush prairies (Wheeler *et al.* 1992a).

PRESENT VEGETATION AND LAND USE: Subsection is the heart of the Minnesota Cornbelt (Wright 1972). Wheeler *et al.* (1992b) found upland prairie species to be common throughout most of the subsection (based on herbarium records).

RARE PLANT COMMUNITIES: Prairies and associated wetlands that once dominated the subsection are all rare now; these include dry prairie, mesic prairie, wet prairie, glacial till prairie, and calcareous seepage fens. Gravel prairies persist on the steep hills associated with the Minnesota River and the Big Stone moraine. The outcrops of Morton gneiss and Sioux quartzite support diverse "rock specialists" and species of temporary pools. Significant calcareous fens occur in the central portion of the Minnesota River Valley, supporting species such as *Rhynchospora capillacea* (beak-rush), *Scleria verticillata* (nut-rush), and *Cladium mariscoides* (twig-rush).

RARE PLANTS: The drier portions of the subsection, such as the Big Stone moraine, commonly support *Astragalus missouriensis* (Missouri milk-vetch), *Astragalus flexuosus* (slender milk-vetch), *Solidago mollis* (soft goldenrod), and *Happlopappus spinulosus* (cutleaf ironplant). Fire-protected xeric habitat among granite outcrops (along the Minnesota River) support the cactuses, *Coryphantha vivipera* (ball cactus) and *Opuntia macrorhiza* (plains prickly pear). *Lespedeza leptostachya* (prairie bush clover) persists on mesic to dry hill prairies associated with quartzite outcrops and with the Morton gneiss and on gravel prairies associated with abandoned channels of the Glacial River Warren. Several prairie plants are found only in the wetter prairies at the eastern edge of the subsection, including *Asclepias sullivantii* (Sullivant's milkweed), *Cacalia plantaginea* (tuberous indian-plantain), *Eryngium yuccifolium* (rattlesnake-master), and *Parthenium integrifolium* (wild quinine). Other rare species include: *Buchloe dactyloides* (buffalo grass), *Cypripedium candidum* (small white lady's-slipper), *Mammillaria vivipara* (ball cactus), *Myosurus minimus* (mousetail), *Schedonnardus paniculus* (tumblegrass).

RARE ANIMALS: Birds: *Athene cunicularia* (burrowing owl), *Bartramia longicauda* (upland sandpiper), *Lanius ludovicianus* (loggerhead shrike), *Limosa fedoa* (marbled godwit), *Speotyto cunicularia* (burrowing owl); Insects: *Hesperia dacotae* (Dakota skipper), *Oarisma poweshiek* (Powesheik skipper); Arthropods: *Phidippus pius* (jumping spider); Reptiles: *Eumeces fasciatus* (five-lined skink); Fish: *Scaphirhynchus platorynchus* (shovelnose sturgeon).

NATURAL AREAS: State Natural Areas: Blue Devil Valley, Bonanza Prairie, Clinton Prairie, Cottonwood River Prairie, Gneiss Outcrops, Osmundson Prairie; The Nature Conservancy Preserves: Plover Prairie, Clinton Prairie, Schaefer Prairie, Chippewa Prairie, Kasota Prai-

rie, North Heron Lake Preserve, Red Rock Prairie; Others: Alexandria Moraine Prairies (three areas identified as critical landscapes for biodiversity protection), Big Stone Prairie Potholes, Florida Creek Slough, Glacial River Warren, Jeffers Petroglyph Historic Site, Liable Woods, Ottawa Bluffs, Plover Prairie, Staffanson Prairie, University of Minnesota-Morris, Wahpeton Prairie, Yellow Bank Hills Scientific and Natural Area, Salt Lake Wildlife Management Area.

PUBLIC LAND MANAGERS: Wildlife Management Areas: Bashaw, Cedar Rock, Florida Creek, Foley, Gollnick, Indian Lake, Kemen, Kibler, Lac Qui Parle, Little, Minneopa, Ottawa, Perch Creek, Prairie, Ras-Lynn, Salt Lake, Sena, Swan Lake, Thielke Lake, Vallers, Victory, Vogel, Walnut Lake, Walter, Watline, West Toqua, White Prairie; Waterfowl Production Areas: Barry Lake, Bomsta, Colbert, Eids Lutheran, Farrell, Florida Creek, Haseman, Hastad, Hegland, Helgesen, Hillman, Historical Society, Krogsrud, Landers, Pearson, Prairie, Redhead Marsh, Rothi, Tangen, Taylor, Twin Lakes, Williams; State Parks: Big Stone Lake, Flandrau, Upper Sioux Agency; Others: Cottonwood County Park, Eagle Nest County Park, Renville County Park #2, Seven Mile Creek County Park, Skalbakken County Park, Granite Falls Memorial Park, Big Stone National Wildlife Refuge.

CONSERVATION CONCERNS:

BOUNDARIES: The subsection could be further subdivided, separating out parts (primarily till plain or lake plain) with different drainage conditions, soil textures, or slope classes that resulted in vegetation differences. This would require further research because intensive agricultural land use has destroyed original patterns of drainage and vegetation.

Figure 9.—*Subsection II.1: Big Stone moraine, Traverse County, Minnesota. The steep side slopes of Glacial River Warren, seen in this photo, and limited areas of steep kettle-kame topography are among the only unfarmed portions of this subsection. Dry-mesic and dry prairie dominate the slopes. The woodlands in the background, which were much less extensive before settlement are the result of fire exclusion. Most of the gently rolling moraines of this subsection are intesively farmed. Minnesota Department of Natural Resources photo by R. Dana.*

Figure 10.—*Subsection II.1: Outcrops of granitic bedrock in the Minnesota River Valley near Ortonville, Minnesota, provide a fire-protected, dry habitat which supports cactus species. Heavy grazing in surrounding prairie has allowed exotic grasses to become the dominant vegetation. Minnesota Department of Natural Resources photo by R. Dana.*

SUBSECTION II.2. Coteau des Prairies **(Prairie Coteau); dissected loess-covered till plain of pre-Illinoian, Illinoian, and late Wisconsinan age, non-dissected till plain of late Wisconsinan age; tallgrass prairie.**

DISCUSSION: The coteau is typified by highly dissected, loess-covered till plains that are Illinoian, pre-Illinoian, and late Wisconsinan in age (Lehr and Gilbertson 1988). These were originally covered with tallgrass and midgrass (mixed grass) prairie. The outer edges of the coteau are non-dissected, non-loess-covered late Wisconsinan (Des Moines lobe) end and ground moraines.

SUB-SUBSECTIONS: The Inner Coteau des Prairies (II.2.1) consists of highly dissected moraines of pre-Wisconsinan drift, capped by thick loess deposits. The Lake Benton-Adrien Coteau (II.2.2) is a landscape of rolling moraine ridges of late Wisconsinan drift mantled with loess 1 to 3 feet thick. The Ivanhoe-Worthington Coteau (II.2.3), a series of terminal and end moraines separated by ground moraines, ranges from gently undulating to steeply rolling and hilly (Hargrave 1992). Its northeastern edge is a steep escarpment, with the Minnesota lowlands to the northeast, cut by several streams occupying narrow, straight ravines. (See figure 3.)

ELEVATION: 1,140 to 1,995 feet (347 to 608 m).

AREA: 4,275 square miles (11,073 sq km).

STATES: Minnesota.

CLIMATE: Annual precipitation ranges from 24 inches in the west to 27 inches in the east; 11 to 12 inches arrive during the growing season (Hargrave 1992). Average growing season is 145 to 150 days.

BEDROCK GEOLOGY: Glacial drift is as thick as 800 feet, but there are exposures of bedrock at the southwestern edge of the section in Rock

and Pipestone Counties (Olsen and Mossler 1982). A massive outcrop of red upper Precambrian quartzite is located in those counties (Wright 1972, Morey 1976, Olsen and Mossler 1982).

LANDFORMS: The coteau contains areas typified by several landforms, including highly dissected, loess-covered till plains that are Illinoian, pre-Illinoian, and late Wisconsinan in age (Lehr and Gilbertson 1988), and non-dissected, non-loess-covered late Wisconsinan (Des Moines lobe) end and ground moraines.

LAKES AND STREAMS: See sub-subsections.

SOILS: Soils are primarily Mollisols (primarily Aquolls and Udolls, some Borolls and Ustolls). Cummins and Grigal (1981) map both dry prairie and moist prairie soils; most of the dry prairie soils occur on dissected or eroded topography, and moister prairie soils occur on rolling end moraines with variable local relief.

PRESETTLEMENT VEGETATION: Tallgrass prairie covered almost the entire landscape; wet prairies covered much less of the landscape than in Subsections I.1 and II.1 (Marschner 1974). Wet prairie was restricted to narrow stream margins in much of the subsection. Forest was similarly restricted to ravines along a few streams, such as the Rock and Redwood Rivers.

The prairies were drier in this subsection than in Subsection II.1, accounting for the prevalence of prairie plants characteristic of midgrass prairies further to the west.

NATURAL DISTURBANCE: Fire and drought maintained the prairie.

PRESENT VEGETATION AND LAND USE: The highest density of upland prairie plants on the coteau is in this subsection, according to Wheeler *et al.* (1992b).

RARE PLANT COMMUNITIES: Although prairie vegetation originally dominated the entire subsection, all prairie types are now rare, including calcareous seepage fen, dry prairie (hill subtype), dry prairie (sand-gravel subtype), glacial till hill prairie, mesic prairie, mesic prairie (crystalline bedrock subtype), and wet prairie. Maple-basswood forest is also locally present.

RARE PLANTS: *Asclepias sullivantii* (Sullivant's milkweed), *Heteranthera limosa* (mud plantain), *Isoetes melanopoda* (quillwort sp.), *Lespedeza leptostachya* (prairie bush clover), *Plantago elongata* (slender plantain), *Platanthera praeclara* (western prairie fringed orchid), *Rhynchospora capillacea* (hair-like beak-rush).

RARE ANIMALS: Birds: *Athene cunicularia* (burrowing owl), *Bartramia longicauda* (upland sandpiper), *Calcarius ornatus* (chestnut-collared longspur), *Lanius ludovicianus* (loggerhead shrike); Fish: *Notropis topeka* (Topeka shiner); Reptiles: *Emydoidea blandingii* (Blanding's turtle); Insects: *Hesperia dacotae* (Dakota skipper), *Hesperia ottoe* (Ottoe skipper), *Oarisma powesheik* (Powesheik skipper).

NATURAL AREAS: State Natural Areas: Compass Prairie, Prairie Bush Clover, Prairie Coteau; Others: Blue Gentian Prairie, Glynn Prairie, Hole-in-the-Mountain Prairie, Lundbland Prairie, Split Rock Creek Recreation Area.

PUBLIC LAND MANAGERS: Wildlife Management Areas: Altona, Badger Lake, Burke, Carlson, Casey Jones, Coon Creek, Expandere, Hole-in-the-Mountain, Penthole, Pipestone, Prairie Marshes, Salt and Pepper Creek, Sangl, Sherwood, Sioux Nation, Talcot Lake; Waterfowl Production Areas: Des Moines River, Spirit Lake; State Parks: Blue Mounds, Camden, Kilen Woods, Lake Stetek; Others: Garvin County Park, Hole-in-the-Mountain County Park, Sunrise County Park.

CONSERVATION CONCERNS:

SUB-SUBSECTION II.2.1. Inner Coteau des Prairies**; loess-mantled pre-Wisconsinan drift, mostly gently rolling; tallgrass prairie.**

DISCUSSION: This is the loess-mantled terrain beyond the outer margin of Wisconsin Glaciation. The drainage system is better developed than in more recently glaciated portions of the coteau, and there are relatively few wetlands. A massive outcrop of red quartzite bedrock is a prominent landmark. Uninterrupted prairie originally covered the unit.

ELEVATION: 1,420 to 1,770 feet (432 to 540 m).

AREA: 785 square miles 2,033 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Outcrops of Sioux quartzite are exposed in northern Rock County and southern Pipestone County (Olsen and Mossler 1982, Morey 1976, Wright 1972); but over much of the sub-subsection, glacial drift is 200 to 400 feet thick. Beneath this drift, upper Precambrian Sioux quartzite is the most common bedrock, followed by Cretaceous shale, sandstone, and clay (Morey 1976).

LANDFORMS: Loess-capped till plain. The loess mantle has smoothed the topography of the underlying till plain, creating a landscape with long, gentle slopes (University of Minnesota *et al.* 1981a). The southwestern part of the coteau consists of glacial drift covered with loess 4 to 10 feet thick (Hargrave 1992); the loess thickens to the southwest and probably originated from the outwash deposits of the Big Sioux River (Wright 1972).

LAKES AND STREAMS: Few wetlands because of the well-developed drainage system.

SOILS: Cummins and Grigal (1981) map most of the sub-subsection as dry prairie soils. Soils are classified as Mollisols (Aquolls, Udolls, Borolls, and Ustolls).

PRESETTLEMENT VEGETATION: The original vegetation was almost entirely tallgrass prairie, with only small areas of wet prairie. Forest was present along the Rock River.

NATURAL DISTURBANCE: Fire and drought maintained the prairie.

PRESENT VEGETATION AND LAND USE: The land is used primarily for crop land; little or no woodland and pasture occurs (University of Minnesota *et al.* 1981a).

RARE PLANTS: *Aristida purpurea* var. *longiseta* (red three-awn), *Bacopa rotundifolia* (water-hyssop), *Buchloe dactyloides* (buffalo grass), *Cyperus acuminatus* (umbrella-sedge), *Heteranthera limosa* (mud plantain), *Isoetes melanopoda* (a species of quillwort), *Limosella aquatica* (mudwort), *Marsilea vestita* (hairy water clover), *Myosurus minimus* (mousetail), *Opuntia macrorhiza* (plains prickly pear), *Plantago elongata* (slender plantain), *Platanthera praeclara* (western prairie fringed orchid), *Schedonnardus paniculatus* (tumblegrass), *Solidago mollis* (soft goldenrod), *Tillaea aquatica* (pigmyweed), *Verbena simplex* (narrow-leaved vervain).

RARE ANIMALS: Birds: *Athene cunicularia* (burrowing owl), *Calcarius mccownii* (McCown's longspur (extirpated)); Amphibians: *Acris crepitans blanchardi* (Blanchard's cricket frog); Reptiles: *Tropidoclonion lineatum* (lined snake); Fish: *Notropis topeka* (Topeka shiner), *Fundulus sciadicus* (plains topminnow); Insects: *Hesperia dacotae* (Dakota skipper).

NATURAL AREAS: State Natural Areas: Blue Mounds State Park, Pipestone National Monument, Split Rock Creek State Park, Prairie Coteau Scientific and Natural Area, Pipestone County; The Nature Conservancy Preserves: Hole-in-the-Mountain Prairie.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: Overgrazing, gravel mining, and conversion of the few areas presently supporting native plant communities to cropland.

BOUNDARIES: The boundary is defined by pre-Wisconsinan drift, traditionally treated as Kansan drift, as mapped by Hobbs and Goebel (1982).

SUB-SUBSECTION II.2.2. Lake Benton-Adrian Coteau**; loess-capped end moraine; tallgrass prairie.**

DISCUSSION: The Bemis moraines are prominent features of this unit. Several large meltwater gorges breach the Bemis moraine, creating local areas of steeply hilly topography, and the outer scarp has been dissected by drainage downslope. To the southwest is the loess-mantled, eroded pre-Wisconsinan drift. The northern boundary is the Bemis moraine.

ELEVATION: 1,453 to 1,995 feet (443 to 608 m).

AREA: 935 square miles (2,421 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Bedrock is not exposed here. Glacial drift is 200 to 800 feet thick over bedrock (Olsen and Mossler 1982). Cretaceous shale, sandstone, and clay are the upper bedrock in most of the sub-subsection, but there is also upper Precambrian quartzite (Morey 1976).

LANDFORMS: Loess-capped Bemis end moraine of the Des Moines lobe. The loess is 1 to 3 feet thick.

LAKES AND STREAMS: few wetlands because of the well-developed drainage pattern.

SOILS: Cummins and Grigal (1981) map most of the sub-subsection as dry prairie soils. Soils are classified primarily as Mollisols (Borolls, Udolls, and Aquolls).

PRESETTLEMENT VEGETATION: This unit was almost entirely tallgrass prairie. Hill prairie, containing dry prairie species, is locally common on the numerous steep slopes of the sub-subsection.

NATURAL DISTURBANCE: Fire and drought.

PRESENT VEGETATION AND LAND USE: Most of the sub-subsection is now farmed; crops include corn, soybeans, oats, and flax (University

Figure 11.—*Sub-subsection II.2.2: Prairie Coteau Scientific and Natural Area, Pipestone County, Minnesota. Dry hill prairie originally dominated the rolling hills of the Coteau. Conditions are drier than in much of Sections I and II, accounting for the prevalence of plants of the midgrass prairie. Minnesota Department of Natural Resources photo by E. Fuge.*

of Minnesota *et al.* 1981a). Little or no woodland or pasture occurs here.

RARE PLANTS: *Antennaria parvifolia* (small-leaved pussytoes), *Aristida purpurea* var. *longiseta* (red three-awn), *Astragalus flexuosus* (slender milk-vetch), *Botrychium campestre* (prairie moonwort), *Carex hallii* (Hall's sedge), *Cypripedium candidum* (small white lady's-slipper), *Helianthus nuttallii* (Nuttall's sunflower), *Platanthera praeclara* (western prairie fringed orchid), *Triglochin palustris* (marsh arrow-grass).

RARE ANIMALS: None identified to date.

NATURAL AREAS: See subsection.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: Bemis Moraine Prairies have been identified as a critical landscape for biodiversity protection.

SUB-SUBSECTION II.2.3. Ivanhoe-Worthington Coteau**; ground moraine and stagnation moraine; tallgrass prairie.**

DISCUSSION: This sub-subsection includes Altamont ground moraines and stagnation moraines and Bemis ground moraines. At the outer edge, where Sub-subsection II.2.3 meets Subsection II.1, the Altamont ground moraine forms a straight, steep escarpment with the Minnesota lowlands to the northeast. It drops 300 to 400 feet, from approximately 1,600 feet in the southwest to 1,200 feet in the northeast. Although the elevations are not as high as those of the Lake Benton-Adrian Coteau immediately to the south, most of the divide between the Missouri and Mississippi drainage is located within this sub-subsection (University of Minnesota *et al.* 1981a).

ELEVATION: 1,140 to 1,800 feet (347 to 549 m).

AREA: 2,555 square miles (6,617 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK GEOLOGY: The bedrock is covered with 100 to 800 feet of glacial drift (Olsen and Mossler 1982). This drift is shallowest near the base of the escarpment that defines the northern boundary of the sub-subsection.

Immediately beneath the glacial drift, most of the sub-subsection has Cretaceous shale, sandstone, and clay. However, there are also extensive areas of upper Precambrian Sioux quartzite (Morey 1976). There are no rock outcrops within the sub-subsection.

LANDFORMS: Ground moraine and stagnation moraines. The Bemis ground moraines, located along the southern edge, are flat and contain large areas of poorly drained soils. In the southeast, these poorly drained soils cover broad expanses of flat land; in the southwest, the poorly drained lands occupy drainageways in the depressions between numerous low ridges.

LAKES AND STREAMS: Several large lakes formed along the boundary between the Bemis end moraine (in Sub-subsection II.2.2) and the Bemis ground moraine; these include Lake Ocheda, Okabena Lake, Lake Menton, Lake Shaokotan, and Lake Mindeshike.

The Altamont ground moraine, which forms the outer margin of the sub-subsection, is deeply eroded by many narrow, straight stream channels. As a result of the dissected topography, most of the soils are well drained.

The Altamont ice-stagnation moraines contain most of the lakes larger than 160 acres in the sub-subsection and many small lakes. Many streams originate in the stagnation moraine and flow into either the Missouri or the Mississippi drainage systems.

SOILS: Most of the sub-subsection is mapped as well-drained loamy soils. Most of the remaining soils are mapped as poorly drained loamy soils; these are concentrated on the Altamont ice-stagnation moraine and the Bemis ground moraine in the northwest and the Bemis ground

moraine in the southeast (University of Minnesota *et al.* 1981a, Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: The entire sub-subsection was dominated by tallgrass prairie or wet prairie. Hill prairie, containing species more characteristic of the western midgrass prairies, also occurred. The steep scarp on the northern edge of the coteau supported oak, elm, ash, and basswood in its gullies, which are protected from the winds and fires of the Coteau and which also receive meltwaters from winter snow accumulations (Wright 1972).

NATURAL DISTURBANCE: Fire and drought maintained the prairie.

PRESENT VEGETATION AND LAND USE: Almost the entire sub-subsection is farmed.

RARE PLANTS: *Botrychium campestre* (prairie moonwort), *Cypripedium candidum* (a small white lady's-slipper), *Desmodium illinoensis* (Illinois tick-trefoil), *Eleocharis parvula* (a species of spike-rush), *Lespedeza leptostachya* (prairie bush clover), *Opuntia macrorhiza* (plains prickley pear), *Rhynchospora capillacea* (hair-like beak-rush), *Sanicula canadensis* (Canadian black snakeroot), *Schedonnardus paniculatus* (tumblegrass), *Scleria verticillata* (whorled nut-rush), *Triglochin palustris* (marsh arrow-grass), *Trillium nivale* (snow trillium).

RARE ANIMALS: Birds: *Calcarius mccownii* (McCown's longspur (extirpated)), *Numenius americanus* (long-billed curlew (extirpated)).

NATURAL AREAS: See subsection.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: Des Moines River Prairies have been identified as a critical landscape for biodiversity protection.

SECTION III. SOUTHEASTERN MINNESOTA AND WEST-CENTRAL WISCONSIN SAVANNA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest Province; Des Moines lobe (late Wisconsinan age) glacial features and pre-Illinoian glacial features; savanna prevalent, also tallgrass prairie, sugar maple-basswood forest.**

Section III (see pages 33-34 for description) contains four subsections: Hardwood Hills, Big Woods, Anoka Sand Plain, Southern Oak Plains. The section and subsections are shown on the large three-State map (Plate 1).

SUBSECTION III.1. Hardwood Hills **(Alexandria moraine complex); end moraines, stagnation moraines, ground moraine, drumlin fields, and pitted outwash; sugar maple-basswood forest and oak savanna.**

SUB-SUBSECTIONS: Leaf Hills, Blue Hills. (See figure 3.)

ELEVATION: 1,100 to 1,600 feet (335 to 488 m).

AREA: 7,566 square miles (19,597 sq km).

STATES: Minnesota.

CLIMATE: Continental, with extreme differences between summer and winter temperatures (Hargrave 1992). Total annual precipitation ranges from 24 inches in the west to 27 inches in the east. Growing season precipitation ranges from 10.5 to 11.5 inches. Annual snowfall averages 44 to 48 inches (Wendland *et al.* 1992). Growing season ranges from approximately 122 days in the north to 140 days in the south. Extreme minimum temperature ranges from -35˚F to -40˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: From 100 to 500 feet of glacial drift covers the bedrock over most of the subsection, with the thickest drift in the northwestern half (Olsen and Mossler 1982). Middle Precambrian granitic bedrock is locally exposed in the southeast, along the Crow River near the town of Richmond (Morey 1976, 1981). Bedrock underlying the subsection is diverse. In the south are Cretaceous shale, sandstone, and clay; lower Precambrian granite, metasedimentary and metaigneous gneiss, schist, and migmatite; and amphibolite and granulite (Morey 1976). To the north are metasedimentary rocks; iron formation; greenstone; and metavolcanic rocks, including basalt, andesite, pillow lava, tuff, and ultramafic and rhyolitic rocks.

LANDFORMS: Ice-stagnation moraines, end moraines, ground moraines, and outwash.

LAKES AND STREAMS: Kettle lakes are extremely common within the subsection, on both moraine and outwash deposits. There are more than 400 lakes larger than 160 acres and many more small lakes and potholes, covering 8 to 9 percent of the landscape. Few major streams are in the subsection; instead, this is a headwater area where streams originate.

SOILS: Soil textures range from loamy sands and sandy loams on the outwash plains to loams and clay loams on the moraines. Loamy soils are prevalent. Most of the soils are classified as Mollisols (primarily Borolls and Aquolls, with some Udolls), soils developed under grasslands, but there are some Alfisols, developed under forested conditions (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: The irregular topography and the many lakes and wetlands provided a partial barrier to fire, resulting in woodland or forest rather than prairie vegetation. The exception to this was in Sub-subsection III.1.2 and the southwest portion of Sub-subsection III.1.1, which supported prairie. Along the

prairie boundary to the west was a mosaic of aspen-oak land, and oak openings or savanna (Marschner 1974). Mixed forests of oaks, sugar maple, basswood, and other hardwoods grew in more fire-protected sites farther east. Tallgrass prairie was present on the more level terrain within the subsection.

NATURAL DISTURBANCE: Fire from the tallgrass prairie to the west was important in the oak savanna and to a far lesser extent in the sugar maple-basswood forest, where windthrow was probably more prevalent and provided greater control on the forest composition.

PRESENT VEGETATION AND LAND USE: Although large areas are under cultivation, much of the land supports second-growth forest, especially the steeper portions of the landscape. In agricultural areas, the forests are commonly grazed. Many of the poorly drained potholes remain for either recreational or wildlife use. Tourism is important, especially in areas with concentrations of lakes (Hargrave 1992).

RARE PLANT COMMUNITIES: Subsection contains several remnant dry prairies, mesic prairies, and glaciated till hill prairies. High-quality examples of tamarack swamp, black spruce swamp, and poor fen occur, as do boreal hardwood-conifer forest and aspen-birch forest.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: State Natural Areas: Agassiz Dunes, Partch Woods, Roscoe Prairie; Other: Glacial Lakes, Moe Woods, Ordway Prairie, Regal Meadow, Rockville Tamarack Bog, Seven Sisters Prairie, Strandness Prairie.

PUBLIC LAND MANAGERS: Wildlife Management Areas: Badger, Barnesville, Dorr, Emerson, Gustafson, Hubbel Pond, Shelley Island; State Parks: Glacial Lakes, Glendalough, Maplewood, Monson Lake, Sibley; State Forests: White Earth; Waterfowl Production Areas: Bjerketvedt, Edwin Lake, Gustafson, Hagen, Haugtvedt, Hintermeister, Julsrud, Kenna, Lager Larson, Larson, McDowell, Nicholson, Pomme de Terre, Underdahl; Other: Tamarac National Wildlife Refuge, Collegeville Game Refuge, Tilsberg Park, West Mill Recreation Area, Inspiration Peak State Wayside.

CONSERVATION CONCERNS: Grazing in woodlands adversely impacts the native flora.

BOUNDARIES: The Alexander moraines are being treated here as a narrower belt than was done previously. This mapping decision is based on the fact that the moraines at the north edge of the subsection become dominated by greater amounts of northern species (e.g., trembling aspen, paper birch, white pine, red pine, and jack pine) as the soils become sandier on some geomorphological units that have been included in the subsection in the past. These sandy units include the Wadena drumlins, the St. Croix moraine, and the Park Rapids-Staples outwash, all of which seem more appropriately lumped with Subsection X.5 to the north.

SUB-SUBSECTION III.1.1. Leaf Hills**; ice-stagnation and ground moraines, numerous kettle lakes; sugar maple-basswood forest and oak savanna.**

DISCUSSION: The Leaf Hills, treated as a natural division by Kratz and Jensen (1983), is topographically diverse. Sugar maple-basswood is present on ice-stagnation topography and ground moraine; it also occupies areas of outwash with many small lakes. The boundary of sugar maple-basswood with prairie is occasionally sharp at the boundary of the subsection, where the ice-stagnation topography consists largely of lakes. Where the ice-stagnation topography has few or only small lakes, oak forest or savanna dominates.

Correlation of soils, as described in Cummins and Grigal (1981), to original forest vegetation is relatively poor within the sub-subsection. This is not a comment on the quality of the soil survey, but rather on the transitional and dynamic nature of the climate, soils, and vegetation of this unit. With present climatic conditions, the lakes and irregular moraines at the western boundary are adequate to allow oak savanna and sugar maple-basswood to establish and persist; warmer, drier conditions would result in an expansion of prairie to the east. According to

Grimm (1984), Wright's (1976) radiocarbon-dated pollen diagrams from within the Big Woods showed prairie covering most of the area 7,200 years ago, followed by an expansion of oak woodland between 5,000 and 2,400 years ago. About 300 years ago, small populations of mesic hardwood species expanded dramatically, apparently in response to a climatic change.

ELEVATION: 1,100 to 1,600 feet (335 to 488 m).

AREA: 6,662 square miles (17,260 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: Irregular stagnation moraine, ground moraines (with drumlins), end moraines, and outwash.

LAKES AND STREAMS: Many lakes larger than 160 acres; many smaller lakes and wetlands, primarily in kettles on the stagnation moraine and pitted outwash. Few large streams are found in the sub-subsection, but many small streams originate within the rough terrain.

SOILS: Soils are derived from loamy and sandy till and sandy outwash; loamy soils are the most common. Mollisols formed under prairie vegetation, and Alfisols formed under forest vegetation. The most common Mollisols are Udolls, Borolls, and Aquolls; the common Alfisols are Boralfs, Udalfs, and Aqualfs (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: Oak woodland and sugar maple-basswood were the most common vegetation. At the west edge, tallgrass prairie, brush prairie, and aspen-oak woodlands were present; the sharpness of the transition to oak woodland or sugar maple-basswood forest depended upon the steepness of the moraines and the number of lakes and wetlands. Steep topography and/or many lakes resulted in an abrupt transition from prairie to oak woodland and maple-basswood.

NATURAL DISTURBANCE: Fire was the most prevalent form of disturbance in the (oak) woodlands and prairies at the western edge. Windthrow was probably more prevalent in the maple-basswood forest.

PRESENT VEGETATION AND LAND USE: Wheeler *et al.* (1992b) found flora associated with oak openings and barrens to be relatively common in the northern portion of what was treated as the Leaf Hills.

In the western part of the Alexandria moraine, where topography is steep, there are remnant dry-mesic prairies and potholes rimmed by wet prairie and marsh. Scattered aspen and oak openings remain. Maple-basswood forest occurs in pockets at the fire-protected east ends of many lakes.

RARE PLANTS: *Trillium nivale* (snow trillium), *Cirsium hillii* (Hill's thistle), *Cypripedium candidum* (white lady's-slipper).

RARE ANIMALS: *Buteo lineatus* (red-shouldered hawk), *Clemmys insculpta* (wood turtle).

NATURAL AREAS: The Nature Conservancy Preserves: Seven Sisters Prairie, Ordway Prairie, Staffanson Prairie, Moe Woods.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: Overgrazing of remnant prairies of the Alexander moraine system; non-sustainable forest management on private lands.

BOUNDARIES: Rough ice-stagnation topography, kettle lakes, and creek or river channels form the western border with the prairie. This is similar to what Grimm (1984) found in the Big Woods, where he interprets both the occurrence of water bodies and irregular ice-stagnation topography as important factors determining the vegetation; the water bodies and irregular topography provided a barrier to fire, thus allowing the forest to survive.

Although both the Leaf Hills and Big Woods are part of the Des Moines lobe (Wisconsin Glaciation), the tills of the Leaf Hills are generally considered to be sandier than those of the Big Woods. The ridges of the Leaf Hills are also larger. Outwash, stagnation topography, and ground moraine are present in both the Leaf Hills and the Big Woods subsection (Hobbs and Goebel 1982).

SUB-SUBSECTION III.1.2. Blue Hills**; pitted outwash and sandy ground moraine, numerous kettle lakes; wet prairie and trembling aspen-dominated "brushland" and "brush prairie."**

DISCUSSION: The Blue Hills consists of a small area of pitted outwash and ground moraine that occupies the east boundary of the Upper Minnesota River Country subsection. The vegetation of the sub-subsection consists largely of prairie or brush prairie surrounding numerous wetland depressions on pitted outwash.

ELEVATION: 1,150 to 1,428 feet (350 to 435 m).

AREA: 901 square miles (2,336 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Bedrock is covered with 100 to 300 feet of glacial drift (Olsen and Mossler 1982). Underlying bedrock is Cretaceous shale, sandstone, and clay; lower Precambrian granitic rocks, including metasedimentary and metaigneous gneiss, schist, and migmatite; and upper amphibolite to lower granulite facies (Morey 1976).

LANDFORMS: Pitted outwash of the Belgrade-Glenwood outwash plain and ground moraine of the Osakis till plain (University of Minnesota *et al.* 1979, Hobbs and Goebel 1982).

LAKES AND STREAMS: Kettle lakes and potholes are common, making up approximately 5 percent of the land surface (University of Minnesota *et al.* 1979). There are 53 lakes larger than 160 acres, but no large streams.

SOILS: Soils are derived both from loamy tills and sandy or gravelly outwash (University of Minnesota *et al.* 1979). Soils of the area are shown largely as grassland soils, primarily Aquolls, but also include Udolls, Ustolls, and Psamments (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: Marschner (1974) shows the vegetation as predominantly tallgrass prairie, with many potholes dominated by wet prairie and surrounded by oak openings or savanna. The combination of sandy soils and level topography was probably responsible for prairie vegetation. The western boundary of the sub-subsection, made up of steep, irregular ice-contact ridges, consisted of a narrow band of oak openings.

NATURAL DISTURBANCE: Fire probably originated both in the tallgrass prairie to the west and within the sub-subsection itself. Fire carried well because of the relatively flat topography combined with sandy soils.

PRESENT VEGETATION AND LAND USE: Descriptions of the vegetation presently found on nature preserves within the sub-subsection indicate that the vegetation forms a complex mosaic of plant communities, the result of local differences in drainage conditions, soil texture, rockiness, slope, and aspect. Gravel prairie and tallgrass prairie are found on the uplands; wet prairie, marshes, and shrub swamps are found in the potholes (The Nature Conservancy 1988).

Approximately 80 percent of the land is used for crops, 5 to 10 percent is used for pasture, and 5 to 10 percent is used for forest. The remaining 5 to 10 percent of the land remains as marshes or other wetlands (University of Minnesota *et al.* 1979).

RARE PLANT COMMUNITIES: Gravel prairie and a few dry oak savannas.

RARE PLANTS: *Astragalus neglectus* (Cooper's milk-vetch), *Cirsium hillii* (Hill's thistle), *Cypripedium candidum* (white lady's-slipper).

RARE ANIMALS: *Haliaeetus leucocephalus* (bald eagle), *Emydoidea blandingii* (Blanding's turtle).

NATURAL AREAS: The Nature Conservancy Preserves: Roscoe Prairie, Regal Meadow.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: Conversion of the prairies and wetlands to cropland.

BOUNDARIES: The relatively flat outwash and ground moraine of the sub-subsection is surrounded by steeper stagnation moraine and end moraines of the Alexandria moraine complex.

SUBSECTION III.2. Big Woods **(northern Waconia-Waseca moraine); stagnation and end moraines; hardwood forests dominated by a mix of oaks, basswood, sugar maple, and other hardwoods.**

DISCUSSION: This subsection has been known as the Big Woods (Grimm 1984). Along the western boundary adjacent to the prairie of Section II, water bodies and irregular ice-stagnation topography provide a barrier to allow the forests of the Big Woods to persist. The same features formed the fire barrier to the south and east. The subsection itself has irregular, hilly topography with many lakes and wetlands. It includes portions of the Waconia-Waseca moraine, Minnesota Valley outwash, Lonsdale-Lerdal till section, and the Prior Lake and Emmons-Faribault moraines (University of Minnesota *et al.* 1973).

SUB-SUBSECTIONS: None.

ELEVATION: 750 to 1,150 feet (229 to 351 m).

AREA: 3,092 square miles (8,008 sq km).

STATES: Minnesota.

CLIMATE: Annual precipitation ranges from 29 inches in the west to 31 inches in the east; growing season precipitation ranges from 12 to 13 inches (Hargrave 1992). Annual average snowfall is 44 to 48 inches (Wendland *et al.* 1992). Growing season length is approximately 145 to 150 days. Extreme minimum temperature ranges from -35˚F to -40˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: From 100 to 400 feet of glacial drift cover the bedrock of the subsection (Olsen and Mossler 1982). The underlying bedrocks are Ordovician and Cambrian sandstone, shale, and dolomite to the south and Cretaceous shale, sandstone, and clay to the north (Morey 1976).

LANDFORMS: Ice-stagnation features and end moraines.

LAKES AND STREAMS: Many lakes and bogs on the irregular moraines (University of Minnesota *et al.* 1979). More than 6 percent of the subsection's surface is occupied by lakes.

SOILS: Loams and clay loams (University of Minnesota *et al.* 1979). These are classified as both Mollisols (primarily Udolls and Aquolls) and Alfisols (primarily Udalfs and Aqualfs) (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: Oak woodland and maple-basswood forest were the most common vegetation types on the irregular ridges of the subsection. Based on his study of the GLO survey notes, Grimm (1984) found that the actual order of dominance in the sugar maple-basswood forest was elm (27 percent), basswood (14 percent), sugar maple (12 percent), bur oak (10 percent), ironwood, red oak, and aspen (7 percent). He also found that along the western margin of the subsection, aspen was most common (53 percent), followed by bur oak (22 percent). On all other margins, the oak woodland was dominated by a mix of aspen, red oak, bur oak, and to the east, white oak.

NATURAL DISTURBANCE: Although fire occurred within the subsection, it was much less common than on the prairies of Section I to the southwest, primarily due to the irregular topography. Windthrow was probably also an important natural disturbance, but no references were encountered in the literature.

PRESENT VEGETATION AND LAND USE: More than 75 percent of the subsection is cropland; an additional 5 to 10 percent is pasture. The remaining 10 to 15 percent of the subsection remains as either upland forest or wetland (University of Minnesota *et al.* 1979, 1980b, 1981a).

RARE PLANT COMMUNITIES: Dry prairie (sand-gravel subtype), glacial till hill prairie, and mesic prairie. Numerous high-quality areas of maple-basswood forest occur in the subsection, along with flood-plain forests and a few dry oak savannas.

RARE PLANTS: *Erythronium propullans* (dwarf trout lily) and *Trillium nivale* (snow trillium), *Besseya bullii* (kitten-tails), *Valeriana edulis* ssp. *ciliata* (valerian).

RARE ANIMALS: *Buteo lineatus* (red-shouldered hawk), *Clemmys insculpta* (wood turtle), *Emydoidea blandingii* (Blanding's turtle).

NATURAL AREAS: State Natural Areas: Black Dog Preserve, Cannon River Trout Lily, Chamberlain Woods, Mary Schmidt Crawford Woods, Savage Fen, Townsend Woods, Kasota Prairie, Mississippi River Islands, Wolsfeld Woods; The Nature Conservancy Preserves: Hardscrabble Point Woods; Other: Nerstrad Big Woods State Park, Lowry Woods, River Bend Nature Center.

PUBLIC LAND MANAGERS: Wildlife Management Areas: Boyd, Cannon River, Dwyer, Esker, Karnitz, Milest, Paulson, Vale; State Parks: Lake Maria, Minnesota Valley Trail, Sakatah Lake; Park Reserves: Carver, Crow-Hassan, Elm Creek, Hyland Lake, Lake Rebecca, Murphy-Hanrehan; Other: McLeod County Park #3, Rice County Wilderness Area, Richter Woods County Park, Carleton College Arboretum, Central Park, Izaak Walton League Park, Morris T. Baker Regional Park, Straight River Wildflower Preserve, Trout Lily Preserve.

CONSERVATION CONCERNS: Loss of remaining woodlots, prairies, and wetlands; heavy selective cutting of red oak from private forest lands.

BOUNDARIES: The southern portion of the Waconia-Waseca moraine is not included in the subsection because it contains fewer lakes and wetlands than the northern portion of the moraine. The subsection is characterized by more southern tree species and greater overall floristic diversity than the Alexandria moraine (Leaf Hills sub-subsection) to the northwest. Soils are generally loamier. To the north is the Anoka Sand Plain, which has sandier soils and flatter topography. To the south and southwest, Section I is flat to rolling ground moraine with prairie soils and vegetation.

Figure 12.—*Subsection III.2: Maple-basswood forest occupies fire-protected sites in this subsection. Common tree species of this forest type included elm, basswood, sugar maple, bur oak, ironwood, red oak, and aspen. Maple-basswood forest also occupies irregular topography, which provided fire-protection in Sub-subsections III.1.1, III.1.2, and locally in Subsection III.4. Minnesota Department of Natural Resources photo by C.K. Converse.*

SUBSECTION III.3. Anoka Sand Plain**; outwash plain and sand lake plain; northern pin oak and bur oak barrens.**

DISCUSSION: Subsection consists of flat, sandy lake plain and outwash plain along the Mississippi River. Recent mapping suggests that much of the sand plain, once thought to be fluvial, is probably lacustrine in origin (Meyer *et al.* 1993, Meyer 1993, Meyer and Hobbs 1993).

SUB-SUBSECTIONS: None.

ELEVATION: 750 to 1,050 feet (229 to 320 m).

AREA: 1,960 square miles (5,079 sq km).

STATES: Minnesota.

CLIMATE: Total annual precipitation ranges from 27 inches in the west to 29 inches in the east; growing-season precipitation ranges from 12 to 13 inches (Hargrave 1992). Annual average snowfall is 48 to 52 inches (Wendland *et al.* 1992). Growing season length ranges from approximately 136 to 156 days; the longest growing season is in the south. Extreme minimum temperature is approximately -40˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Bedrock is locally exposed in the St. Cloud area and in the St. Croix River Valley. Surface glacial deposits are usually less than 200 feet thick (Olsen and Mossler 1982). The subsection is underlain by Cambrian and Ordovician dolomite, sandstone, and shale (Morey 1976).

LANDFORMS: The major landform is a broad outwash plain, which contains small dunes, kettle lakes, and tunnel valleys, but there are small inclusions of ground moraine (Wright 1972). Parts of the sand plain are considered to be a lake plain, known as Glacial Lake Ann (Keen and Shane 1990). Low moraines are locally exposed above the outwash, and there are small dune features (Wright 1972). Ice-block depressions and southwest-trending tunnel valleys also occur on the plain.

LAKES AND STREAMS: There are 38 lakes larger than 160 acres; approximately 3 percent of the subsection's surface is covered by water. Peatlands occupy the linear depressions of many tunnel valleys.

SOILS: Soils are derived primarily from the fine sands of the outwash plain; most of these sandy soils are droughty, upland soils (Psamments), but there are organic soils (Hemists) in the ice block depressions and tunnel valleys as well as poorly drained prairie soils (Aquolls) along the Mississippi River (Cummins and Grigal 1981). About 70 to 80 percent of the soils are well drained or excessively well drained sands, and another 20 percent are very poorly drained (University of Minnesota *et al.* 1980b).

PRESETTLEMENT VEGETATION: The predominant vegetation on the droughty uplands was oak barrens and openings; characteristic trees included small and poorly formed bur oak and northern pin oak (Kratz and Jensen 1983). Jack pine was only locally present along the northern edge of the subsection. Brushland characterized large areas of the sand plain. Upland prairie formed a narrow band along the Mississippi River, as did areas of flood-plain forest (Marschner 1974). Bogs, wet prairies, and swamp forest occupied depressions in the sand plain. The largest area of wet prairie occurred in eastern Anoka County, along several strings of ice-block depressions and tunnel valleys. Small patches of maple-basswood forest also occurred on fire-protected sites.

NATURAL DISTURBANCE: Both fire and drought were probably important influences on the vegetation of the sand plain. Drought was found to cause mortality for two of the dominant species of the oak barrens and savannas, northern pin oak and bur oak, with northern pin oak appearing to be more susceptible (Faber-Langendoen and Tester 1993). During severe periods of drought, vegetation cover was greatly reduced on parts of the sand plain, resulting in eolian erosion and sand dune movement; this was documented for the Lake Ann portion of the Anoka Sand Plain ca. 7,400, 5,800, and 4,900 years B.P. (Keen and Shane 1990).

PRESENT VEGETATION AND LAND USE: Sod and vegetable crops are grown extensively on drained peat and muck areas (University of Minnesota *et al.* 1980). Urban development is expanding rapidly into the subsection. Wheeler

et al. (1992b) found species associated with oak openings and oak barrens to be abundant in the sand plain.

RARE PLANT COMMUNITIES: Dry oak savanna, dry prairie, and dry oak forest originally covered much of this landscape; high-quality remnants of these plant communities persist, along with high-quality examples of rich fens, wet meadows, flood-plain forest, emergent marsh, mixed hardwood swamps, tamarack swamps, shrub swamps, and some upland maple-basswood forests.

RARE PLANTS: *Aristida tuberculosa* (sea-beach needlegrass), *Besseya bullii* (kitten-tails), *Parthenium integrifolium* (wild quinine), *Polygala cruciata* (cross milkwort), *Rotala ramosior* (toothcup), *Scleria triglomerata* (tall nut-rush), *Xyris torta* (twisted yellow-eyed grass).

RARE ANIMALS: *Grus canadensis* (sandhill crane), *Emydoidea blandingii* (Blanding's turtle).

NATURAL AREAS: State Natural Areas: Black Dog Preserve, Boot Lake, Clear Lake, Helen Allison Savanna; Other: Cedar Creek Natural History Area, Anoka Sandplain (both identified as critical landscapes for biodiversity protection), MacDougall Homestead, Poplar Lake Open Space, Sandhill Crane Meadows, Springbrook Nature Center, Talahi Park; The Nature Conservancy Preserves: Cold Spring Heron Colony Preserve, Helen Allison Savanna.

PUBLIC LAND MANAGERS: Wildlife Management Areas: Athens, Bethel, Carlos Avery, Crane Meadow, Crooked Road, Fremont, Kunkel, Lamprey Pass, Marget Lake, Michaelson Farm, Mountain, Rice Area Sportsmen Club, Rice-Skunk, Sand Prairie, Santiago, Spectacle Lake, Suconnix; State Parks: Fort Snelling, Lake Maria; State Forests: Sand Dunes; Regional Parks: Anoka County Riverfront, Bunker Hills, Coon Rapids Dam, Crow Hassan, Elm Creek, Grass-Vadnais (Snail Lake), Hidden Falls-Crosby, Long Lake, Martin-Island-Linwood Lake, Minnehaha, Mississippi Gorge, Rum River Central; Park Reserves: Diamond Lake, Lake Hiawatha, Lyndon-Cedarglade, Powderhorn Lake; County Parks: Goose Lake County Wetlands, Ham Lake, Neds Lake; Municipal Parks: Girard Lake, Minnehaha; Other: Fort Snelling Military Reservation, John Anderson Memorial Park, Minnesota Valley National Wildlife Refuge, Mississippi National River and Recreation Area, Sherburne National Wildlife Refuge.

CONSERVATION CONCERNS: Suburban sprawl along the Twin Cities-St. Cloud corridor is resulting in major loss of remaining forests, prairies, and wetlands. Planned development is needed.

Figure 13.—*Subsection III.3: Helen Allison Savanna Scientific and Natural Area, Anoka County, Minnesota. Allison Savanna is in one of numerous areas of dunes scattered within the Anoka sand plain. Savannas of bur and northern pin oak grow on the droughty outwash and lacustrine sands of the plain. Blowouts and other openings on the sand soils support prairie grasses and other pioneer plant species. Minnesota Department of Natural Resources photo by B.C. Delaney.*

SUBSECTION III.4. Southern Oak Plains **(oak savanna); loess-covered limestone and dolomite or pre-Illinoian ground moraine; bur oak openings and tallgrass prairie.**

DISCUSSION: Much of the subsection is a rolling plain of loess-mantled ridges over sandstone and carbonate bedrock and till. At the southwestern edge of the subsection are moraine ridges that are a continuation of those found in the Big Woods, but they are smaller. As a result, fires from the surrounding prairies to the south, west, and east burnt frequently enough to maintain oak opening rather than forest. At the northern edge, Kratz and Jensen (1983) include St. Croix moraines; these moraines are sandy and stony, with some inclusions of calcareous drift. Oak openings or woodland is also the dominant vegetation on these moraines.

The subsection has traditionally been called the Southern Oak Barrens in Minnesota (Kratz and Jensen 1983), but this name implies a lack of moisture or fertility as being responsible for the open savanna dominated by bur oak. The bur oak savannas were actually located on mesic sites, and the open structure was caused by fire frequency, not low fertility.

SUB-SUBSECTIONS: None.

ELEVATION: 650 to 1,400 feet (198 to 426 m).

AREA: 3,593 square miles (9,306 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: Annual normal precipitation ranges from 28 inches in the north to 31 inches in the south, and growing season precipitation ranges from 12.5 to 13 inches (Hargrave 1992). Annual average snowfall ranges from less than 40 inches in the southwest to 52 inches in the northeast (Wendland *et al.* 1992). Average growing season ranges from 146 to 156 days in Minnesota and has been estimated at 150 days for Wisconsin (Hole and Germain 1994). Extreme minimum temperature ranges from -35˚F to -40˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Glacial drift is generally less than 100 feet thick, and maximum drift thickness is about 200 feet (Olsen and Mossler 1982). Ordovician and Devonian dolomite (some limestone, sandstone, and shale) is locally exposed, especially in the dissected stream valleys at the eastern edge (Morey 1976, Olsen and Mossler 1982). The gently sloping topography of the subsection is largely the result of resistant, underlying dolomite of the Prairie du Chien Group, which has produced a broad cuesta (Martin 1965, Finley 1976).

LANDFORMS: Much of the subsection is a loess plain over bedrock or till. Also included are late Wisconsinan end moraines, stagnation moraine, and outwash. Topography is generally gently rolling, but there are more dissected ravines at the eastern edge. The stagnation moraine in the southwest is not large, but slopes are often steep.

LAKES AND STREAMS: The few large lakes are restricted to the end moraines to the north. The southern two-thirds of this subsection has a fairly well developed drainage network, resulting from the loess cap over glacial till; the end moraines in the north have an undeveloped drainage network (Hargrave 1993). Wisconsin's prairie pothole region located in northwestern St. Croix and southwestern Polk Counties, has numerous small lakes, ponds, and wet depressions. This is one of Wisconsin's most significant grassland landscapes, where restoration efforts may focus on grassland birds. Two major rivers flow through the subsection, the Mississippi and the St. Croix.

SOILS: The subsection is a mosaic of Alfisols and Mollisols, with Alfisols correlated with savanna vegetation and steeper slopes, and Mollisols correlated with either upland prairie on relatively flat ridgetops or wetland prairies in broad depressions. Common soils include Aquolls, Udolls, Udalfs, and Aqualfs (Cummins and Grigal 1981). Prairie soils cover only a minor portion of the landscape at the northern edge of the subsection in Wisconsin (Hole 1976), even though the vegetation was mapped as tallgrass prairie (Finley 1976). The eroded surface under the mantle of loess is sandy or gravelly (Cummins and Grigal 1981). Twenty to forty feet of local relief characterizes most of the subsection. Soils within the subsection are locally

derived from the underlying residuum of dolomite bedrock (Cummins and Grigal 1981, Hole and Germain 1994).

PRESETTLEMENT VEGETATION: The presettlement vegetation was primarily bur oak savanna, but also included tallgrass prairie and maple-basswood forest. The tallgrass prairie was concentrated on the least dissected portions of the landscape, in the center of the subsection and at the northern edge in Wisconsin. The Wisconsin prairie, one of the largest in the State, is unusual in having forest soils rather than prairie soils. Oak brushlands were common along the edges of the prairie in Wisconsin. Bur oak savanna was concentrated on the rolling moraine ridges at the western edge of the subsection and in the dissected ravines at the eastern edge. Maple-basswood was restricted to minor portions of the landscape with the greatest fire protection, either in steep, dissected ravines or where stream orientation reduced fire frequency or severity.

NATURAL DISTURBANCE: Fire is the most important disturbance within the subsection. The GLO surveyors commented on the prevalence of fires in the Wisconsin part of this subsection (Finley 1976). Native American land management with fire may have been partially responsible for maintaining the prairies. The Upper Mississippian Orr culture occupied the Mississippi and St. Croix river corridors as early as 1400 to 1600 A.D. (Tanner 1986). The Dakota tribe had villages along both the east and west side of the Mississippi River in the 1760's; there were still Dakota villages west of the Mississippi in 1810.

PRESENT VEGETATION AND LAND USE: Wheeler *et al.* (1992b) found species associated with oak openings and barrens to be abundant in the western portion of the Southern Oak Plains subsection. Prairie species were more common in the east, where the topography was less dissected, than on the moraines of the southwest. Much of the area has been farmed.

RARE PLANT COMMUNITIES: Both tallgrass prairie and oak savanna, once the characteristic vegetation, are now rare due to fire suppression or conversion to agriculture. High-quality examples of several prairie and savanna types persist, including bluff prairie, dry prairie, mesic prairie, dry oak savanna, and dry oak forest. Mesic oak forest, rich fen, and tamarack swamp (seepage subtype) also occur.

RARE PLANTS: Many of the rare plants are restricted to prairies. **Minnesota only:** *Asclepias sullivantii* (Sullivant's milkweed), *Desmodium illinoense* (Illinois tick-trefoil), *Eryngium yuccifolium* (rattlesnake-master), *Erythronium propullans* (dwarf trout lily), *Orobanche uniflora* (one-flowered broom-rape), *Parthenium integrifolium* (wild quinine), *Polanisia Jamesii* (James' polanisia), *Valeriana edulis* (valerian). **Wisconsin only:** *Anemone caroliniana* (Carolina anemone), *Astragalus crassicarpus* (prairie plum). **Minnesota and Wisconsin:** *Besseya bullii* (kitten-tails), *Lespedeza leptostachya* (prairie bush clover).

RARE ANIMALS: Minnesota only: *Buteo lineatus* (red-shouldered hawk), *Falco peregrinus* (Peregrine falcon), *Lanius ludovicianus* (loggerhead shrike), *Seiurus motacilla* (Louisiana waterthrush), *Clemmys insculpta* (wood turtle), *Emydoidea blandingii* (Blanding's turtle). **Minnesota and Wisconsin:** *Crotalus horridus* (timber rattlesnake).

NATURAL AREAS: Minnesota: State Natural Areas: Falls Creek, Hastings, Hythecker Prairie, Iron Horse Prairie, Lost Valley Prairie, Pigs Eye Island Heron Rookery, Prairie Creek Woods, Shooting Star Prairie, St. Croix Savanna, Wild Indigo; Nature Centers: Carpenter, Lee and Rose Warner, Maplewood, River Bend; Others: Bailey Woods, Belwin Outdoor Education Center, Hwy 56 Wildflower Route, Jim's Prairie, McKnight Prairie, Nerstrand Woods, Poplar Lake Open Space, Ritter Farm City Park, Wilder Forest. **Wisconsin**: State Natural Areas: Kinnickinnic River Gorge and Delta, Apple River Canyon.

PUBLIC LAND MANAGERS: Minnesota: Wildlife Management Areas: Aurora, Beaver Creek, Cannon River, Cartney, Gores Pool #3, Nelson Fen, Oak Glen, Paul Hugo Farm, Tutstrum, Upper Iowa River; State Parks: Afton, Fort Snelling, Helmer Myre, Lake Louise, Nerstrand Woods, R.J. Dorer, Rice Lake; County Parks: Beaver Lake, Spring Lake, Square Lake; Regional Parks: Battle Creek, Cottage Grove Ravine, Grass-Vadnais (Snail Lake), Hidden Falls-Crosby, Lake Elmo, Lebanon Hills, Lilydale-Harriet Island; Park Reserves: Miesville Ravine, Murphy-Hanrehan, Spring Lake; Nature Preserves:

Grace, Tamarack, Tanglewood; Other: Mississippi National River and Recreation Area (and Wisconsin), Old Mill Park, Twin Cities Army Ammunition Plant, Rice County Wilderness Area. **Wisconsin:** State Parks: Kinnickinnic, Willow River; National Scenic Riverways: Lower St. Croix; Wildlife Areas: St. Croix Islands.

CONSERVATION CONCERNS: Most surviving prairie/savanna remnants are associated with steep gravelly-sandy bluffs, usually along river valleys. A few deep soil prairies persist in rights-of-way and cemeteries, but agricultural use totally dominates the landscape. Good wetland communities and significant aquatic habitats persist, especially along the St. Croix River and its major tributaries. The watersheds of the St. Croix, Mississippi, Whitewater, and Root Rivers have all been identified as critical landscapes for biodiversity protection in Minnesota.

BOUNDARIES: In my treatment, the Minnesota part of the subsection is smaller than that delineated by Kratz and Jensen (1983). I have combined the heavily eroded, steep bluffs of the eastern portion of their "Southern Oak Barrens Section" into the Blufflands (Paleozoic Plateau (Hallberg *et al.* 1983) or Driftless) of Section IV, which continues into Wisconsin. The central, less dissected portion of the subsection, which supported upland tallgrass prairie and bur oak savanna, is retained in this subsection.

The subsection continues into west-central Wisconsin, where upland prairie and bur oak openings grow on silt loams over acidic, sandy loam glacial drift on undulating to rolling topography (Hole 1968, 1976; Hole and Germain 1994).

Figure 14.—*Subsection III.4: St. Croix Savanna Scientific and Natural Area, Washington County, Minnesota. Broad, dry ridges of sand and gravel support open savannas of bur oak, surrounded by tallgrass and midgrass prairie. Most of the tallgrass prairie and oak savanna has been converted to agriculture. Minnesota Department of Natural Resources photo by J.C. Almendinger.*

Figure 15.—*Subsection III.4: A small remnant of wet prairie persists in a moist depression in Ramsey County, Minnesota. Within the subsection, wet prairies originally occurred in swales and shallow depressions within tallgrass prairies and oak savannas, and also along the margins of marshes and wet meadows. Minnesota Department of Natural Resources photo by D.S. Wovcha.*

SECTION IV. DRIFTLESS AREA **(Paleozoic Plateau or Blufflands); part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest Province; highly dissected, loess-capped unglaciated landscape, including some pre-Illinoian age glacial features; oak savanna, tallgrass prairie, midgrass prairie, sugar maple-basswood forest.**

Section IV (see pages 35-37 for description) contains three subsections: Prairie du Chien, Eau Claire, Maple-Basswood Forested River Ravines. The section and subsection are shown on the large three-State map (Plate I).

SUBSECTION IV.1. Prairie du Chiens**; limestone and dolomite bedrock predominant; oak savanna and tallgrass prairie, some sugar maple-basswood forest.**

DISCUSSION: Subsection is distinguished by the predominance of limestone and dolomite bedrock. Algific talus slope is restricted to this subsection, and relict white pine forests also occur here.

SUB-SUBSECTIONS: None.

ELEVATION: 603 to 1,450 feet (184 to 442 m).

AREA: 7,904 square miles (20,480 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: See section.

BEDROCK GEOLOGY: Large exposures of bedrock occur in the steep ravines. These exposures are primarily Ordovician dolomite, limestone, and sandstone in Minnesota; Cambrian sandstone, shale, and dolomite are exposed along the valley walls of the Mississippi River (Morey 1981, Morey *et al.* 1982, Sims *et al.* 1966). Devonian dolomite and limestone are more locally exposed along the western edge of the subsection, in Minnesota. In Wisconsin, Ordovician dolomites have the most exposures (Ostrom 1981).

LANDFORMS: See section.

LAKES AND STREAMS: Several major rivers flow through the subsection, forming steep ravines and, on some of the streams, broad alluvial plains. These rivers include the Mississippi, Wisconsin, Pecatonica, and the lower reaches of the Black and Chippewa; the Kickapoo forms the western boundary between Subsections IV.3.1 and IV.1.

SOILS: Prairie soils on the ridges; these are thick silt loams (loess) over cherty residuum over dolomite (Hole 1968, 1976; Hole and Germain 1994; Cummins and Grigal 1981). On some valley walls, soils are silt loam over sandstone. Soils are classified as Udalfs on ridges and fertile Udolls on valley floors (Anderson and Grigal 1984).

PRESETTLEMENT VEGETATION: Almost all the tallgrass prairie was restricted to this subsection; tallgrass prairie and bur oak savanna were the major vegetation types on ridge tops and dry upper slopes. Oak forest was common on moister slopes (Marschner 1974, Finley 1976, Lange 1990). Although the tallgrass prairies were restricted to the relatively narrow ridgetops, they often extended continuously for 30 or more miles along major stream divides. See section.

NATURAL DISTURBANCE: Fire was important on the upland prairie and oak-dominated ecosystems. Windthrows was probably more prevalent and important in the maple-basswood forest. Recent records of tornados and ice storms indicate that they had local impact on forest vegetation.

PRESENT VEGETATION AND LAND USE: The ridge tops and stream valleys are heavily used for agriculture; oak and hardwood forests persist on steep slopes.

RARE PLANT COMMUNITIES: Prairies, although once prevalent, are now rare. A rare natural community, algific talus slope, is found along the steep bluffs of tributaries of the Mississippi River. Relict pine forests are also common, especially at the southern edge of the subsection in Wisconsin.

RARE PLANTS: Minnesota only: *Arenaria dawsonensis* (rock sandwort), *Carex davisii* (Davis's sedge), *Chrysosplenium iowense* (golden saxifrage), *Leersia lenticularis* (catchfly grass), *Melica nitens* (three-flowered melic), *Scutellaria ovata* (ovate-leaved skullcap), *Valeriana edulis* (valerian). **Wisconsin only:** *Aconitum noveboracense* (northern monkshood), *Agalinis gattingeri* (round-stemmed false foxglove), *Asplenium pinnatifidum* (pinnatifid spleenwort), *Commelina erecta* var. *deamiana* (narrow-leaved dayflower), *Dasistoma macrophylla* (mullein foxglove), *Eclipta alba* (yerba de tajo), *Lespedeza violacea* (violet bush clover), *Lespedeza virginica* (slender bush clover), *Myosotis laxa* (small forget-me-not), *Onosmodium hispidissimum* (marbleseed), *Parthenium integrifolium* (wild quinine), *Pellaea atropurpurea* (purple cliff brake), *Phegopteris hexagonoptera* (broad beech fern), *Polygala incarnata* (pink milkwort), *Psoralea esculenta* (pomme-de-prairie), *Rhamnus lanceolata* var. *glabrata* (lance-leaved buckthorn), *Triphora trianthophora* (nodding pogonia), *Silene virginica* (fire pink). **Minnesota and Wisconsin:** *Adoxa moschatellina* (moschatel), *Lesquerella ludoviciana* (bladder pod), *Napaea dioica* (glade mallow), *Orobanche uniflora* (one-flowered broomrape).

RARE ANIMALS: Minnesota only: *Hybopsis x-punctata* (gravel chub), *Moxostoma duquesnei* (black redhorse). **Wisconsin only:** *Wilsonia citrina* (hooded warbler), *Acris crepitans blanchardi* (Blanchard's cricket frog), *Elaphe obsoleta* (rat snake), *Libytheana bachmanii* (snout butterfly), *Gomphurus externus* (plains clubtail (dragonfly)), *Macromia taeniolata* (royal river cruiser (dragonfly)), *Stylurus plagiatus* (russet-tipped clubtail (dragonfly)). **Minnesota and Wisconsin:** *Crotalus horridus* (timber rattlesnake).

Figure 16.—*Subsection IV.1: Rush Creek Bluffs, Crawford County, Wisconsin. Bluff prairie occupies the dry south- and west-facing ridgetops within the Driftless Area. Moister slopes support forests of oak and maple-basswood, as well as oak savannas. Forests occupy the broad flood plain of the Mississippi River. Photo by E. Epstein.*

NATURAL AREAS: Wisconsin: State Natural Areas: Wyalusing Hardwood Forest, Brady's Bluff Prairie, Dewey Heights Prairie, Midway Railroad Prairie, New Observatory Woods, Tiffany Bottoms, Tower Hill Bottoms, Durst Rockshelter, Pine Hollow, Lodde's Mill Bluff, Avoca Prairie-Savanna, Blue River Sand Barrens, Five-Mile Bluff Prairie, Nelson-Trevino Bottoms, Honey Creek, Spring Green Reserve, Natural Bridge and Rockshelter, Trenton Bluff Prairie, Mazomanie Bottoms, Olson Oak Woods, Belmont Mound Woods, Rush Creek, Whitman Bottoms Floodplain Forest, Battle Bluff Prairie, Ipswich Prairie, Robinson Creek Pines, Cook Creek Cliffs, Rush River Delta, Morgan Coulee Prairie, Black Earth Prairie, Ferry Bluff, Wauzeka Bottoms, Eureka Maple Woods, Adiantum Woods, Arena Pines-Sand Barrens, Bakken's Pond, Mazomanie Oak Barrens, Richwood Bottoms, Smith Slough, Woodman Sand Prairie, Pecatonica River Woods, Gasner Hollow Prairie, Snow Bottom. **Minnesota:** State Natural Areas: Cannon River Turtle Preserve, Racine Prairie, Cannon Valley Trail.

PUBLIC LAND MANAGERS: See section. **Minnesota:** State Parks: Carley, Frontenac. State Forests: R.J. Dorer. Wildlife Management Areas: Gores.

CONSERVATION CONCERNS: See section.

BOUNDARIES: Boundaries are based on interpretation by Hole and Germain (1994) in Wisconsin and my interpretation of Morey *et al.* (1982) in Minnesota.

SUBSECTION IV.2. Eau Claire**; sandstone bedrock predominant; oak forest, savanna, and brushlands.**

DISCUSSION: The drier soils of this subsection result in greater fire frequency and more oak dominance than in the other subsections.

SUB-SUBSECTIONS: None.

ELEVATION: 653 to 1,416 feet (199 to 432 m).

AREA: 4,440 square miles (11,504 sq km).

STATES: Wisconsin.

CLIMATE: See section.

BEDROCK GEOLOGY: Large exposures of Cambrian sandstone bedrock, with some dolomite and shale, occur in the steep ravines (Ostrom 1981, Morey *et al.* 1982).

LANDFORMS: See section.

LAKES AND STREAMS: No natural lakes. The Chippewa, Black, and Baraboo Rivers flow through the subsection.

SOILS: Soils are silt loams and sandy loams over sandstone on a rolling to steep landscape. Surface soil is derived from a mix of leached loess and sandstone residuum (Hole and Germain 1994, Hole 1968). Soils are primarily Udalfs (Hole 1976).

PRESETTLEMENT VEGETATION: The original vegetation was a mosaic of oak forest, dominated by white oak, black oak, and bur oak; oak savanna or oak opening dominated by bur oak, with some white and black oak; and oak brushlands (Finley 1976). The brushlands were more common in this subsection than anywhere else in Wisconsin. Hemlock, rare this far south in Wisconsin, also occurred on north and east sandstone exposures in the southeast.

NATURAL DISTURBANCE: Fire was important in maintaining oak forest and still more important for maintaining the oak savanna. The brushlands were lands that had recently burnt.

PRESENT VEGETATION AND LAND USE: Heavy agricultural land use on the ridge tops and in the alluvial valleys. Steep side slopes remain largely forested.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Wisconsin only: *Talinum rugospermum* (prairie fame-flower), *Prenanthes aspera* (rough white lettuce), *Sullivantia renifolia* (kidney-leaved sullivantia), *Asclepias lanuginosa* (wooly milkweed), *Anemone caroliniana* (Carolina anemone), *Scutellaria parvula* var. *parvula* (small skullcap).

RARE ANIMALS: Wisconsin only: *Ammodramus henslowii* (Henslow's sparrow), *Ammodramus savannarum* (grasshopper sparrow), *Chondestes grammacus* (lark sparrow), *Dendroica cerulea* (cerulean warbler), *Empidonax virescens* (Acadian flycatcher), *Icterus spurius* (orchard oriole), *Ophisaurus attenuatus* (slender glass lizard), *Ammocrypta asprella* (crystal darter), *Cycleptus elongatus* (blue sucker), *Polyodon spathula* (paddlefish), *Lycaeides melissa samuelis* (Karner blue butterfly), *Ophiogomphus aspersus* (brook snaketail (dragonfly)).

NATURAL AREAS: Wisconsin: State Natural Areas: Tamarack Creek Bog, Gullickson's Glen, Putnam Park, La Crosse River Trail Prairie, Fort McCoy, Otter Creek Oak Barrens, Nine Mile Island, Caryville Savanna, Bass Hollow.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS:

BOUNDARIES: Boundaries are based on interpretations of soils by Hole (1976) and bedrock geology by Morey *et al.* (1982).

SUBSECTION IV.3. Maple-Basswood Forested River Ravines**; steeply dissected topography on limestone, dolomite, or sandstone; forest dominated by sugar maple-basswood.**

DISCUSSION: This subsection is designated on the basis of extensive sugar maple-basswood-dominated forests, concentrated in the steepest, most fire-protected topography within the section. Three areas where maple-basswood forest dominated within the section have been designated as distinct sub-subsections because they are spatially disjunct from each other, separated by other units of Section IV.

SUB-SUBSECTIONS: Kickapoo-Wisconsin River Ravines, a protected 1,300-square-miles block between the Kickapoo River and the Wisconsin River in Wisconsin (IV.3.1); Chippewa River Ravines, the northern edge of the subsection (IV.3.2) in St. Croix and Pierce Counties, Wisconsin, where fire protection is provided by several north-south-oriented ravines; and Mississippi River Ravines, the steep ravines of the Mississippi River and its major tributaries in Minnesota (IV.3.3). (See figure 3.)

ELEVATION: 625 to 1,450 feet (190 to 442 m).

AREA: 3,859 square miles (10,001 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: See section.

BEDROCK GEOLOGY: Large exposures of bedrock occur in the steep ravines, primarily Ordovician dolomite, limestone, and sandstone in Minnesota, with Cambrian sandstone, shale, and dolomite exposed along the valley walls of the Mississippi River (Morey 1981, Sims *et al.* 1966).

LANDFORMS: See section.

LAKES AND STREAMS: No natural lakes. Both the Kickapoo and Wisconsin Rivers form boundaries of Sub-subsection IV.3.1, and the Chippewa River flows through Sub-subsection IV.3.2.

SOILS: Silt loam over acid till in the north; silt loam over cherty red clay (residuum), dolomite, and sandstone in the south (Hole 1968, 1976; Hole and Germain 1994; Cummins and Grigal 1981). Soils are classified as Udalfs on the ridges and Orthents on the flood plain (Anderson and Grigal 1984).

PRESETTLEMENT VEGETATION: Maple-basswood forest on highly dissected topography with fire protection. It occurred primarily on north-facing slopes, especially in lower slope positions. Maple-basswood forest was concentrated in three areas within Section IV, as represented by Sub-subsections IV.3.1, IV.3.2, and IV.3.3).

NATURAL DISTURBANCE: Fire was presumably less prevalent within the maple-basswood forest than in adjacent oak savanna or prairie.

PRESENT VEGETATION AND LAND USE: Most of the forest has been cleared for agriculture except on the steep valley walls.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

BOUNDARIES: Boundaries are based on interpretations by Hole and Germain (1994) and my interpretations of Marschner (1974).

SUB-SUBSECTION IV.3.1. Kickapoo-Wisconsin River Ravines**; steeply dissected topography on dolomite, sandstone, or shale; forest dominated by sugar maple-basswood.**

DISCUSSION: This sub-subsection is designated on the basis of extensive sugar maple-basswood-dominated forests, concentrated in the steepest, most fire protected topography within the section.

ELEVATION: 630 to 1,450 feet (192 to 442 m).

AREA: 1,300 square miles (3,370 sq km).

STATES: Wisconsin.

CLIMATE: See section.

BEDROCK GEOLOGY: Underlying bedrock consists of Ordovician dolomite, with some sandstone and shale; and Cambrian sandstone, with some shale and dolomite (Morey 1981, Sims *et al.* 1966). Sandstone is exposed in some of the steep ravine walls (Hole and Germain 1994).

LANDFORMS: See section.

LAKES AND STREAMS: No natural lakes. Both the Kickapoo and Wisconsin Rivers form boundaries of the sub-subsection.

SOILS: Soils are primarily silt loams (loess) over residuum. The residuum is derived from underlying dolomite bedrock (Hole 1976, Hole and Germain 1994).

PRESETTLEMENT VEGETATION: The dominant vegetation was sugar maple-basswood forest.

NATURAL DISTURBANCE: Fire was probably less prevalent within the maple-basswood forest than in adjacent oak savanna or prairie. Two areas of windthrown forest were noted in the original GLO surveyor's notes (Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: Most of the forest has been cleared for agriculture except on the steep valley walls.

RARE PLANT COMMUNITIES: Relict hemlock stands occur within the sub-subsection.

RARE PLANTS: *Aconitum noveboracense* (northern monkshood), *Carex prasina* (drooping sedge), *Minuartia dawsonensis* (northern rock sandwort), *Rhododendron lapponicum* (Lapland rosebay), *Sullivantia renifolia* (kidney-leaved sullivantia), *Trillium nivale* (snow trillium).

RARE ANIMALS: *Helmitheros vermivorus* (worm-eating warbler), *Oporornis formosus* (Kentucky warbler).

NATURAL AREAS: Wisconsin: State Natural Areas: Mt. Pisgah Hemlock-Hardwoods, Ableman's Gorge, Hub City Bog, Bear Creek Cave, Pewits Nest, Baxter's Hollow, McGilurais Woods, Pine Glen, Honey Creek, Koshawago Springs.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS:

BOUNDARIES: Boundaries are based on interpretations by Hole and Germain (1994).

SUB-SUBSECTION IV.3.2. Chippewa River Ravines**; steeply dissected topography on dolomite; sugar maple-basswood-dominated forest.**

DISCUSSION: This sub-subsection is designated on the basis of extensive sugar maple-basswood-dominated forests, concentrated in the steepest, most fire protected topography within the section. Several north-south-oriented ravines provide such fire protection.

ELEVATION: 720 to 1,320 feet (219 to 420 m).

AREA: 864 square miles (2,239 sq km).

STATES: Wisconsin.

CLIMATE: See section.

BEDROCK GEOLOGY: Ordovician dolomite underlies the sub-subsection (Ostrom 1981, Morey *et al.* 1982).

LANDFORMS: See section.

LAKES AND STREAMS: No natural lakes. The Chippewa River flows through the sub-subsection.

SOILS: Soils are developed from silt loam (loess) over pre-Wisconsinan till (Hole 1976, Hole and Germain 1994). The till ranges from leached (acidic) to calcareous. Soils are classified primarily as Udalfs (Hole 1976).

PRESETTLEMENT VEGETATION: Maple-basswood forest occurred within the highly dissected topography of the sub-subsection. Fire protection is provided by several north-south-oriented ravines.

NATURAL DISTURBANCE: Several areas of windthrown forest were noted by GLO surveyors (Canham and Loucks 1984). Fire was probably less prevalent within the maple-basswood forest than in adjacent oak savanna or prairie.

PRESENT VEGETATION AND LAND USE: Most of the forest has been cleared for agriculture except on the steep valley walls.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: Wisconsin: State Natural Areas: Plum Creek Woods.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS:

BOUNDARIES: Boundaries are based on my interpretations of soil surveys, topographic maps, and the distribution of forest types as mapped by Finley (1976).

SUB-SUBSECTION IV.3.3. Mississippi River Ravines**; steeply dissected topography on either limestone, dolomite, sandstone, or shale; sugar maple-basswood-dominated forest.**

DISCUSSION: This subsection is designated on the basis of extensive sugar maple-basswood-dominated forests, concentrated in the steepest, most fire protected topography along the Mississippi River and some of its major tributaries.

ELEVATION: 625 to 1,378 feet (190 to 420 m).

AREA: 1,695 square miles (4,393 sq km).

STATES: Minnesota.

CLIMATE: See section.

BEDROCK GEOLOGY: Large exposures of bedrock occur in the steep ravines, primarily Ordovician dolomite, limestone, and sandstone; and Cambrian sandstone, shale, and dolomite are exposed along the valley walls of the Mississippi River (Morey 1981, Sims *et al.* 1966).

LANDFORMS: See section.

LAKES AND STREAMS: No natural lakes. The Mississippi River forms the eastern boundary of the sub-subsection.

SOILS: Soils are silt loam (loess) over residuum; texture of the residuum ranges from clay to sand (Cummins and Grigal 1981). The underlying bedrock is dolomite. Soils are classified as Udalfs on ridges and Orthents on flood plains (Anderson and Grigal 1984, Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: Maple-basswood forest on highly dissected topography of the sub-subsection, protected from fire by the steep ravines of the Mississippi River and its major tributaries.

NATURAL DISTURBANCE: Fire was probably less prevalent within the maple-basswood forest than in adjacent oak savanna or prairie.

PRESENT VEGETATION AND LAND USE: Most of the forest has been cleared for agriculture except on the steep valley walls.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Dodecatheon amethystinum* (jewelled shooting star), *Sanicula trifoliata* (black snakeroot), *Solidago sciaphila* (cliff goldenrod), *Talinum rugospermum* (rough-seeded fameflower).

RARE ANIMALS: Fish: *Lampetra appendix* (American brook lamprey), *Notropis amnis* (pallid shiner), *Notropis emiliae* (pugnose minnow), *Cycleptus elongatus* (blue sucker), *Ictalurus furcatus* (blue catfish), *Etheostoma chlorosomum* (bluntnose darter), *Ammocrypta asprella* (crystal darter); Mussels: *Fusconaia ebena* (ebony shell), *Elliptio crassidens* (elephant ear); Insects: *Cicindela splendida cyanocephalata* (tiger beetle); Arthropods: *Sassacus papenhoei*, *Phidippus apacheoanus* (jumping spiders).

NATURAL AREAS: State Natural Areas: Kellogg-Weaver Dunes, Mound Prairie, Rushford Sand Barrens. Research Natural Areas: Reno Bottoms.

PUBLIC LAND MANAGERS: State Parks: Beaver Creek Valley, Forestville, O.L. Kipp, John A. Latsch Whitewater. State Forests: R.J. Dorer. State Trails: Root River. Wildlife Management Areas: Keller, McCarthy Lake, Whitewater. Other: Upper Mississippi River Wildlife and Fish Refuge.

CONSERVATION CONCERNS:

BOUNDARIES: Boundaries are based on my interpretations of Marschner (1974) and topographic maps.

Figure 17.—*Sub-subsection IV.3.3: Extensive flood plain forest occupies the broad flood plain of the Mississippi River in the foreground. The highly dissected slopes of the Driftless Area (Paleozoic Plateau) are in the background. Minnesota Department of Natural Resources photo by H. Dunevitz.*

SECTION V. SOUTHEASTERN WISCONSIN SAVANNA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest Province; glaciated landscape of late Wisconsinan age; savanna (most common), tallgrass prairie, deciduous forest.**

Section V (see pages 38-39 for description) contains four subsections: Central Wisconsin Sand Plain, Southeastern Wisconsin Till Plain, Lake Winnebago Clay Plain, Rock River Hill Country. The section and subsections are shown on the large three-State map (Plate I).

SUBSECTION V.1. Central Wisconsin Sand Plain**; sand lake plain and outwash plain; jack pine barrens, sedge meadows, and conifer swamps.**

DISCUSSION: Glacial Lake Wisconsin occupied much of the subsection, depositing glacial lacustrine sediments. Sub-subsections: Black River Falls (V.1.1), Camp Douglas (V.1.2), Stevens Point (V.1.3), Waupaca (V.1.4) (see figure 4).

ELEVATION: 787 to 1,331 feet (240 to 406 m).

AREA: 3,934 square miles (10,194 sq km).

STATES: Wisconsin.

CLIMATE: The growing season can be as long as 150 days in the subsection. However, it is shorter than 120 days in lowland outwash and lake plain areas, which are subject to late spring and early fall frosts (Hole and Germain 1994). Average annual precipitation is approximately 32 inches, and average annual snowfall ranges from 40 inches in the south to approximately 48 inches in the north (Wendland *et al.* 1992). Extreme minimum temperature ranges from approximately -35˚F to less than -40˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Subsection is underlain by Cambrian sandstone (Ostrom 1981, Morey *et al.* 1982), which is locally exposed as buttes, such as Friendship Mound and Roche à Cris (Roche-A-Cri), where the sandstone is most resistant to weathering (Martin 1965, Hole 1968, Hole and Germain 1994). Precambrian-age (Archean) gneiss and amphibolite occur at the northern edge of the sub-subsection (Morey *et al.* 1982). Granitic rock of the Wolf River batholith (Precambrian age) occurs in the northeast.

LANDFORMS: The western three-quarters of the subsection is flat lacustrine sand plain and outwash plain, characterized by either extremely droughty or poorly drained soils (Hole 1968, 1976). The lake plain has areas of stabilized sand dune. The remaining eastern quarter of the subsection is rolling and undulating moraine and pitted outwash, with a narrow band of lacustrine sands at the extreme eastern edge. There are numerous exposed sandstone buttes in the west (Hole and Germain 1994). The buttes often stand 200 to 300 feet above the adjacent plain.

A broad outwash plain is located in the center, generally along the east side of the Wisconsin River, and bordering the western edge of the pitted outwash and moraine.

West of the outwash plain was a broad expanse of sand lake plain, which had both poorly drained sands and excessively drained sands. On the lake plain, there is a complex mosaic of plant communities that include conifer-dominated swamp forest, marsh and sedge meadow, and jack pine-northern pin oak barrens. The predominant landforms are glacial lake bed and outwash plain, with some pitted outwash and ground moraine at the eastern edge.

LAKES AND STREAMS: No large natural lakes. The Wisconsin River is the largest river that flows

through the subsection; other rivers include the Yellow, Lemonweir, and the East Fork of the Black.

SOILS: Parent material for soils is sand, either poorly drained or excessively drained on the outwash and lake plain. Sedge peat has formed on the sand lake plain and more locally on the outwash. Soils on the moraines and pitted outwash are loamier.

PRESETTLEMENT VEGETATION: Droughty outwash and sand lake plain supported jack pine-northern pin oak barrens. Poorly drained outwash and sand lake plain supported sedge meadows, bog, marsh, or conifer swamps of tamarack and black spruce. The pitted outwash and moraines supported forests of white oak, black oak, and bur oak.

NATURAL DISTURBANCE: Fire and seasonal flooding both occurred commonly.

PRESENT VEGETATION AND LAND USE: Most of the dry barrens and poorly drained lake plain remain with original vegetation, but the poorly drained soils of the outwash plain have been ditched and converted to agriculture.

RARE PLANT COMMUNITIES: Coastal plain marsh and white pine-red maple-dominated flatwoods occur nowhere else in Wisconsin.

RARE PLANTS: *Anemone multifida* (Hudson Bay anemone), *Bartonia virginica* (screwstem), *Fuirena pumila* (umbrella sedge), *Myriophyllum farwellii* (Farwell's water-milfoil), *Oxytropis campestris* var. *chartacea* (Fassett's locoweed), *Polygala cruciata* (cross milkwort), *Rhexia virginica* (Virginia meadow beauty), *Thelypteris simulata* (Massachusetts fern).

RARE ANIMALS: *Erynnis persius persius* (Persius dusky wing), *Incisalia irus* (frosted elfin), *Lycaeides melissa samuelis* (Karner blue), *Ophisaurus attenuatus* (western slender glass lizard), *Sistrurus catenatus* (eastern massasauga rattlesnake), *Tympanuchus cupido* (greater prairie chicken).

NATURAL AREAS: Wisconsin: State Natural Areas: Necedah Oak-Pine Savanna and Forest (also Federal Research Natural Area), Castle Mound Pine Forest, Buena Vista Quarry Prairie, Summerton Bog, Lawrence Creek, Buena Vista Prairie Chicken Meadow, Ennis Lake-Muir Park, Comstock Bog-Meadow, Keller Whitcomb Creek Woods, Sohlberg Silver Lake, Bass Lake Fen, Myklebust Lake, New Hope Pines, Dewey Marsh, Roche-A-Cri (Roche à Cris) Mound, Washburn Marsh, Pope Lake, Lost Lake, Mud Lake Bog, Baraboo River Floodplain Forest, Observatory Hill, Mud Lake-Radley Creek Savanna, Plainfield/Second Lake, Pickerel Lake, Brooks Bluff, and Jay Creek Pine Forest, Ketchum Pines, Quincy Bluff; State Parks: Roche-A-Cri (Roche à Cris), Buckhorn, and Mill Bluff; The Nature Conservancy Preserves: Page Creek Marsh, Summerton Bog, Quincy Bluff.

PUBLIC LAND MANAGERS: National Wildlife Refuges: Necedah; State Forests: Black River; Wildlife Areas: Sandhill, Meadow Valley, Buena Vista Marsh, Wood County; Other: Numerous county forests.

CONSERVATION CONCERNS: Several factors are causing the continued degradation of the ecosystems of this subsection, including fire exclusion, continued alteration of wetlands through ditching/diking, expansion of the cranberry industry, and mining of ground water for irrigation. Large areas consist of pine plantation. Opportunities for large-scale conservation projects are outstanding due to large amounts of publicly owned land and relatively few competing uses for land by the private sector.

SUB-SUBSECTION V.1.1. Black River Falls**; droughty sand lake plain; jack pine barrens.**

DISCUSSION: Sub-subsection is level, droughty lacustrine sands originally dominated by pine and oak barrens.

ELEVATION: 800 to 1,331 feet (244 to 406 m).

AREA: 361 square miles (935 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Underlying bedrock is predominantly Cambrian sandstone, but Precambrian-age (Archean) gneiss and amphibolite occur at the northern edge of the sub-subsection (Morey *et al.* 1982). There are numerous buttes of the most erosion-resistant sandstone.

LANDFORMS: The sand lake plain contains scattered sandstone buttes.

LAKES AND STREAMS: No large lakes or major streams.

SOILS: Cambrian bedrock is the parent for droughty, infertile Boone sands, classified as Quartzipsaments (Hole 1976, Hole and Germain 1993).

PRESETTLEMENT VEGETATION: Jack pine-northern pin oak barrens were prevalent, with some dominance by oak forest. Wetlands, though not extensive, supported mixed conifer swamps of tamarack and black spruce.

NATURAL DISTURBANCE: Fire.

PRESENT VEGETATION AND LAND USE: Most of the dry barrens of the lake plain remain dominated by original vegetation, although these barrens have probably been altered by fire suppression.

RARE PLANT COMMUNITIES: Rare communities include white pine flatwoods, pine barrens, and coastal plain marsh.

RARE PLANTS: *Bartonia virginica* (screwstem), *Carex folliculata* (long sedge), *Myriophyllum farwellii* (Farwell's water-milfoil), *Oryzopsis canadensis* (Canadian rice grass), *Polygala cruciata* (cross milkwort), *Rhexia virginica* (Virginia meadow beauty), *Thelypteris simulata* (Massachusetts fern).

RARE ANIMALS: *Erynnis persius persius* (Persius dusky wing), *Incisalia irus* (frosted elfin), *Lycaeides melissa samuelis* (Karner blue), *Ophisaurus attenuatus* (western slender glass lizard). *Dendroica kirtlandii* (Kirtland's warbler) has been sighted within this sub-subsection, but breeding pairs have not been documented.

NATURAL AREAS: State Natural Areas: Castle Mound Pine Forest, Washburn Marsh, Robinson Creek Pines, Jay Creek Pine Forest, Ketchum Pines.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS:

SUB-SUBSECTION V.1.2. Camp Douglas**; poorly drained sand lake plain; conifer swamp and marsh.**

DISCUSSION: Sub-subsection is level, wet muck and mineral soil dominated by wet meadow and swamp forest.

ELEVATION: 885 to 1,300 feet (270 to 396 m).

AREA: 699 square miles (1,810 sq km).

STATES: Wisconsin.

CLIMATE: See subsection. The wet depressions are the most frost-prone part of Subsection V.1.

BEDROCK GEOLOGY: Underlying bedrock is predominantly Cambrian sandstone, but Precambrian-age (Archean) gneiss and amphibolite occur at the northern edge of the sub-subsection (Morey *et al.* 1982). See subsection.

LANDFORMS: A broad expanse of sand lake plain, part of Glacial Lake Wisconsin.

LAKES AND STREAMS: No natural lakes. Numerous small streams flow across the sub-subsection into the Wisconsin River.

SOILS: Soils are primarily formed on sand; they include poorly drained mineral soils (Humaquepts and Aquic Udipsamments) and organic soils, both muck and peat (Histosols) (Hole 1976, Hole and Germain 1994). There are also small inclusions of lacustrine clays.

PRESETTLEMENT VEGETATION: On the lake plain, moving from west to east, there was first a broad zone of conifer-dominated swamp forest, then a several-mile-wide zone of marsh and

sedge meadow. Tamarack was dominant along the edges of the poorly drained lake basin, while black spruce dominated the center of the basin (Finley 1976). Northern white-cedar was absent. The marshes and sedge meadows were the most extensive in the State. Dominant grasses included blue joint grass and cordgrass (Hole and Germain 1994). White pine-red pine forest occurred on slightly better drained sandy sites.

NATURAL DISTURBANCE: Both fire and seasonal flooding were important for maintaining the marshes and wet meadows, and fire was probably equally important in the conifer swamps and pine forests.

PRESENT VEGETATION AND LAND USE: Most of the poorly drained lake plain remains dominated by vegetation similar to the original vegetation.

RARE PLANT COMMUNITIES: Coastal plain marsh and pine barrens.

RARE PLANTS: *Bartonia virginica* (screwstem), *Myriophyllum farwellii* (Farwell's water-milfoil), *Polygala cruciata* (cross milkwort), *Rhexia virginica* (Virginia meadow beauty).

RARE ANIMALS: *Erynnis persius persius* (Persius dusky wing), *Incisalia irus* (frosted elfin), *Lycaeides melissa samuelis* (Karner blue), *Ophisaurus attenuatus* (western slender glass lizzard), *Pedioecetes phasianellus* (sharp-tailed grouse), *Sistrurus catenatus* (eastern massasauga rattlesnake).

NATURAL AREAS: State Natural Areas: Necedah Oak-Pine Savanna, Necedah Oak-Pine Forest.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: Natural vegetation is affected by fire exclusion, continued alteration of wetlands through ditching/diking, and expansion of the cranberry industry.

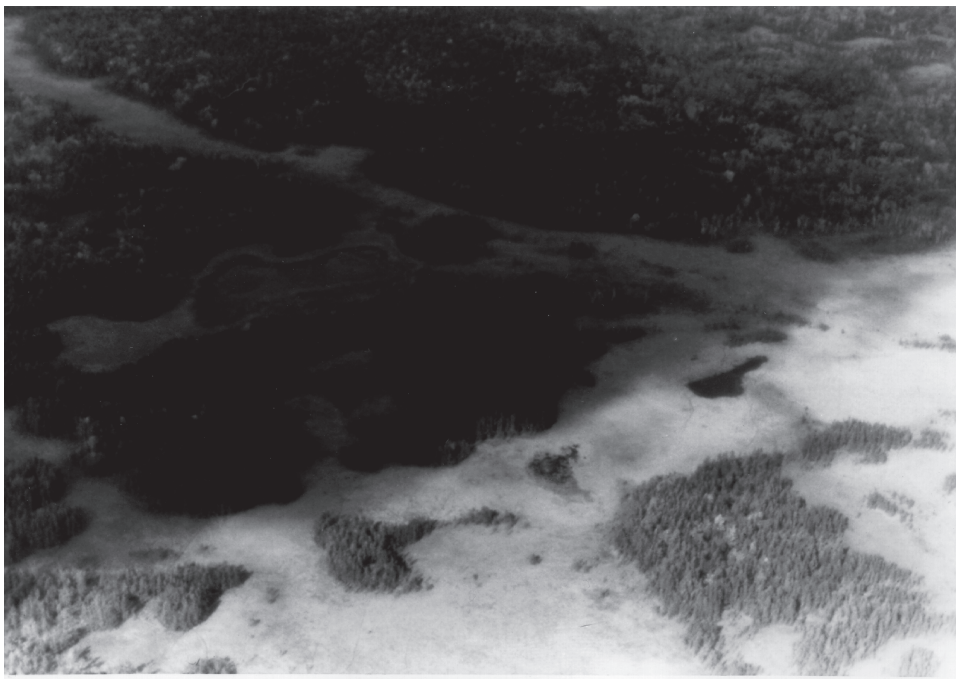


Figure 18.—*Sub-subsection V.1.2: Brockway Ponds, Jackson County, Wisconsin. The flat lake-plain landscape is largely poorly drained, containing extensive wetlands dominated by sedges, and small ponds with disjunct plant species from the Atlantic Coastal Plain. The sandy uplands support dense forests of jack pine; before fire-control, these forests burnt regularly and were described as open barrens. A recent jack-pine budworm infestation has resulted in high mortality of jack pine on this site. Photo by Eric Epstein.*

SUB-SUBSECTION V.1.3. Stevens Point**; droughty sand outwash and lake plain; jack pine-pin oak barrens, conifer swamp, marsh and wet meadow.**

DISCUSSION: Sub-subsection is level outwash sands along the Wisconsin River, originally dominated by barrens of jack pine and northern pin oak.

ELEVATION: 886 to 1,145 feet (270 to 349 m).

AREA: 1,345 square miles (3,485 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Underlying bedrock is predominantly Cambrian sandstone, but Precambrian-age (Archean) gneiss and amphibolite occur at the northern edge of the sub-subsection (Morey *et al.* 1982). See subsection.

LANDFORMS: This broad outwash plain is generally concentrated along the east side of the Wisconsin River, bordering the western edge of the pitted outwash and moraine (Sub-subsection V.1.4). Lacustrine sands occupy the center and western edge of the sub-subsection. Stabilized sand dunes are also present (Hole 1976).

LAKES AND STREAMS: The Wisconsin River flows through the sub-subsection. It has been dammed to create Petenwell Lake; there are no large, naturally occurring lakes.

SOILS: Soils have formed in outwash and lacustrine sands. Plainfield sands (Udipsamments) predominate and are more fertile than the Boone sands of Sub-subsection V.1.1 (Hole 1976, Hole and Germain 1994). A narrow band of poorly drained mineral soils and shallow peats occur along the eastern boundary of the sub-subsection, where it meets Sub-subsection V.1.4.

PRESETTLEMENT VEGETATION: Jack pine and northern pin oak dominated the prevalent droughty soils, covering an area of 400 to 500 square miles (Finley 1976). Jack pine and northern pin oak occurred as either closed canopy forests or open barrens. Wetlands were restricted to the eastern edge of the sub-subsection. Marsh and sedge meadow were nearest the jack pine, probably due to the short fire interval; and swamp forest of black spruce and tamarack was further to the east. Northern white-cedar was absent or rare. An area of tallgrass prairie was in the extreme east, southwest of Plainfield.

NATURAL DISTURBANCE: Fire was probably the most important.

PRESENT VEGETATION AND LAND USE: Irrigation has allowed wide-scale conversion to agriculture.

RARE PLANT COMMUNITIES: Rare communities include coastal plain marsh, white pine-red maple flatwoods, and oak barrens.

RARE PLANTS: *Bartonia virginica* (screwstem), *Myriophyllum farwellii* (Farwell's water-milfoil), *Opuntia fragilis* (brittle prickly-pear), *Polygala cruciata* (cross milkwort), *Rhexia virginica* (Virginia meadow beauty).

RARE ANIMALS: *Erynnis persius persius* (Persius dusky wing), *Incisalia irus* (frosted elfin), *Lycaeides melissa samuelis* (Karner blue), *Ophisaurus attenuatus* (western slender glass lizard).

NATURAL AREAS: State Natural Areas: Buena Vista Quarry Prairie, Buena Vista Prairie Chicken Meadow, Sohlberg Silver Lake, Dewey Marsh, Roche-A-Cri (Roche à Cris) Mound, Quincy Bluff.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: Natural vegetation is affected by fire exclusion and mining of ground water for irrigation.

SUB-SUBSECTION V.1.4. Waupaca**; sandy end moraine, ground moraine, and pitted outwash; oak forest, oak savanna, and tallgrass prairie.**

DISCUSSION: Sub-subsection is a mosaic of sandy, rolling ground moraine, steep end moraine, and pitted outwash originally dominated by oak forest and savanna.

ELEVATION: 787 to 1,180 feet (240 to 360 m).

AREA: 1,529 square miles (3,963 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Cambrian sandstone underlies most of the sub-subsection, but granitic rock of the Wolf River batholith (Precambrian age) occurs in the northeast.

LANDFORMS: Landforms are diverse, consisting of pitted outwash, hummocky end moraines, and ground moraine. Many of the hills are sandstone cored (Hole 1976, Peck and Lee 1961).

LAKES AND STREAMS: Numerous small kettle lakes, ponds, and wetlands within the hummocky end moraine and on the pitted outwash.

SOILS: Sandy soils are predominant, with sands and loamy sands on the outwash and loamy sands to sandy loams on the moraines. Most of the soils are well to excessively drained, but some localized areas have poorly drained mineral and organic soils.

PRESETTLEMENT VEGETATION: Oak forest, with large amounts of northern pin oak, were dominant. Areas of oak savanna and tallgrass prairie were north and east of Plainfield, where there was a broad plain of pitted outwash, unbroken by end-moraine ridges.

NATURAL DISTURBANCE: Fire was probably common on this landscape, based on dominance of oak forest, oak savanna, and tallgrass prairie.

PRESENT VEGETATION AND LAND USE: Irrigation has allowed farming of large areas of level sandy land. Some of these soils are prone to erosion by wind after removal of vegetation cover. Many of the present forests are dominated by a mix of white, red, and bur oaks.

RARE PLANT COMMUNITIES: Rare communities include oak barrens, wet mesic prairie, fens, and coastal plain marshes. Fens occur commonly within this sub-subsection.

RARE PLANTS: *Bartonia virginica* (screwstem), *Carex sychnocephala* (many-headed sedge), *Myriophyllum farwellii* (Farwell's water-milfoil), *Opuntia fragilis* (brittle prickly-pear), *Polygala cruciata* (cross milkwort), *Rhexia virginica* (Virginia meadow beauty), *Valeriana sitchensis* ssp. *uliginosa* (marsh valerian).

RARE ANIMALS: *Aeshna mutata* (spatterdock darner (dragonfly)), *Lycaeides melissa samuelis* (Karner blue), *Ophisaurus attenuatus* (western slender glass lizard).

NATURAL AREAS: State Natural Areas: Summerton Bog, Lawrence Creek, Ennis Lake-Muir Park, Comstock Bog-Meadow, Bass Lake Fen, Myklebust Lake, New Hope Pines, Pope Lake, Observatory Hill, Mud Lake-Radley Creek Savanna, Plainfield-Second Lakes, Pickerel Lake, Brooks Bluff.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: Wind erosion can be a serious problem on many of the sandy soils after clearing for agriculture.

SUBSECTION V.2. Southeastern Wisconsin Till Plain**; clay or silt loam-textured soils on till plain and end moraine; oak openings, oak forest, tallgrass prairie, and sugar maple-basswood forest.**

DISCUSSION: This subsection has been subdivided into four sub-subsections, primarily on the basis of vegetation, with locally good correspondence of the dominant vegetation types to glacial landform and substrate. The treatment is based on that of Hole and Germain (1994), but many of their smaller map units have been eliminated. Delineation of sub-subsections on the basis of glacial landform and substrate alone was not successful at the scale of this map, although correlation of the vegetation to combinations of abiotic conditions would be possible at a more localized scale. The combination of a general lack of relief and the local heterogeneity of glacial landforms does not lend itself to regional mapping at this scale.

Sub-subsections: Milwaukee (V.2.1), Madison (V.2.2), Galena-Platteville (V.2.3), Kettle Moraine (V.2.4) (see figure 4).

ELEVATION: 580 to 1,535 feet (177 to 468 m).

AREA: 7,397 square miles (19,161 sq km).

STATES: Wisconsin.

CLIMATE: Growing season is 142 to 184 days (Hole and Germain 1994). Average annual precipitation is 32 to 34 inches, and average annual snowfall ranges from 36 inches in the south to approximately 44 inches in the north (Wendland *et al.* 1992). Extreme minimum temperature ranges from warmer than -30˚F along Lake Michigan in the south to colder than -35˚F inland and farther north (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Drift over bedrock is generally less than 50 feet thick, except in the east where it is 100 to 200 feet thick (Trotta and Cotter 1973). The predominant bedrocks are Silurian dolomite to the east along Lake Michigan, and Ordovician dolomite in the central and western parts of the subsection (Ostrom 1981, Morey *et al.* 1982). Some limestone, sandstone, and shale are present in both of these bedrocks. Undifferentiated Devonian marine deposits are localized along the Lake Michigan shoreline. Cambrian sandstone, with some dolomite and shale, is along the far western edge of the subsection. Precambrian quartzite is localized in the west and Precambrian rhyolite, granite, and diorite are localized west of Lake Winnebago (Morey *et al.* 1982).

LANDFORMS: Till plain (ground moraine) is predominant; but there are also areas of dissected plain, end moraines, outwash deposits, lake plain, and ice-stagnation topography with many kettle lakes.

LAKES AND STREAMS: Large kettle lakes are concentrated within pitted outwash deposits and within or adjacent to end moraines. More linear lakes are within the ground moraine, trending in the same direction as the surrounding ground moraine features, but these are much less common. There are few major rivers in the subsection. The larger rivers include the Rock, Sugar, and a short segment of the Wisconsin.

SOILS: A silt-loam cap of loess covers the soils of most of the subsection, but there are also clay soils developed from glaciolacustrine deposits and sand soils developed from outwash deposits. Soils derived from the loess are silt loam at the surface, but subsoils are generally calcareous loam (till) or calcareous sand and gravel outwash (Hole and Germain 1994). The loess cap is typically about 2 feet thick.

PRESETTLEMENT VEGETATION: Bur oak openings (savannas), oak forest, and tallgrass prairie were predominant in the western part of the subsection, but sugar maple-basswood forest was common to the east where there is greater fire protection because of dissected topography and numerous kettle lakes. Even the trend of features such as drumlin ridges and adjacent wetlands have helped to determine the dominant vegetation within this subsection. On some southwest-northeast trending drumlin fields, tallgrass prairie and savanna were dominant; where north-south-trending drumlins served as fire barriers, sugar maple-basswood forests dominated.

NATURAL DISTURBANCE: Fire maintained the tallgrass prairies, oak savannas, and oak forests.

PRESENT VEGETATION AND LAND USE: Most of the subsection has been heavily developed for agriculture, except for Sub-subsection V.2.4, which occupies steep, irregular topography.

RARE PLANT COMMUNITIES: Tallgrass prairie and oak savanna are rare, even though both were originally dominant over large areas. Also fen, tamarack fen, wet prairie, and wet mesic prairie.

RARE PLANTS: *Asclepias sullivantii* (prairie milkweed), *Aster furcatus* (forked aster), *Fimbristylis puberula* (chestnut sedge), *Lespedeza leptostachya* (prairie bush clover), *Platanthera leucophaea* (prairie white-fringed orchid).

RARE ANIMALS: *Oarisma poweshiek* (Poweshiek skipper), *Papaipema beeriana* (liatris borer moth), *Papaipema silphii* (Silphium borer moth), *Venustaconcha ellipsiformis ellipsiformis* (Ellipse, a mussel), *Podiceps grisegena* (red-necked grebe), *Sterna forsteri* (Forster's tern).

NATURAL AREAS: State Natural Areas: Oshkosh-Larsen Trail Prairies, Puchyan Prairie, Ripon Prairie, Spruce Lake Bog, Oakfield Ledge, Waupun Park Maple Forest, Fountain Creek Wet Prairie, Fourmile Island Rookery, Mayville Ledge Beech-Maple Woods, Neda Mine, Gibraltar Rock, Audubon Goose Pond, Waterloo Fen and Springs, Snapper Prairie, Faville Prairie, Bean Lake, Cherokee Marsh, Westport Drumlin Prairie, Red Cedar Lake, Rocky Run Oak Savanna, Koro Prairie, Blue Spring Oak Opening, Hook Lake Bog, and South Waubesa Wetlands; The Nature Conservancy Preserves: Chiwaukee Prairie, Gromme Preserve (Rush Lake), Renak-Polak Woods.

PUBLIC LAND MANAGERS: National Wildlife Refuges: Horicon; State Forests: Kettle Moraine.

CONSERVATION CONCERNS:

SUB-SUBSECTION V.2.1. Milwaukee**; silt loam-capped (loess) rolling ground moraine; sugar maple-basswood in the east.**

DISCUSSION: Sub-subsection is defined by sugar maple-basswood forest dominance. This forest type is dominant within the subsection where there is adequate protection from recurring fires, generally provided by either steep, irregular topography, broad stream valleys, strings of kettle lakes, or broad wetlands.

Soils are silt loam at the surface, but subsoils are generally calcareous loam (till) or calcareous sand and gravel outwash (Hole and Germain 1994). The loess cap is typically about 2 feet thick.

ELEVATION: 580 to 1,220 feet (177 to 372 m).

AREA: 2,134 square miles (5,530 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Drift thickness over bedrock is generally 100 to 200 feet (Trotta and Cotter 1973). The predominant bedrock underlying the drift is Silurian dolomite, but there is also Ordovician dolomite along the western edge of the sub-subsection; some limestone, sandstone, and shale are included in both the Silurian and Ordovician bedrocks (Ostrom 1981, Morey *et al.* 1982).

LANDFORMS: Ground moraine covers most of the sub-subsection, but there are outwash channels and end moraines.

LAKES AND STREAMS: Streams such as the Rock, Crawfish, Beaverdam, and Fox Rivers act as fire barriers within this sub-subsection. Kettle lakes are also common, both on end moraines and in narrow outwash channels.

SOILS: A silt-loam loess cap covers most of the loamy and clayey tills. Soils are typically Alfisols.

PRESETTLEMENT VEGETATION: Uplands supported sugar maple-basswood forest, with varying amounts of red oak, elm, and white ash. White and black oaks were probably also present in the forests. Wetlands were numerous and often provided barriers to fire. Marshes and sedge meadows were common, as were conifer

swamps (which were much less common on the prairie, savanna, and oak forest-dominated parts of the subsection). Wetlands were quite extensive in portions of this sub-subsection.

NATURAL DISTURBANCE: Little information is currently available about disturbance in forested portions of the sub-subsection.

PRESENT VEGETATION AND LAND USE: Much of this sub-subsection is intensively farmed, but many of the wetlands remain dominated by native vegetation.

RARE PLANT COMMUNITIES: Patterned peatland, southern mesic forest (sugar maple-beech).

RARE PLANTS: *Aster furcatus* (forked aster), *Solidago caesia* (blue-stemmed goldenrod), *Lithospermum latifolium* (American gromwell), *Plantago cordata* (heart-leaved plantain).

RARE ANIMALS: *Calephelis muticum* (swamp metalmark).

NATURAL AREAS: State Natural Areas: Spruce Lake Bog, Sander's Park Hardwoods, Oakfield Ledge, Mayville Ledge Beech-Maple Woods, Neda Mine, VanderBloemen Bog, Cedarburg Beech Woods, Cedarburg Bog, Sapa Spruce Bog, Kurtz Woods (169), Riveredge Creek and Ephemeral Pond (197); The Nature Conservancy Preserves: Zinn Preserve.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: There are major fragmentation and isolation impacts on the native vegetation. Exotic plants are rampant.

SUB-SUBSECTION V.2.2. Madison**; rolling to hilly drumlins, end moraine, and outwash; bur oak openings (savanna) and oak forest in the west.**

DISCUSSION: Sub-subsection is defined on the basis of its dominant vegetation, bur oak openings (savannas) and oak forests. This vegetation occupies rolling to hilly outwash, drumlins on till plain, or end moraine with more fire protection than the flat to rolling sites occupied by tallgrass prairie, but less fire protection than sites occupied by sugar maple-basswood forest.

ELEVATION: 746 to 1,535 feet (227 to 468 m).

AREA: 3,982 square miles (10,320 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Drift over bedrock is generally less than 50 feet thick, except in the east where it is 100 to 200 feet thick (Trotta and Cotter 1973). The predominant bedrocks are Silurian dolomite and Ordovician dolomite with some limestone, sandstone, and shale (Ostrom 1981). Cambrian sandstone, with some dolomite and shale, is along the western edge of the sub-subsection.

LANDFORMS: Ground moraine predominates, often containing extensive drumlin fields. There are also numerous end moraines. Outwash features occur, often as narrow channels between drumlins.

LAKES AND STREAMS: Large lakes and streams are not common in those parts of the subsection dominated by oak savanna or forest.

SOILS: Soils are silt loam at the surface, but subsoils are generally calcareous loam (till) or calcareous sand and gravel outwash (Hole and Germain 1994). The loess cap is typically about 2 feet thick. Under oak savannas and forests, forest soils (Typic hapludalfs) have developed (Hole and Germain 1994, Hole 1976).

PRESETTLEMENT VEGETATION: Savanna occupied rolling ground moraine (including the southwest-northeast-trending drumlins) or outwash without major fire barriers, such as streams, lakes, or wetlands. It also occurred on some steep end moraines, where soils were excessively drained and no major wetlands served as fire breaks. Oak forests are typically

found on ground moraine with minor streams or wetlands forming fire breaks, or on relatively steep, dissected end moraine without major fire breaks.

Oak openings (savanna) were dominated by bur oak, and the oak forests were dominated by bur oak, white oak, and black oak. Marshes, wet meadows, and wet prairies were the major wetland types occupying the narrow drainageways and depressions within the oak savannas and forests; swamp forests were uncommon, probably because of the frequently occurring fires of the oak ecosystems.

NATURAL DISTURBANCE: Fire was important in maintaining oak savanna and forest. Native American land management may have contributed to the amount of fire occurring within this portion of Wisconsin; from 1810 to 1830 several Winnebago villages were along the Wisconsin River and on Lake Mendota and other lakes in Dane and Columbia Counties (Tanner 1986).

PRESENT VEGETATION AND LAND USE: The entire sub-subsection is intensively farmed. Forest persists primarily on steeper end moraines and in poorly drained depressions.

RARE PLANT COMMUNITIES: Oak openings (savannas), wet mesic prairie, wet prairie, and fens.

RARE PLANTS: *Asclepias sullivantii* (prairie milkweed), *Aster furcatus* (forked aster), *Lespedeza leptostachya* (prairie bush clover), *Platanthera leucophaea* (prairie white-fringed orchid), *Solidago ohioensis* (Ohio goldenrod).

RARE ANIMALS: *Podiceps grisegena* (red-necked grebe), *Sterna forsteri* (Forster's tern), *Papaipema silphii* (silphium borer moth).

NATURAL AREAS: State Natural Areas: Puchyan Prairie, Lost Lake, Waupun Park Maple Forest, Fountain Creek Wet Prairie, Muskego Park Hardwoods, Peat Lake, Fourmile Island Rookery, New Munster Bog Island, Gibraltar Rock, Karcher Springs, Silver Lake Bog, Waterloo Fen and Springs, Snapper Prairie, Faville Prairie, Bean Lake, Cherokee Marsh, Red Cedar Lake, Rocky Run Oak Savanna, Koro Prairie, Hook Lake Bog, South Waubesa Wetlands, Lulu Lake Fen, Cherry Lake Sedge Meadow, Parfrey's Glen, Bueleh Bog, Genesee Oak Opening and Fen, Pickerel Lake Fen, Berlin Fen, Lima Bog; The Nature Conservancy Preserves: Gromme Preserve (Rush Lake).

PUBLIC LAND MANAGERS: National Wildlife Refuges: Horicon.

CONSERVATION CONCERNS: Of the extensive original oak openings, only small preserves remain. The landscape is heavily disturbed and severely fragmented.

SUB-SUBSECTION V.2.3. Galena-Platteville **(Prairie du Chien cuestas and Niagaran cuesta); loamy soils on till plain and recessional moraines; tallgrass prairie.**

DISCUSSION: Sub-subsection is defined by the dominance of tallgrass prairie, which occurs on broad, gently rolling portions of the till plain (ground moraine) or on outwash.

ELEVATION: 580 to 1,095 feet (177 to 334 m).

AREA: 1,054 square miles (2,727 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Drift thickness over bedrock is generally less than 50 feet (Trotta and Cotter 1973). The largest area of prairie in the west, in Dane and Columbia Counties, is located on the broad Galena-Platteville and Prairie du Chien cuestas of Ordovician dolomite (Finley 1976, Morey *et al.* 1982). In the southeast along Lake Michigan, the large prairies occur on the broad, gently sloping Niagaran cuesta of Silurian dolomite.

LANDFORMS: The landform where tallgrass prairie vegetation dominates is typically ground moraine, but prairie also occupies some outwash channels as well as the rolling recessional end moraines near Lake Michigan in southeastern Wisconsin.

LAKES AND STREAMS: No lakes within the prairies. Several small rivers cross the prairie near Lake Michigan, including the Root, Des Plaines, and Pike.

SOILS: Soils are silt loam at the surface, derived from loess; subsoils are generally calcareous loam (till) or calcareous sand and gravel outwash (Hole and Germain 1994). The loess cap is typically about 2 feet thick. Prairie soils had a thick (6 to 12 inches), dark, surface horizon that resulted from the deep penetration and eventual decomposition of prairie grasses. Prairie soils were classified as Typic Argiudolls (Hole 1976, Hole and Germain 1994).

PRESETTLEMENT VEGETATION: Within the tallgrass prairie were areas of bur oak savanna. Wetlands were generally not extensive, but consisted of either wet prairie or sedge meadow (Hole and Germain 1994, Finley 1976).

NATURAL DISTURBANCE: Fire was important for maintaining tallgrass prairie. Native American land management with fire may have been partially responsible for maintaining the prairies. Winnebago villages were near Lake Mendota and other lakes and streams in Dane and Columbia Counties from at least 1810, and several Potawatomi villages were in the prairie region along Lake Michigan from approximately the same date (Tanner 1986).

PRESENT VEGETATION AND LAND USE: The entire sub-subsection is intensively farmed. Only small areas of wet or wet mesic prairies persist.

RARE PLANT COMMUNITIES: Tallgrass prairie, including mesic prairie, wet mesic prairie, and wet prairie. Fens also occur at the foot of calcareous slopes.

RARE PLANTS: *Asclepias sullivantii* (prairie milkweed), *Aster furcatus* (forked aster), *Lespedeza leptostachya* (prairie bush clover), *Liatris spicata* (marsh blazing star), *Platanthera leucophaea* (prairie white-fringed orchid). Near the Lake Michigan shoreline, *Fimbristylis puberula* (chestnut sedge), *Phlox glaberrima* ssp. *interior* (smooth phlox), *Solidago ohioensis* (Ohio goldenrod).

RARE ANIMALS: *Papaipema silphii* (silphium borer moth), *Podiceps grisegena* (red-necked grebe), *Sterna forsteri* (Forster's tern).

NATURAL AREAS: State Natural Areas: Ripon Prairie, Chiwaukee Prairie, Audubon Goose Pond, Renak-Polak Beech Maple Woods; The Nature Conservancy Preserves: Chiwaukee Prairie.

PUBLIC LAND MANAGERS: National Wildlife Refuges: Horicon.

CONSERVATION CONCERNS: Of the extensive original tallgrass prairies and oak openings, only small preserves remain. The landscape is heavily disturbed and severely fragmented.

SUB-SUBSECTION V.2.4. Kettle Moraine**; steep ice-disintegration topography with kettle lakes; bur oak opening and white oak-black oak forest in south, sugar maple-basswood forest in more fire-protected north.**

DISCUSSION: Sub-subsection V.2.4 is a narrow band of ice-disintegration topography, formed as an interlobate area between the Green Bay and Lake Michigan lobes of the Wisconsin Glaciation (Clayton *et al.* 1991). The band of irregular sand and gravel ridges begins east of Lake Winnebago and continues south into Illinois, becoming less prominent in Kenosha, Racine, and southern Walworth Counties.

ELEVATION: 918 to 1,195 feet (280 to 364 m).

AREA: 226 square miles (585 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: The Kettle moraine is underlain by Silurian-age dolomite for the

northeastern two-thirds of its length and by Ordovician dolomite for the southwestern third, beginning in Waukesha County (Ostrom 1981, Morey *et al.* 1982). Glacial drift thickness over bedrock ranges from less than 50 feet to 400 feet (Trotta and Cotter 1973).

LANDFORMS: The Kettle moraine is steep ice-disintegration topography, with numerous kettle lakes on steep ridges of fluvial sand and gravel.

LAKES AND STREAMS: Many kettle lakes within or at the edge of this narrow sub-subsection.

SOILS: Typic Hapludalfs are most common (Hole 1976). Outwash sands and gravels are overlain by loess, generally less than 20 inches thick.

PRESETTLEMENT VEGETATION: At the southern edge, bur oak openings and white oak-black oak forests, with small inclusions of wet prairie, sedge meadow, and marsh, were the dominant vegetation (Finley 1976). Farther to the north, where strings of kettle lakes and steep moraines created fire barriers, sugar maple-basswood forests were largely unbroken on the landscape, except where conifer swamps occupied small wetlands.

NATURAL DISTURBANCE: Fire in areas dominated by oak savannas and forests.

PRESENT VEGETATION AND LAND USE: Heavy development and recreational pressures threaten.

RARE PLANT COMMUNITIES: Fens are common, as indicated from the number of State Natural Areas named for their fens; also oak openings and tallgrass prairies.

RARE PLANTS: *Besseya bullii* (kitten-tails), *Cypripedium candidum* (white lady's-slipper), *Lithospermum latifolium* (American gromwell), *Platanthera leucophaea* (prairie white-fringed orchid), *Scirpus cespitosus* (tussock bulrush).

RARE ANIMALS: *Oarisma poweshiek* (Poweshiek skipper), *Papaipema beeriana* (liatris borer moth), *Calephelis muticum* (swamp metalmark), *Regina septemvittata* (queen snake), *Wilsonia citrina* (hooded warbler).

NATURAL AREAS: Wisconsin: State Natural Areas: Scuppernong Prairie, Haskell Noyes Memorial Woods, Milwaukee River and Swamp, Spring Lake, Kewaskum Maple-Oak Woods, Ottawa Lake Fen, Kettle Moraine Fen and Low Prairie, Eagle Oak Opening, Young Prairie, Milwaukee River Floodplain Forest, Kettle Hole Woods, Crooked Lake Wetlands, Butter Lake and Flynn Springs, Milwaukee River Tamarack Lowlands, Johnson Hill Kame, Kettle Moraine Red Oaks, Bluff Creek, Kettle Moraine Oak Openings, Cliff Messenger Dry Prairie and Savanna Preserve, Clover Valley Fen and Peat Lake; The Nature Conservancy Preserves: Lulu Lake Preserve.

PUBLIC LAND MANAGERS: Kettle Moraine State Forest.

CONSERVATION CONCERNS: Several preserves protect fens, prairies, and adjacent oak-dominated upland areas. Recreational and residential development around the numerous kettle lakes may severely limit natural area management and expansion of natural areas in many areas. The Kettle moraine is considered a critical landscape for many uncommon or rare species characteristic of southern Wisconsin, especially vertebrates, but also invertebrates, plants, and aquatic organisms. This is the most intact landscape in southeastern Wisconsin.

SUBSECTION V.3. Lake Winnebago Clay Plain**; clay lake plain and ground moraine; sugar maple-basswood forest.**

DISCUSSION: Subsection is an extension of the more expansive lake plain north of the tension zone in Subsection VIII.1, but much of the flat to undulating landscape is also ground moraine that has been reworked by proglacial lake waters (Lineback *et al.* 1983, Farrand *et al.* 1984). Unlike Subsection VIII.1, its silty soils are Alfisols rather than Spodosols.

SUB-SUBSECTIONS: None.

ELEVATION: 748 to 1,070 feet (228 to 326 m).

AREA: 1,165 square miles (3,018 sq km).

STATES: Wisconsin.

CLIMATE: Growing season ranges from 143 to 150 days (Wisconsin Agricultural Statistics Service 1987). Average annual precipitation is 30 to 32 inches, and average annual snowfall ranges from 40 inches in the south to approximately 48 inches in the north (Wendland *et al.* 1992). Extreme minimum temperature ranges from approximately -30˚F along Lake Michigan to -35˚F farther inland (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Subsection is underlain by Ordovician dolomite, with some limestone and shale (Ostrom 1981). Depth to bedrock ranges from less than 50 feet to 200 feet (Trotta and Cotter 1973).

LANDFORMS: Flat till plain and lake plain are prevalent. Much of the till plain has been reworked by proglacial lake waters.

SOILS: Soils are red clays, containing parent material both from local dolomite and reworked, northern lacustrine deposits. Portions of the red, clay soils are derived from iron formations in the Precambrian bedrock farther to the north (Hole 1976). Soils are more carbonate rich than those farther to the north because of the underlying dolomite of the subsection. Tills low in pebbles and cobbles have been mistaken for lacustrine deposits in the area north and west of Lake Winnebago. The most common soil of the subsection is silty clay loam to clay loam in texture. It has almost equal parts of sand, silt, and clay; gravel, primarily dolomite, makes up 10 to 20 percent of the coarse fraction. Soils are classified as Alfisols.

PRESETTLEMENT VEGETATION: Sugar maple-basswood forest covered most of the landscape; bur oak openings were present in the southwest, where fire probably originated farther to the southwest on the ground moraine of Sub-subsections V.2.2 or V.2.3 (Finley 1976). These oak openings extended to the north of Lake Winneconne and Lake Butte des Morts on rolling ground moraine, and they may have persisted partially as a result of Native American land management with fire. There were Mosouakie villages and later Winnebago villages along Lakes Winnebago, Winneconne, and Butte des Morts, and along the Fox River from before 1600 to 1830 (Tanner 1986). These lakes were along the major trade route from the Wisconsin River, with a portage connecting to the Fox River and Green Bay. Swamp forest grew in the wet depressions of the ground moraine. Two large wetland areas consisted of wet meadow, wet prairie, and lowland shrubs (Finley 1976), one surrounding Lake Poygan and the other along the Fox River. East of Lake Winnebago, along the North Branch of the Manitowoc River, there was also a large area of lowland hardwoods.

NATURAL DISTURBANCE: Fire was probably important at the southern edge. Large windthrows were noted within the northern part (Cottam and Loucks 1984).

PRESENT VEGETATION AND LAND USE: Much of the subsection has been converted to agriculture, often requiring some ditching to improve drainage conditions on the flat landscape.

RARE PLANT COMMUNITIES: Wet-mesic prairie. Oak savanna occurred here historically.

RARE PLANTS: *Platanthera leucophaea* (prairie white-fringed orchid) and a single historic record for *Plantago cordata* (heart-leaved plantain).

RARE ANIMALS: *Acipenser fulvescens* (lake sturgeon), *Sterna forsteri* (Forster's tern).

NATURAL AREAS: State Natural Areas: Oshkosh-Larsen Trail Prairies, Hortonville Bog, and High Cliff Escarpment.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: Winnebago Pool (includes Lakes Winnebago, Poygan, and Butte des Morts) is especially important for lake sturgeon, Forster's tern, and other aquatic species. A comprehensive management plan has been strongly recommended for these lakes.

SUBSECTION V.4. Rock River Hill Country**; dissected Wisconsinan- and pre-Wisconsinan-age till and loess over bedrock; tallgrass prairie and oak forests.**

DISCUSSION: The Rock River Hill Country subsection is an area of steep, dissected topography, which also contains broad outwash plains. Soils are often thin, developed from a recent silt-loam cap of loess over old Altonian- and Illinoian-age glacial drift. This subsection continues south into Illinois, where its western portion is called the Rock River Hill Country, and its eastern portion is called the Winnebago Section of the Northeastern Morainal Division (Schwegman 1973).

SUB-SUBSECTIONS: None.

ELEVATION: 740 to 1,157 feet (226 to 353 m).

AREA: 1,048 square miles (2,716 sq km).

STATES: Wisconsin (this subsection also continues south into Illinois).

CLIMATE: Growing season ranges from 150 to 160 days (Wisconsin Agricultural Statistics Service 1987). Average annual precipitation is 32 to 36 inches, and average annual snowfall ranges from 32 inches in the south to approximately 40 inches in the north (Wendland *et al.* 1992). Extreme minimum temperature ranges from approximately -30˚F in the south to -35˚F farther north (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Subsection is underlain by Ordovician-age dolomite, with some limestone and shale (Ostrom 1981, Morey *et al.* 1982). Cambrian sandstone is exposed in the valleys of the Rock and Sugar Rivers. Bedrock is within 3 to 4 feet of the surface locally (Hole and Germain 1994).

LANDFORMS: The topography consists of dissected uplands of pre-Wisconsinan till and Wisconsinan-age outwash deposits, which form broad, flat to rolling plains (Hole and Germain 1994). Glaciation within the subsection is considered to date from at least 25,000 years ago (Zenda Formation at the east edge). Over much of the subsection, glaciation occurred as long as 130,000 years ago (Walworth Formation) (Clayton *et al.* 1991).

LAKES AND STREAMS: No lakes within the subsection; numerous small creeks within this highly dissected landscape. Among the larger streams are the Rock and Sugar Rivers.

SOILS: Pre-Wisconsinan till, and paleosols derived from this till, underlie a silt cap (loess) and are exposed on dissected uplands (Hole 1976). Wisconsinan-age outwash deposits form extensive rolling plains. Loess is about 2 feet deep over either leached sandy loam or loam, which is calcareous at a depth of about 6 feet. Under oak savannas, Typic Hapludalfs form; under prairie, Typic Argiudolls are representative soils (Hole and Germain 1994).

PRESETTLEMENT VEGETATION: The dominant vegetation over most of the landscape was upland prairie and oak forest. Tallgrass prairie was concentrated on a broad till plain in Green County and on both till and outwash plains on both sides of the Rock River in Rock County. Oak forest was quite extensive, especially along the more dissected bluffs and ravines of the numerous small streams of the subsection. Sugar maple-basswood was locally present along some streams, where the topography was hilly and often rocky. The largest areas of sugar maple-basswood forest occur along Sugar and Richland Creeks in Green County. Sedge meadow, wet prairie, and shrubs form linear corridors along several of the small creeks and also along the Sugar River. The Sugar River supports a significant corridor of flood-plain forest.

NATURAL DISTURBANCE: Fire maintained upland prairie and oak forests over much of the landscape. Native American land management with fire may be partially responsible for the persistence of tallgrass prairie. The Azatlan (Juntunen) culture had villages along the Rock River between circa 1400 and 1600, and the Winnebago tribe had villages along the Rock River between 1810 and 1830 (Tanner 1986).

PRESENT VEGETATION AND LAND USE: Heavy agriculture has caused major fragmentation and reduction of natural vegetation.

RARE PLANT COMMUNITIES: Tallgrass prairie, including mesic, wet-mesic, and wet prairie, along with a site for oak opening.

RARE PLANTS: *Besseya bullii* (kitten-tails), *Chaerophyllum procumbens* (wild chervil), *Diarrhena americana* (beak grass), *Hypericum sphaerocarpum* (round-fruited St. John's-wort), *Napaea dioica* (glade mallow).

RARE ANIMALS: *Dendroica dominica* (yellow-throated warbler), *Hesperia ottoe* (Ottoe skipper), *Nyctanassa violacea* (yellow-crowned night heron), *Speyeria idalia* (regal fritillary).

NATURAL AREAS: State Natural Areas: Abraham's Woods, Oliver Prairie, Browntown Oak Forest, Swenson Wet Prairie, Avon Bottoms, Newark Road Prairie, Lima Bog, Ward/Swartz Decatur Woods, Kessler Railroad Prairie, and Muralt Bluff Prairie.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: The pursuit of a joint "grassland" management project with Illinois, focused on the Sugar River corridor, has been suggested. Elsewhere the landscape is highly disturbed and fragmented. There is a great potential for managing this landscape, where management would target rare and declining grassland bird species, and, east of the Sugar River, the ornate box turtle.

BOUNDARIES: I chose to combine parts of two divisions recognized in Illinois, the Winnebago Section of the Northeastern Morainal Division and the Freeport Section of the Rock River Hill Country Division (Schwegman 1973). I separated the Winnebago Section, which has Altonian-age glacial drift that is better drained, from the adjacent Morainal Section of the Northeastern Morainal Division, which has many glacial lakes and poorer drainage. The Freeport Section to the west has both Illinoian and early Wisconsinan (Altonian) drift. Outwash is more extensive in the Winnebago Section, and eroded bluffs and dells are more common in the Freeport Section, but both of these features are shared by both sections. There may well be justification for dividing this subsection (V.4) into two sub-subsections.

I also chose to include this subsection as part of the savanna province, rather than as a part of the prairie province (cf. Bailey and Cushwa [1981], who treat Subsection V.4 as part of the Tall-grass Prairie Province). I had two reasons for this. First, the vegetation in Subsection V.4 is a mosaic of maple-basswood and oak forests, oak savannas, and prairie, in contrast to Section I and Section II, where prairie dominates broad expanses of land, and both savannas and forests are uncommon. Second, the annual precipitation in Subsection V.4 is heavier than in most of the tallgrass prairie, with a gradual increase in annual precipitation, and possibly more important, winter precipitation farther to the east. This climatic difference may be as important as the changes in topography for resulting in a mosaic of forest and prairie.

SECTION VI. SOUTHERN LOWER MICHIGAN**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Hot-Summer Continental Division, Eastern Deciduous Forest; Great Lakes-moderated climate (Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990); late Wisconsinan-age, glaciated landscape underlain by Paleozoic bedrock; white oak-black oak savannas and forests, beech-sugar maple forest.**

Section VI (see pages 40-41 for description) contains six subsections: Washtenaw, Kalamazoo Interlobate, Allegan, Ionia, Huron, Saginaw Lake Plain. The section and subsections are shown on the large three-State map (Plate I).

SUBSECTION VI.1. Washtenaw**; glacial lake plain, end moraine, ground moraine, and outwash; beech-sugar maple forest, elm-ash forest, deciduous swamp, white oak-black oak savannas, wet prairies, coastal marshes.**

DISCUSSION: This subsection, located in extreme southeastern Michigan, is characterized by the longest growing season in the State.

SUB-SUBSECTIONS: the Maumee Lake Plain (VI.1.1), Ann Arbor Moraines (VI.1.2), and the Jackson Interlobate (VI.1.3). (See figure 5.)

ELEVATION: 572 to 1,280 feet (175 to 390 m).

AREA: 5,995 square miles (15,530 sq km).

STATES: Michigan.

CLIMATE: Subsection VI.1 has the longest growing season in the section and in Michigan, ranging from approximately 130 days inland to 180 days along Lake Erie and Lake St. Clair in the east (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -26˚F inland to -16˚F in the south along Lake St. Clair and Lake Erie. Total annual precipitation averages between 28 and 36 inches, and total snowfall averages 30 to 50 inches.

BEDROCK GEOLOGY: Surface glacial deposits, which are as thick as 300 feet near the inland margin of the subsection and locally less than 5 feet near the Lake Erie shoreline, are underlain by Pennsylvanian, Mississippian, Devonian, and Silurian marine and nearshore bedrock, including sandstone, shale, coal, marine limestone and dolomite, and gypsum and other evaporites (Dorr and Eschman 1984, Milstein 1987). Bedrock is only locally exposed in stream banks and near the shorelines of Lake Erie. The oldest Silurian bedrock is near the surface and locally exposed to the south. Mississippian and Pennsylvanian sandstone and shale are locally exposed in the west, in Sub-subsection VI.1.3.

LANDFORMS: Glacial lake plain characterizes Sub-subsection VI.1.1; ground moraine, end moraine, and outwash cover the remainder of the subsection. See sub-subsections.

LAKES AND STREAMS: See sub-subsections.

SOILS: Soils are classified as Alfisols (Aqualfs) by the Soil Conservation Service (1967). See sub-subsections.

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: This subsection has some of the most intensive urban, industrial, and agricultural land use in the State. It supports closed-canopy oak forests due to fire suppression. The oak ecosystems of this and adjacent subsections were classified and

described by Archambault *et al.* (1990), and the ecological species groups of their groundflora were described and classified (Archambault *et al.* 1989). Coastal marshes are described in Albert *et al.* 1988. See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: Subsection VI.1 supports several rare species, most of which occupy the prairies, marshes, or shorelines of the Great Lakes. See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VI.1.1. Maumee Lake Plain**; beech-sugar maple forest, elm-ash forest, deciduous swamp, white oak-black oak savannas, wet prairies, coastal marshes.**

DISCUSSION: Sub-subsection is a flat, clay lake plain dissected by broad glacial drainageways of sandy soil. The lake-moderated climate and productive loamy soils resulted in early and intensive agricultural development.

ELEVATION: 580 to 750 feet (177 to 229 m).

AREA: 2,309 square miles (5,981 sq km).

STATES: Michigan.

CLIMATE: Climate is somewhat moderated by Lake St. Clair and Lake Erie. Growing season is generally long, ranging from 150 to 180 days; growing season is longer near the shorelines of the Great Lakes and shorter inland (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -18˚F to -26˚F, with lowest temperatures along the inland edge of the sub-subsection. Snowfall is relatively light, ranging from 30 inches in the south to 50 inches in the north. Average annual precipitation ranges from 30 to 32 inches.

BEDROCK GEOLOGY: Along Lake Erie, lacustrine deposits are more than 100 feet thick along the inland edge of the lake plain, but less than 5 feet thick near the shoreline. The surface lacustrine deposits are underlain by Mississippian, Devonian, and Silurian marine and nearshore bedrock, including sandstone, shale, coal, limestone, dolomite, gypsum, and other evaporites (Dorr and Eschman 1984, Milstein 1987). Bedrock is only locally exposed in stream banks and near the shorelines of Lake Erie. The oldest Silurian bedrock is near the surface in the south. Commercial deposits of rock salt and saline wells occur in the Silurian Salina Formation near Detroit.

LANDFORMS: The southern two-thirds of the sub-subsection is clay lake plain, with several broad channels of lacustrine sand. The northern third is primarily lake plain, with clay soils; but it includes several 1- to 3-mile-wide end moraines (Farrand 1982). These moraines have been reworked by water.

Beach ridges and small sand dunes are common on the sand channels. The clay plain is generally broad and flat.

SOILS: Wet loamy and clayey soils are prevalent. Soil permeability is generally low, and these soils require drainage for agricultural use. Soils are calcareous at shallow depth. Soils in the sand channels are poorly or very poorly drained in depressions and excessively drained on dunes. Sandy soils in lower slope positions are often calcareous, while those on dune ridges are acidic. Sand soils are prone to wind erosion when cultivated. Soils are classified as Alfisols (Ochraqualfs and Hapludalfs) and include Haplaquolls, Udipsamments, and Haplaquepts (USDA Soil Conservation Service 1967).

LAKES AND STREAMS: No natural lakes in the sub-subsection. Major rivers include the Huron, Rouge, Raisin, Clinton, Detroit, and St. Clair. The St. Clair River flows from Lake Huron to Lake St. Clair, and the Detroit River connects Lake St. Clair to Lake Erie.

PRESETTLEMENT VEGETATION: The presettlement vegetation of the clay lake plain differed greatly from that of the sand lake plain. Most of the clay lake plain supported forest, either upland or wetland. In contrast, the sand lake plain supported oak barrens (savanna) on the uplands and wet prairies or marshes in the lowlands (Comer *et al.* 1993a).

The forests of the clay lake plain responded to differences in slope class and drainage. On flatter portions (10 feet per mile slope or less) of the lake plain or in shallow basins or depressions, lowland hardwoods were prevalent. In closed depressions, black ash was the common dominant. Where the topography was flat or gradually sloping, black ash was still the dominant species, but American elm and basswood were also common co-dominants. As slope increased slightly and drainage conditions improved, beech, white oak, white ash, and hickory became more common, but were generally less common than black ash and elm. Cottonwood, sycamore, trembling aspen, and [red or silver] maple were other common wetland species of the clay lake plain. Where drainage conditions were improved by streams, there were mesic forests dominated by beech, sugar maple, white oak, [American] elm, and hickory.

The beach ridges and low dunes of the sand lake plain supported open "barrens" or savannas of white and black oak. Small areas of dry prairie also occurred on the ridges, but were much less prevalent than savannas. Depressions and flat portions of the sand lake plain were often poorly drained, supporting wet prairies. Within the wet prairies were small beach ridges that supported scattered white oak, black oak, red oak, ash, and popple [cottonwood]. Elm was common on the moist edges of the prairie and within the swamps. Pin oak, now a common species within the swamps of the sand lake plain, was seldom referenced in the GLO survey notes; pin oak may have been much less prevalent before drainage of the wet prairies and fire exclusion.

Extensive marshes occurred along the entire coast of Lakes Erie and St. Clair. The marshes, which extended into water 4 to 5 feet deep, were 1 to 2 miles wide in places and extended for miles up major rivers such as the Huron. Upland of the marshes, there was typically a broad zone of swamp forest; but locally along Lake St. Clair and Lake Erie, 1- to 3-mile-wide expanses of wet prairie occurred.

NATURAL DISTURBANCE: There were few references in GLO notes to natural disturbances on this part of the lake plain. The only area of extensive windthrown trees was at the extreme north edge of the sub-subsection in parts of St. Clair and Macomb Counties (Comer *et al.* 1993a). The windthrows were most extensive on the flat, clay lake plain, which supported swamp forest.

Water level fluctuation of the Great Lakes, important for maintaining swamp forest, wet prairie, and marsh vegetation, was not well documented in the GLO notes of this sub-subsection, but was well documented further north along Saginaw Bay of Lake Huron (Sub-subsection VI.5.1 and Subsection VI.6).

PRESENT VEGETATION AND LAND USE: There is a long history of land use by humans, beginning with Native Americans, who farmed the flood plains of the Huron River. They may also have been responsible for fires that maintained the open conditions of the oak barrens and drier portions of the prairies.

The clay soils of the sub-subsection were among the first areas in the State farmed by European settlers. Most clay lands have been ditched and tiled and are among the most valued agricultural lands in the State. Portions of the sand plain were also ditched for agriculture, but the wettest areas remain, either as swamp forest, wet prairie, or marsh. Diking and pumping have allowed vast expanses of wet prairie and some areas of marsh to be farmed. The only remaining tracts of forest are small, usually only 40 to 80 acres.

RARE PLANT COMMUNITIES: Wet, wet-mesic, and dry sand prairie were originally extensive, along with oak savannas or "openings," but these now remain as only small remnants, primarily on State-owned lands. Prairies and savannas on the lake plain are called "lakeplain prairie or oak opening" because of the distinctive flora and fauna.

RARE PLANTS: Most of the species in this sub-subsection are associated with either Great Lakes marshes or lakeplain prairies. *Agalinis gattingeri* (Gattinger's gerardia), *Agalinis skinneriana* (Skinner's gerardia), *Aristida longispica* (three-awned grass), *Asclepias hirtella*

(tall green milkweed), *Asclepias sullivantii* (Sullivant's milkweed), *Cacalia plantaginea* (prairie Indian-plantain), *Carex hyalinolepis* (sedge), *Carya laciniosa* (shellbark or kingnut hickory), *Hypericum gentianoides* (gentian-leaved St. John's-wort), *Juncus biflorus* (two-flowered rush), *Juncus brachycarpus* (short-fruited rush), *Lechea pulchella* (Leggett's pinweed), *Ludwigia alternifolia* (seedbox), *Nelumbo lutea* (American lotus), *Platanthera leucophaea* (prairie fringed orchid), *Sagittaria montevidensis* (arrowhead), *Scirpus clintonii* (Clinton's bulrush), *Silphium perfoliatum* (cup-plant), *Strophostyles hevola* (trailing wild bean).

RARE ANIMALS: *Asio flammeus* (short-eared owl), *Chlidonias niger* (black tern), *Dysnomia torulosa rangiana* (northern riffleshell), *Dysnomia triquetra* (snuffbox), *Elaphe vulpina gloydi* (eastern fox snake), *Erimyzon oblongus* (creek chubsucker), *Etheostoma spectabile* (orangethroat darter), *Euphyes dukesi* (Duke's skipper), *Falco peregrinus* (Peregrine falcon), *Obovaria subrotunda* (round hickorynut, a mussel), *Opsopoeodus vemiliae* (pugnose minnow), *Rallus elegans* (king rail), *Simpsoniconcha ambigua* (salamander mussel), *Sterna forsteri* (Forster's tern), *Sterna hirundo* (common tern), *Tyto alba* (common barn owl), *Villosa fabalis* (bean villosa, a mussel).

NATURAL AREAS: State Natural Areas: Dickinson Island; The Nature Conservancy Preserves: Erie Marsh, Highland Cemetery; Michigan Nature Association Preserves: American Lotus Plant Preserve, Sibley Prairie.

PUBLIC LAND MANAGERS: State Game Areas: Petersburg, Pointe Mouillee; State Wildlife Areas: Ford, St. Clair Flats, St. John's Marsh, Erie; State Parks: Algonac, Sterling; State Environmental Areas: Stony Island, Grassy Island, Pointe Mouillee, Monroe, Maumee Bay; State Recreation Areas: Rochester-Utica, Proud Lake; Metroparks: Oakwoods, Lower Huron, Lake Erie, Stony Creek, Metro Beach, Willow.

CONSERVATION CONCERNS: Management and restoration of lakeplain prairies and oak openings are a high priority and have been initiated in both State parks and State game areas. The entire native clam fauna, especially the large unionids, is being threatened by the zebra mussel invasion in the Detroit River.

SUB-SUBSECTION VI.1.2. Ann Arbor Moraines; **loamy end and ground moraines; oak-hickory forest, beech-sugar maple forest, and deciduous swamp forest.**

DISCUSSION: Sub-subsection is a long, narrow band (120 miles long and 20 to 24 miles wide) of fine- and medium-textured end and ground moraine bordered by flat lake plain on the east and by sandy outwash, end moraine, and ice-contact features to the west. The moraines of the sub-subsection continue south into Ohio. Agricultural development has been relatively extensive, but many of the lowlands and steeper upland ridges remain forested.

ELEVATION: 750 to 1,150 feet (230 to 350 m).

AREA: 1,632 square miles (4,225 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 150 to 160 days; localized areas near the Maumee Lake Plain (VI.1.1) have a growing season of approximately 170 days (Eichenlaub *et al.* 1990). Average annual precipitation gradually increases from 30 inches in the north to 36 inches in the south. Annual snowfall shows a similar trend, with 40 inches in the north and 50 inches in the south. Extreme minimum temperature ranges from -22˚F to -24˚F.

BEDROCK GEOLOGY: Bedrock is not exposed in the sub-subsection. Glacial deposits are 100 to 250 feet thick over bedrock; the thickest glacial deposits are near the center of the long sub-subsection for much of its length. Underlying bedrock is Mississippian and Devonian (Paleozoic) sandstone and shale (Dorr and Eschman 1984, Milstein 1987). Devonian sandstone and shale are localized along the eastern edge, Mississippian shale underlies the center, and Mississippian sandstone is in the southwest.

LANDFORMS: Narrow parallel bands of both end moraine and till plain (ground moraine). More than 80 percent of the ground moraine is flat, with slopes in the 0 to 6 percent slope class.

Ground moraine forms a broad plain. Individual hills of the ground moraine are several miles in area, but are seldom higher than 80 feet.

The topography of the end moraines is more rolling, with slopes in the 7 to 15 percent slope class. Less than 1 percent of the end moraines have slopes greater than 15 percent. End-moraine ridges can be distinct ridges, one to several miles across and several miles long; or they can be broken into several smaller ridges separated by glacial outwash channel and post-glacial drainages. Most of the ridges are 30 to 80 feet high; the highest ridges, about 170 feet high, are located in the north.

LAKES AND STREAMS: Few lakes. Major rivers that cross the sub-subsection are the Huron and Raisin.

SOILS: Loam- and sandy loam-textured soils cover most of the sub-subsection. Fine-textured soils, primarily silt loams and clay loams, are more common on the eastern edge. Poorly drained mineral soils are common on lower slopes of the ground moraine. Organic soils are restricted to outwash channels. Soils are classified as gently sloping Hapludalfs with some Argiaquolls and Argiudolls (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The loams and sandy loams originally supported oak and oak-hickory forests. White oak appeared to be the most common species of the oak forest. Black oak was common on the drier ridge tops, and red oak was most common on lower slopes. Oak savannas, dominated by white oak and black oak, probably occurred within the sub-subsection, especially along the western edge, where fires from Sub-subsection VI.1.3 were carried by westerly winds. Beech and sugar maple were restricted to silt loams and clay loams. The distribution of these mesic species was quite restricted; they occurred in some relatively flat and wet areas of ground moraine at the southeastern end of the sub-subsection and on well-drained, irregular end moraine at the northeastern end.

Swamp forest was common in lower slope positions on both ground and end moraine. Common species in the swamps included black ash, red maple, American elm, swamp white oak, bur oak, and basswood. On the flood plain, hackberry, red elm, red ash, and American elm were common.

NATURAL DISTURBANCE: Windthrow probably occurred on the steeper end moraines and within the poorly drained swamp forests. Native American fire management, generally concentrated on the sandier soils of Sub-subsections VI.1.3 and VI.2.1, may have impacted forests at the western margin of Sub-subsection VI.1.2.

PRESENT VEGETATION AND LAND USE: Almost all the ground moraines have been farmed, but the steeper moraines remain forested with oak. Most of the land was cleared for agriculture by the mid 19th century.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: The flood plains support several rare plant species, including *Chelone obliqua* (purple turtlehead), *Cypripedium arietinum* (ram's head lady's slipper), *Galearis spectabilis* (showy orchid), *Gentiana flavida* (white gentian), *Hybanthus concolor* (green violet), *Hydrastis canadensis* (goldenseal), *Morus rubra* (red mulberry), *Muhlenbergia richardsonis* (mat muhly), *Panax quinquefolius* (ginseng), *Spiranthes ovalis* (lesser ladies'-tresses).

RARE ANIMALS: *Ambystoma texanum* (small-mouth salamander), *Carunculina glans* (purple lilliput), *Clinostomus elongatus* (redside dace), *Clonophis kirtlandii* (Kirtland's snake), *Cryptotis parva* (least shrew), *Moxostoma duquesnei* (black redhorse), *Nerodia erythrogaster neglecta* (copperbelly water snake), *Phoxinus erythrogaster* (southern redbelly dace), *Pleurobema clava* (clubshell).

NATURAL AREAS: Michigan Nature Association Preserves: Copperbellied Water Snake Nature Sanctuary; The Nature Conservancy Preserves: Ives Road Fen, Sharon Hollow; Other: Horner Woods, Radrick Bog and Forest, Cranbrook Nature Sanctuary, Bicentennial Woods, George Reserve, Saginaw Forest, Osborne Mill Riverland Preserve.

PUBLIC LAND MANAGERS: State Game Areas: Lost Nation; State Recreation Areas: Bald Mountain, Island Lake, Waterloo, Lake Hudson; Metroparks: Dexter-Huron, Stony Creek,

Hudson Mills; County Parks: Parker Mill; Research Areas: Mud Lake Bog.

CONSERVATION CONCERNS: Agricultural use of lands in the sub-subsection has been extensive. Few ecologically intact areas are known; these are generally flood-plain forests or small woodlots.

SUB-SUBSECTION VI.1.3. Jackson Interlobate**; coarse-textured end moraine, outwash, and ice-contact topography; oak savanna and oak-hickory forest, hardwood swamps, prairie fens, bogs.**

DISCUSSION: Sub-subsection VI.1.3 is the northern portion of an interlobate area between three glacial lobes, which formed approximately 13,000 to 16,000 years B.P. The interlobate is more than 150 miles long. This sub-subsection consists of most of the northeastern two-thirds of the interlobate, which is characterized by relatively steep end-moraine ridges surrounded by pitted outwash deposits; kettle lakes and wetlands are common within the outwash.

ELEVATION: 750 to 1,280 feet (229 to 390 m).

AREA: 2,581 square miles (6,689 sq km).

STATES: Michigan.

CLIMATE: Growing season is 140 to 150 days, generally decreasing to the north (Eichenlaub *et al.* 1990). Danger of late spring frosts is great due to numerous lowland depressions (outwash and kettle lakes). Average snowfall is 40 to 50 inches; greatest amounts are in the extreme north and extreme south. Annual precipitation is 30 to 32 inches, with highest amounts in the south. Extreme minimum temperature ranges from -22˚F to -28˚F, with coldest values in the north.

BEDROCK GEOLOGY: The underlying Mississippian and Pennsylvanian bedrock, primarily sandstone (Dorr and Eschman 1984, Milstein 1987), is locally exposed at the surface in Jackson and Hillsdale Counties at the southwestern end of the sub-subsection (Akers 1938). Drift thickness is generally less than 100 feet in both of these counties. In the northeastern part, bedrock is overlain by 250 to 300 feet of glacial drift.

LANDFORMS: Sub-subsection contains broad expanses of outwash sands that surround sandy and gravelly end moraines and ground moraines. End and ground moraines remain as island-like hills surrounded by flat outwash. Large linear segments of end moraine, broken only by narrow outwash channels, are typically located along the margins of the sub-subsection.

Sub-subsection VI.1.3 also includes areas of ice-contact topography. Kettle lakes, kames, eskers, and segments of outwash channel are the predominant features of the ice-contact areas. At the west edge of the sub-subsection, the topography is more gentle; broad, coarse-textured ridges are surrounded by deposits of outwash sand.

Both on the outwash channels and on the ground-moraine ridges, slopes are generally in the 0 to 6 percent class; on the end-moraine and ice-contact ridges, slopes can be as steep as 25 to 40 percent. Most of the small segments of end moraine surrounded by outwash have slopes predominantly in the 0 to 6 percent and 6 to 12 percent classes. The large blocks of end moraine at the margins of the sub-subsection commonly have steeper slopes in the 12 to 25 percent or 25 to 40 percent classes.

LAKES AND STREAMS: Many kettle lakes and ponds on the pitted outwash, end moraines, and ice-contact topography. Extensive wetlands surround many of the lakes and occupy entire ice-block depressions. Both marl and peat deposits were extensively mined in the past.

The headwaters of many major rivers originate in the extensive wetlands of the sub-subsection. These include the Huron, Grand, Kalamazoo, and St. Joseph Rivers.

SOILS: The soils of the moraines are typically well and excessively well drained. Drainage conditions on the outwash are more variable, ranging from excessively well drained to very poorly drained. Thick outwash deposits are

usually characterized by excessively well drained conditions. Shallow outwash deposits are underlain in some places by bedrock or fine-textured till and lacustrine deposits, causing poor or very poor drainage conditions. On ice-contact topography, soils are typically excessively drained on the upland kames and eskers and poorly or very poorly drained in the kettles and outwash channels. Where the topography is steep, organic soils can be 10 to 15 feet deep in narrow outwash channels.

Soil textures range from sand to clay; the most common soil texture is sandy loam on the moraine ridges and sand on the outwash plains. The circumneutral glacial drift that forms the moraines is largely derived from the local limestone bedrock. Illuviation is responsible for the formation of a clay-rich (argillic) horizon in many of the soils on moraines, providing better water-holding capacity than many of the outwash soils. In the ice-contact areas, soils are sands and gravels. The Soil Conservation Service (1967) classifies the soils of the sub-subsection as Hapludalfs with Argiudolls.

PRESETTLEMENT VEGETATION: Vegetation reflects underlying differences in landform and topography. On the sandy moraines, open savannas of black oak, white oak, and hickory were common. GLO surveyors described the open oak forests as "barrens," "oak openings," "barren and scrubby timber," or "scattered timber." Chapman (1984) cites several references linking the open stand conditions to frequent burning by Native Americans. Savanna and prairie were absent or uncommon on the steeper end-moraine blocks at the margins of the sub-subsection, but bur oak savannas were located on the smaller "islands" of gently sloping ground moraine and end moraine at the western edge of the sub-subsection. Other dominants of the oak savannas were white oak, black oak, and chinquapin oak.

Most of the wetlands on the end moraines were shrub or tree swamps located in lower slope position or in small depressions. Wetlands on the lower slopes were typically hardwood swamps. Kettle lakes and swampy depressions on the moraines typically supported shrub swamp, hardwood swamp, or tamarack swamp.

The outwash channels supported large wetlands of several types. At the margins between the uplands and the outwash, calcareous seepages often supported fens. Tamarack grew near the upland margins of the fens. Grass and sedge meadows were found growing adjacent to streams on large areas of the outwash channels.

Swamp forests were most common along margins of major streams on the outwash. Tamarack was common along lake edges and in kettles or depressions in the outwash.

On droughty ice-contact topography, black oak (probably including some northern pin oak) was commonly the dominant forest species. White oak and hickory were also common on slightly moister ice-contact sites, and red oak occupied moist foot slopes.

In areas of ice-contact topography, wetlands were commonly restricted to narrow belts surrounding kettle lakes. These consisted of shrub, hardwood, or conifer swamps. Kettles were sometimes completely occupied by either swamp or bog vegetation.

NATURAL DISTURBANCE: According to recent accounts, lightning fires occasionally occur in both uplands and wetlands within the sub-subsection. In the GLO notes, there were isolated mentions of fires resulting from Native-American activities, as well as numerous historic references to Native-American fires in the oak savannas or barrens of the sub-subsection.

PRESENT VEGETATION AND LAND USE: Most of the uplands have been farmed, except the steepest end moraines and ice-contact ridges, which have been maintained as woodlots or are now either recreational or wildlife management areas. Many of these steep ridges have been pastured in the past. Oak savannas either have been converted to farm land or have grown into closed-canopy oak forests due to fire suppression.

Both agricultural lands and the steeper forested lands are now being rapidly converted to residential developments, especially near metropolitan Detroit. Both residential development and agricultural land use have resulted in rapid eutrophication of lakes and degradation of many wetlands. Road construction and ditching have also modified the hydrology of many wetlands.

RARE PLANT COMMUNITIES: Oak savannas, once prevalent on large parts of the landscape, have been destroyed by agriculture or degraded by fire exclusion.

RARE PLANTS: *Baptisia lactea* (prairie false indigo), *Baptisia leucophaea* (cream wild indigo), *Cacalia plantaginea* (prairie Indian-plantain), *Celtis tenuifolia* (dwarf hackberry), *Cypripedium candidum* (white lady's-slipper), *Eleocharis caribaea* (spike-rush), *Eryngium yuccifolium* (rattlesnake-master), *Eupatorium sessilifolium* (upland boneset), *Filipendula rubra* (queen of the prairie), *Gentiana puberulenta* (downy gentian), *Muhlenbergia richardsonis* (mat muhly), *Sporobolus heterolepis* (prairie dropseed), *Valeriana ciliata* (edible valerian).

RARE ANIMALS: *Ammocrypta pellucida* (eastern sand darter), *Ammodramus henslowii* (Henslow's sparrow), *Cryptotis parva* (least shrew), *Dendroica discolor* (prairie warbler), *Dendroica cerulea* (cerulean warbler), *Nerodia erythrogaster neglecta* (copperbelly water snake), *Neonympha mitchelli mitchelli* (Mitchell's satyr), *Oarisma poweshiek* (Poweshiek skipper), *Oecanthus laricis* (tamarack tree cricket), *Papaipema beeriana* (blazing star borer), *Sistrurus catenatus catenatus* (eastern massasauga rattlesnake), *Tachopteryx thoreyi* (greyback).

NATURAL AREAS: State Natural Areas: Haven Hill; Michigan Nature Association Preserves: Goose Creek Grasslands, Lakeville Swamp, Lefglen, Dwarf Hackberry Trees, Timberland Swamp, Burr Memorial Prairie, Haehnle Memorial, Sand Prairie, Harvey N. Ott; The Nature Conservancy Preserves: Sharon Hollow, Jonathan Woods; Other: George Reserve, Seven Ponds Nature Center, Park Lyndon, Whitehouse Nature Center, Columbia Nature Sanctuary.

PUBLIC LAND MANAGERS: State Game Areas: Onsted, Gregory, Sharonville, Somerset; State Recreation Areas: Waterloo, Highland, Bald Mountain, Pinckney, Holly, Island Lake, Proud Lake, Pontiac Lake, Brighton, Ortonville, Metamora-Hadley; State Parks: Hayes; State Wildlife Areas: Unadilla; Metroparks: Indian Springs, Kensington, Stony Creek; County Parks: Park Lyndon, Independence Oaks.

CONSERVATION CONCERNS: Urban and residential development is destroying many of the lakes and wetlands of the sub-subsection, especially northwest of Detroit. Upland forests, important for wildlife habitat and migration corridors, are also being rapidly fragmented by residential developments.

BOUNDARIES: Sub-subsection VI.1.3 has physiography and soils similar to Sub-subsection VI.5.2, but has a longer growing season (Albert *et al.* 1986).

Figure 19.—*Sub-subsection VI.1.3: Stearns Lake, Livingston County, Michigan. This sub-subsection is an area of steep, sandy end-moraine ridges and flat, poorly drained sandy outwash. Kettle lakes within the outwash are often bordered by broad wetlands, including marshes, wet meadows, and prairie fens. At the time of European settlement, the uplands supported savannas of white oak and black oak; with fire exclusion, these savannas have converted to oak forest. Photo by G. Reese.*

SUBSECTION VI.2. Kalamazoo Interlobate**; outwash, sandy ground and end moraines; oak savanna and oak-hickory forest, swamp forest, bog, tallgrass prairie, wet prairie, and prairie fen.**

DISCUSSION: This subsection is the southern portion of an interlobate area between three glacial lobes, which formed approximately 13,000 to 16,000 years B.P. The entire interlobate area is more than 150 miles long. This flat plain was the northernmost extension of the "Prairie Peninsula," as described by Transeau (1935).

SUB-SUBSECTIONS: Battle Creek Outwash Plain (VI.2.1), Cassopolis Ice-Contact Ridges (VI.2.2).

ELEVATION: 750 to 1,280 feet (229 to 390 m).

AREA: 3,511 square miles (9,096 sq km).

STATES: Michigan.

CLIMATE: Average growing season ranges from approximately 140 days at the north edge of the subsection to more than 160 days in the southwest (Eichenlaub *et al.* 1990). Average annual precipitation ranges from 32 inches in the north to 38 inches in the southwest. Average snowfall ranges from 50 inches in the east to more than 60 inches in the southwest near Lake Michigan. Extreme minimum temperature ranges from -22˚F in the south to -30˚F in the extreme north.

BEDROCK GEOLOGY: The subsection is entirely underlain by Mississippian (Paleozoic) shale (Dorr and Eschman 1984, Milstein 1987). Glacial drift is shallow in the east where there are local exposures of shale, but it is as much as 350 feet thick in the west and southwest (Akers 1938).

LANDFORMS: The center of the subsection (Sub-subsection VI.2.1) consists of a broad outwash plain that contains numerous small lakes and small "islands" of ground moraine. The edges of the subsection consist of steep, narrow bands of end moraine, and the center of the subsection is steep ice-contact topography; these moraines and ice-contact topography are Sub-subsection VI.2.2. See sub-subsections.

LAKES AND STREAMS: Kettle lakes are numerous on both the pitted outwash of Sub-subsection VI.2.1 and on the end moraines and ice-contact ridges of Sub-subsection VI.2.2. Many small kettles contain bogs or swamp forest. Streams are quite numerous on the outwash of Sub-subsection VI.2.1. The largest streams are the Kalamazoo and St. Joseph Rivers.

SOILS: The most common soil textures are sand and sandy loam. Soils are primarily Alfisols and Histosols, with Mollisols (Aquolls and Udolls) in the prairies of the southwest. Soils are classified by the Soil Conservation Service (1967) as gently sloping Hapludalf plus Argiudolls.

PRESETTLEMENT VEGETATION: This subsection contained the only extensive areas of tallgrass prairie found in Michigan (Brewer *et al.* 1984, Hodler *et al.* 1981). Tallgrass prairie was restricted to flat outwash deposits, especially where streams or wetlands did not provide fire barriers. Oak savannas were primarily on broad, rolling "islands" of end moraine. Oak forest was also common throughout, especially in the more dissected ice-contact topography and on the steep end moraine to the north.

NATURAL DISTURBANCE: Early settlers reported fire to be a widely used Native American management tool; the extent of natural fire is not known. Without fire, all the oak openings have closed in to become closed-canopy oak forests.

PRESENT VEGETATION AND LAND USE: All of the upland prairie and most of the upland forests have been converted to agriculture. Forest remains on the steeper end moraines and ice-contact topography. Residential development is encroaching on many of the remaining upland forests. The subsection now supports closed-canopy oak forests due to fire suppression. The oak ecosystems of this and adjacent subsections were classified and described by Archambault *et al.* (1990), and the ecological species groups of their groundflora were described and classified (Archambault *et al.* 1989).

RARE PLANT COMMUNITIES: Tallgrass prairie was originally quite extensive, but prairie lands were among the first farmed in Michigan. Tallgrass prairie persists as small fragments along railroad rights-of-way; small fragments of wet prairie also persist. Oak savannas have been either destroyed by agriculture or heavily degraded by fire suppression.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: Development pressures are high; residential development threatens almost all lakes and mature forests. Similarly, residential development is heavy at the southwestern end of the subsection. The greatest potential for protecting and managing a large natural tract of this landscape is probably in Calhoun, St. Joseph, or Cass Counties. Few preserves adequately represent both the wetlands and uplands of this subsection.

SUB-SUBSECTION VI.2.1. Battle Creek Outwash Plain**; oak savanna, oak and oak-hickory forest, tallgrass prairie, hardwood swamp, wet prairie, and prairie fen.**

DISCUSSION: Sub-subsection is a broad, flat outwash plain containing numerous small lakes and wetlands and small ridges of ground moraine. Major streams flow through the plain, which is divided into two parts by a band of steep ice-contact ridges.

ELEVATION: 750 to 1,050 feet (229 to 320 m).

AREA: 2,750 square miles (7,122 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: Outwash deposits of sand and gravel cover more than half of the sub-subsection. More than 80 percent of the outwash is in the 0 to 6 percent slope class. Small areas of end moraine and ground moraine (till plain) are scattered throughout the outwash plain. Slopes on the moraines are generally in the 0 to 6 percent or 6 to 12 percent slope classes.

Ground moraine is concentrated in the southeast portion of the sub-subsection, where numerous low drumlin ridges are oriented from northeast to southwest. The drumlins, which are commonly separated by narrow outwash deposits, are low and broad; slopes are almost exclusively in the 0 to 6 percent slope class.

LAKES AND STREAMS: Lakes are common on the outwash plain. These lakes occupy ice-block kettles or abandoned channels. Small streams are numerous; two large streams, the St. Joseph and Kalamazoo Rivers, occupy the sub-subsection. Many of the small streams originate within wetlands on the outwash plain.

SOILS: About 80 percent of the outwash sands are well or moderately well drained sands and loamy sands. Very poorly drained soils are common in the narrow outwash channels between drumlins and in ice-block kettles or abandoned stream channels. Peat accumulations can be 6 to 10 feet thick.

Soils on the end moraine and ground moraine are typically sandy loam or loamy sand, and most are well drained. A well-developed argillic horizon is common in these soils.

PRESETTLEMENT VEGETATION: Well-drained soils on the outwash originally supported tallgrass prairie or oak savannas. The prairies were located on the broadest expanses of well-drained outwash plain, where neither steep topography nor streams formed barriers to fire. Tallgrass prairie occupied areas as large as 20 square miles; nearly 50 prairies were known in the sub-subsection. Poorly drained outwash supported swamp forest. There were also wet prairies, marshes, and extensive wet meadows along streams flowing across the outwash plain.

The "islands" of sandy end moraine or ground moraine often supported savannas of either bur oak or white oak-black oak. Bur oak generally occurred on broad, gently sloping ridges, where fires were relatively frequent. White oak-black oak savanna or forest occurred on smaller, more steeply sloping features. White oak was much more common than black oak. On steep or irregular topography, oak forest and oak-hickory forest were dominant.

Sugar maple and beech dominated the drumlin ridges in the southeast. Swamp forest, often dominated by black ash, occurred in the outwash channels between the drumlins.

NATURAL DISTURBANCE: Fire was important for maintaining both the tallgrass prairie and oak savanna. The prevalence of naturally occurring fires is not clearly documented. Native Americans were reported to have used fire as a management tool here at the time of European settlement (Chapman 1984).

PRESENT VEGETATION AND LAND USE: Most of the uplands and large areas of wetland have been converted to agriculture. Drainage has allowed wetlands to be planted to row crops. Many wetlands are used as pasture, especially the grasslands along streams. Many of the large wetlands occupying glacial drainageways and ice-block depressions remain dominated by native vegetation. The shorelines of many of the kettle lakes are being developed for either recreational or residential use.

RARE PLANT COMMUNITIES: Tallgrass prairie, wet prairie, and oak savanna, all originally covering large areas, are now quite rare. Prairie fen is common within the sub-subsection. Prairie fens contain several plants characteristic of tallgrass prairies as well as several plants characteristic of calcareous fens along the northern shorelines of Lake Michigan and Lake Huron. Tamarack and poison sumac are common along the margins of prairie fens.

RARE PLANTS: Many of the rare plants found in the sub-subsection are plants of the tallgrass prairie, more common in the Prairie States further west. *Amorpha canescens* (leadplant), *Baptisia lactea* (prairie false indigo), *Baptisia leucophaea* (cream wild indigo), *Berula erecta* (cut-leaved water parsnip), *Cacalia plantaginea* (prairie Indian-plantain), *Carex oligocarpa* (eastern few-fruited sedge), *Carex straminea* (straw sedge), *Coreopsis palmata* (prairie coreopsis), *Cuscuta pentagona* (dodder), *Cuscuta polygonorum* (knotted dodder), *Cypripedium candidum* (white lady's-slipper), *Eryngium yuccifolium* (rattlesnake-master), *Filipendula rubra* (queen of the prairie), *Gentiana puberulenta* (downy gentian), *Helianthus hirsutus* (whiskered sunflower), *Kuhnia eupatorioides* (false boneset), *Linum virginianum* (virginia flax), *Scutellaria elliptica* (hairy skullcap), *Silene stellata* (starry campion), *Silphium integrifolium* (rosinweed), *Sporobolus heterolepis* (prairie dropseed), *Stellaria crassifolia* (fleshy stitchwort), *Valeriana ciliata* (edible valerian), *Viola pedatifida* (prairie birdfoot violet).

RARE ANIMALS: *Dendroica cerulea* (cerulean warbler), *Dendroica dominica* (yellow-throated warbler), *Myotis sodalis* (Indiana bat), *Neonympha mitchelli mitchelli* (Mitchell's satyr), *Nerodia erythrogaster neglecta* (copperbelly water snake), *Oarisma poweshiek* (Poweshiek skipper), *Sistrurus catenatus* (eastern Massasauga rattlesnake), *Tachopteryx thoreyi* (greyback).

NATURAL AREAS: State Natural Areas: Black Spruce Bog, Proud Lake Shadbush, Russ Forest (Michigan State University); The Nature Conservancy Preserves: Jenney Woods, Tamarack Swamp, Augusta Floodplain, Klumbis Road Prairie (AMTRAK), Thompson Road Prairie (AMTRAK), Lawton Prairie (AMTRAK); Michigan Nature Association Preserves: Pennfield Bog, Dowagiac Woods, Fish Lake Bog, Bean Creek, Flowering Dogwood, Kope Kon, White Pigeon River, Flowerfield Creek, Sauk Indian Trail Prairie, Chen Memorial Prairie, Rattlesnake Master, Shannon, Helmer Brook Prairie, Woodruff Creek, Black Cottonwood, Harvey N. Ott, Wulfenia; Other: Lansing Schools Environmental Education Center, Kellogg Bird Sanctuary, Kalamazoo Nature Center, Fernwood Nature Study Area, Camp Betz Boy Scout Camp.

PUBLIC LAND MANAGERS: State Game Areas: Barry, Crane Pond, Fulton, Gourdneck, Three Rivers; State Recreation Areas: Fort Custer, Yankee Springs; Other: Kellogg Biological Station, Kellogg Forest, Wolf Lake State Fish Hatchery.

CONSERVATION CONCERNS:

SUB-SUBSECTION VI.2.2. Cassopolis Ice-Contact Ridges**; oak and oak-hickory forest, bogs.**

DISCUSSION: Sub-subsection consists of the narrow band of end moraines at the northern edge of the subsection, and also the band of steep, ice-contact features that run roughly north-south through the western half of the subsection.

ELEVATION: 850 to 1,150 feet (260 to 350 m).

AREA: 761 square miles (1,974 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: Steep, narrow bands of ice-contact and end-moraine ridges. The ridges are broken periodically by outwash channels. The height of the ridges ranges from 50 to 200 feet. Glacial drift is 250 to 350 feet thick (Akers 1938).

LAKES AND STREAMS: Kettle lakes are common, as are linear lakes that occupy abandoned drainageways of glacial meltwater streams. Many of the smaller kettles are now occupied by bog or swamp vegetation. Many small streams originate near the margins of the sub-subsection.

SOILS: Well drained and excessively well drained loamy and gravelly sands characterize most of the uplands. Organic soils are common near the margins of the kettle lakes. Organic soils in the kettle bogs can be several feet thick.

PRESETTLEMENT VEGETATION: The steep upland ridges were originally dominated by oak-hickory forest; white oak was the dominant species. White pine became a common co-dominant in the northern third of the sub-subsection. Oak savanna, also dominated by white oak, with some black oak, occurred on some south and west aspect slopes and on some of the more gently sloping ridges. Kettle depressions supported hardwood swamps, tamarack swamps, shrub swamps, and bog.

NATURAL DISTURBANCE: Both natural and anthropogenic fires were probably important within the sub-subsection, but fires probably did not carry as well as on the surrounding flat outwash plains of Sub-subsection VI.2.1.

PRESENT VEGETATION AND LAND USE: Although many of the steep lands were either cleared for crops or grazed by livestock, many of the farms have failed. Much of the land is now managed for timber and wildlife; several State game areas are located here. Residential developments are expanding from nearby urban areas.

RARE PLANT COMMUNITIES: Prairie fens are common along the margins of the sub-subsection. Oak savanna has converted to oak forest, but may yet be restorable. White oak-white pine savanna and forest, once quite common, persist locally.

RARE PLANTS: *Baptisia lactea* (prairie false indigo), *Baptisia leucophaea* (cream wild indigo), *Cacalia plantaginea* (prairie Indian-plantain), *Cypripedium candidum* (white lady's-slipper), *Eryngium yuccifolium* (rattlesnake-master), *Filipendula rubra* (queen of the prairie), *Gentiana puberulenta* (downy gentian), *Sabatia angularis* (rose pink), *Scutellaria elliptica* (hairy skullcap), *Sporobolus heterolepis* (prairie dropseed), *Valeriana ciliata* (edible valerian).

RARE ANIMALS: *Dendroica cerulea* (cerulean warbler), *Neonympha mitchelli mitchelli* (Mitchell's satyr), *Nerodia erythrogaster neglecta* (copperbelly water snake), *Oarisma poweshiek* (Poweshiek skipper), *Sistrurus catenatus* (eastern Massasauga rattlesnake), *Tachopteryx thoreyi* (greyback). (King rail was historically common.)

NATURAL AREAS: The Nature Conservancy Preserves: Thompson Road Prairie (AMTRAK); Michigan Nature Association Preserves: Pennfield Bog; Other: Russ Forest (Michigan State University), Baker Sanctuary, Kalamazoo Nature Center.

PUBLIC LAND MANAGERS: State Game Areas: Barry, Crane Pond, Three Rivers; State Recreation Areas: Yankee Springs.

CONSERVATION CONCERNS: Residential expansion into the remaining forested areas of the sub-subsection is isolating some of the State game areas, reducing their ability to support viable populations of both game and non-game species and making their management more difficult. These forested areas also function as important migration corridors for song birds.

SUBSECTION VI.3. Allegan**; lake plain and moraines; Lake Michigan-modified climate; beech-sugar maple forest, oak forest and savanna, open dune.**

DISCUSSION: The subsection consists of a narrow band of dunes and flat lake plain along Lake Michigan, and both end and ground moraine farther inland.

SUB-SUBSECTIONS: Berrien Springs (VI.3.1), Southern Lake Michigan Lake Plain (VI.3.2), Jamestown (VI.3.3). (See figure 5.)

ELEVATION: 580 to 998 feet (177 to 304 m).

AREA: 2,656 square miles (6,882 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 170 days in the south to 150 days in the north (Eichenlaub *et al.* 1990). Average annual precipitation ranges from 38 inches in the south to 32 inches in the north. Average snowfall ranges from 70 inches in the southern quarter of the subsection to as much as 100 inches farther north; this lake-effect snowfall decreases rapidly at the eastern edge of the subsection. Extreme minimum temperature ranges from -22˚F at the southern edge to -34˚F at the northern edge.

BEDROCK GEOLOGY: Subsection VI.3 is entirely underlain by Paleozoic bedrock; Devonian shale occurs in the southern quarter; and Mississippian shale, sandstone, and gypsum occur farther to the north (Dorr and Eschman 1984, Milstein 1987). Bedrock is generally covered with glacial deposits as thick as 350 feet, but there are local bedrock exposures in Sub-subsections VI.3.2 and VI.3.3 (Akers 1938).

LANDFORMS: Flat lake plain, coastal sand dunes, gently rolling till plain (ground moraine), and rolling to steep end moraines. See sub-subsections.

LAKES AND STREAMS: Very few lakes except for the kettle lakes in Sub-subsection VI.3.1. Large streams crossing the subsection include the Galien, St. Joseph, Kalamazoo, Grand, and Muskegon Rivers, all flowing into Lake Michigan.

SOILS: Soil textures range from sands to clays. The soils of the moraines (Sub-subsections VI.3.1 and VI.3.3) are classified as Hapludalfs plus Argiudolls (USDA Soil Conservation Service 1967). Lacustrine soils at the southern end of Sub-subsection VI.3.2 are classified as Udipsamments plus Hapludalf and Haplaquolls; further north the soils are Haplorthods plus Glossoboralfs. See sub-subsections.

PRESETTLEMENT VEGETATION: Most of the subsection was forested. See Sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VI.3.1. Berrien Springs**; sandy loam, loam, and silt-loam end and ground moraine; beech-sugar maple or white oak forests; swamp hardwoods, tamarack, wetland shrubs, and bogs in kettle depressions.**

DISCUSSION: Climate in this sub-subsection is modified by Lake Michigan, resulting in intensive agricultural land use as orchard and vineyard. Landforms and soils are similar to those of the end moraines of Sub-subsection VI.2.2, although the ridges are not generally as steep.

ELEVATION: 700 to 998 feet (213 to 304 m).

AREA: 770 square miles (1,994 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Sub-subsection is entirely underlain by Paleozoic bedrock; Devonian shale occurs in the southern half; Mississippian shale, sandstone, and gypsum occur farther to the north (Dorr and Eschman 1984, Milstein 1987). Bedrock of the entire sub-subsection is covered with 150 to 350 feet of glacial deposits (Akers 1938).

LANDFORMS: Sub-subsection VI.3.1 consists of a 10- to 20-mile-wide band of ground moraine and end-moraine ridges running parallel to Lake Michigan. The moraines are bounded by flat lake plain to the west and outwash to the east. Most of the ridges are 60 to 100 feet high with moderate to steep slopes.

LAKES AND STREAMS: Kettle lakes, although present on the end moraines, are much less numerous than on the end moraines of Sub-subsections VI.1.3, VI.2.1, and VI.2.2. There are also a few long, narrow lakes on the ground moraine. Several small streams originate on the upland ridges of the sub-subsection. Three large rivers, the Paw Paw, St. Joseph, and Kalamazoo, cut through the moraine ridges, creating steep ravines.

SOILS: Soils of the northern three-quarters are sandy loams underlain by either gravelly sand or clays. Most of these soils are moderately well drained or well drained. Slopes are moderate to steep. Soils in the southern quarter are silt loams, often underlain by clay subsoils. These soils are also generally well drained or moderately well drained. Poorly drained soils are concentrated on the fine-textured ground moraine. Very poorly drained soils occupy kettle depressions on the end moraine.

PRESETTLEMENT VEGETATION: The upland ridges were dominated by forests of beech, sugar maple, and white oak or forests of primarily white oak (Comer *et al.* 1993a). Kettle depressions supported swamp hardwoods, tamarack, wetland shrubs, and bogs.

Most moraines with silt- or clay-rich soils supported forests of beech and sugar maple. Beech-sugar maple forests also dominated many of the moraines with loamy or sandy soils; forests of white oak and black oak also occurred, especially on drier ridge tops. Open oak barrens or savannas were restricted to the steep ridges above the Paw Paw River.

Hardwood swamps or shrub swamps occupied kettle depressions in moraines, regardless of soil texture. Wet prairie and emergent marsh occupied large areas of fine-textured ground moraine; these marshes and prairies contained willow, alder, and scattered ash, [American] elm, and [red] maple. Diverse swamp forest occupied the broad flood plain of the St. Joseph River; species included sycamore, black ash, silver maple, beech, elm, hackberry, and basswood.

NATURAL DISTURBANCE: No natural disturbances were noted in the GLO notes. The oak barrens above the Paw Paw River may have been the result of Native American use of fire for management.

PRESENT VEGETATION AND LAND USE: Most of the sub-subsection is presently vineyard or orchard, even on steep slopes, including most of the flood plain of the St. Joseph River. The only areas not farmed are the steep ravines along creeks and rivers and small wetlands on the end moraines.

RARE PLANT COMMUNITIES: There were originally small prairies and savannas within the

sub-subsection, but all of these have been converted to agriculture.

RARE PLANTS: *Carex davisii* (Davis' sedge), *Carex jamesii* (James' sedge), *Polemonium reptans* (Jacob's ladder or Greek valerian), *Trillium recurvatum* (prairie trillium).

RARE ANIMALS: *Clonophis kirtlandii* (Kirtland's snake), *Dendroica dominica* (yellow-throated warbler), *Hesperia ottoe* (Ottoe skipper), *Lycaeides melissa samuelis* (Karner blue).

NATURAL AREAS: Michigan Nature Association Preserves: Beck Memorial; The Nature Conservancy Preserves: Bakertown Fen (AMTRAK), Bakertown Fen Preserve, Dayton Wet Prairie; Other: Fernwood Nature Study Area, Love Creek Nature Center, Camp Betz Boy Scout Camp.

PUBLIC LAND MANAGERS: Allegan State Game Area.

CONSERVATION CONCERNS: The valuable agricultural lands are being converted to residential developments in the south.

SUB-SUBSECTION VI.3.2. Southern Lake Michigan Lake Plain**; glacial lake plain, sand dunes; beech-sugar maple forest, oak-hickory forest, oak savanna, white oak-white pine forest, open sand dune, coastal plain marsh.**

DISCUSSION: Sub-subsection consists primarily of lacustrine deposits, but it also contains both fine-textured end and ground moraines that have been reworked by water. Along much of the Lake Michigan shoreline, there is a narrow band of steeply sloping sand dunes.

ELEVATION: 580 to 820 feet (177 to 250 m).

AREA: 1,356 square miles (3,511 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: The sub-subsection is entirely underlain by Paleozoic bedrock; Devonian shale occurs in the southern quarter; Mississippian shale, sandstone, dolomite, and gypsum occur farther to the north (Dorr and Eschman 1984, Milstein 1987). Overlying glacial drift is generally thick, from 50 to 350 feet (Akers 1938). There are very localized bedrock exposures of Coldwater shale in Ottawa County. Oil wells tap petroleum reservoirs in the underlying Devonian-age marine deposits (Dorr and Eschman 1984).

LANDFORMS: Sand dunes, up to 200 feet high, form a 1- to 3-mile-wide discontinuous band along the shore of Lake Michigan. The major period of dune formation was during Nipissing Great Lakes time, approximately 4,500 years ago; but smaller foredunes have formed during more recent times of low-water levels of Lake Michigan (Dorr and Eschman 1984).

Fine-textured end and ground moraines were concentrated in the southern half of the sub-subsection. Most of the moraines are flat to gently rolling.

In the northern half, there were extensive sand plains. Large deltas were associated with the Glacial Grand and Muskegon Rivers. Low dunes are common several miles inland; these dunes are associated with Glacial Great Lake shorelines as old as 16,000 years B.P. The topography of most of the lacustrine deposits is flat to gently rolling, gradually increasing in elevation from near the lakeshore.

LAKES AND STREAMS: There are a few small kettle lakes on the sand lake plain. The water level of many of these lakes fluctuates greatly, leaving them almost dry in some summers. These fluctuations result in a distinctive disjunct flora from the Atlantic and Gulf Coastal Plains along the lake margins. There are also a few small lakes on the moraines. Several of the larger rivers, including the Black, Kalamazoo, Grand, Muskegon, and White, have sand dunes where they meet Lake Michigan, creating small lakes behind the dunes. There are often extensive marshes within these shallow lakes.

SOILS: Soil textures range from sand to clay. Most surface lacustrine deposits are sand; those of the moraines are loams or clays.

Along the Muskegon River at the north edge of the sub-subsection, the lacustrine sands are generally excessively drained. A large part of these sands is outwash that contain few lenses of fine-textured material to restrict drainage. Low dunes are locally common.

Poorly drained sands also characterize a large part of the northern half of the sub-subsection. Cemented B horizons are common. Finer textured subsoils are generally responsible for the poor drainage conditions. Small beach ridges and sand dunes on the poorly drained plain are excessively drained.

Soils on the upper and middle slopes of moraines are generally well or moderately well drained. On moraines, slopes of 6 to 12 percent are common. Poorly drained soils are restricted to drainageways and depressions in the moraines.

PRESETTLEMENT VEGETATION: In the southern part of the sub-subsection, forests were dominated by beech and sugar maple on both fine-textured moraines and sandy lacustrine deposits (Comer *et al.* 1993a). In the northern half, forests dominated by eastern hemlock and beech occupied most of the sand lake plain and fine-textured moraines.

In the south, white oak and black oak were common along the bluffs and broad ridges above major rivers, including the Galien, St. Joseph, and Paw Paw. Farther north, upland conifer forest dominated by white pine, along with white oak and some black oak, occupied the bluffs and broad ridges above the major rivers, including the Grand, Muskegon, and Kalamazoo, and also the sandy plains adjacent to White and Muskegon Lakes. Native American fire management may have maintained the white pine and oaks along the rivers.

The dunes supported forests dominated by eastern hemlock and beech. Hemlock-beech forest was the dominant forest type along the dunes of the entire shoreline as far south as Benton Harbor, near the southern edge of the sub-subsection. Although hemlock and beech were the dominant species, white pine, red oak, white oak, and sugar maple were also present. At the northern edge, white pine became increasingly dominant on the dunes, often with hemlock or white oak as co-dominants. Several large areas of open, blowing sand (blowouts) were noted in GLO surveys. These areas, generally less than a half mile wide, extended as much as a mile inland from the shoreline.

The largest wetlands were located along the rivers, where both extensive marshes and lowland hardwoods, often dominated by either black ash or silver maple, formed broad bands for several miles inland from Lake Michigan. Both tamarack swamp and lowland hardwoods swamp were located in bowl-shaped depressions behind the dunes.

Further inland, small kettle depressions within areas of end moraine supported small marshes and both lowland hardwoods and lowland conifers. Broad depressions on both the flat sand lake plain and the ground moraine contained emergent marshes, wet prairies, and both lowland hardwoods and lowland conifers.

NATURAL DISTURBANCE: The GLO survey found several blowouts in dunes. Although not noted by the surveyors, seasonal water level fluctuations occur on the lake plain, often resulting in dominance by either prairie or marsh species tolerant of such fluctuations. Such fluctuations can result in major cyclical changes in plant composition in shallow ponds or depressions as water levels change over a period of several years.

Native American land management with fire may have had a major impact on the vegetation in portions of the sub-subsection. There were local references by surveyors to burned lands along the Galien River and to Indian fields and trails along the Kalamazoo, Grand, and Muskegon Rivers.

PRESENT VEGETATION AND LAND USE: In the past, white pine and hemlock were harvested on the sand lake plain. Sand was mined on some of the dunes, primarily for use as molding and foundry sand. Most of the lands of the sub-subsection are in agriculture. Farming of the sand lake plain required large-scale drainage. Poorly drained portions of the lake plain now support nurseries and blueberry and asparagus

farming. Better drained soils are converted to orchards and vineyards.

Some of the droughtiest and most poorly drained sandy soils remain as wildlife management areas or as recreational lands, either forested or wetland. Large portions of the coastal sand dunes are protected as park lands, but there is also heavy residential development of sections of the dunes.

RARE PLANT COMMUNITIES: The wet prairies of the sub-subsection are distinct from those found in other parts of the State and are called lakeplain wet and wet-mesic prairies. Many of the marshes, which occupy shallow depressions between beach ridges or sand spits (often several miles inland from the present lakeshore), are rich in disjunct species from the Atlantic and Gulf Coastal Plains of the U.S.

RARE PLANTS: Most of the rare plants are coastal plain disjuncts from the Atlantic and Gulf coasts; there are also species characteristic of the sand dunes of the Great Lakes. *Carex platyphylla* (broad-leaved sedge), *Cirsium pitcheri* (Pitcher's thistle), *Echinodorus tenellus* (dwarf burhead), *Eleocharis melanocarpa* (black-fruited spike-rush), *Eleocharis tricostata* (three-ribbed spike-rush), *Hibiscus moscheutos* (swamp rose-mallow), *Juncus biflorus* (two-flowered rush), *Juncus scirpoides* (scirpus-like rush), *Lycopodium appressum* (appressed bog clubmoss), *Orobanche fasciculata* (fascicled broom-rape), *Panicum longifolium* (long-leaved panic-grass), *Potamogeton bicupulatus* (waterthread pondweed), *Pycnanthemum verticillatum* (whorled mountain-mint), *Rhexia mariana* var. *mariana* (Maryland meadow-beauty), *Rhexia virginica* (meadow-beauty), *Sabatia angularis* (rose-pink), *Scirpus hallii* (Hall's bulrush), *Scleria reticularis* (netted nut-rush), *Sisyrinchium atlanticum* (Atlantic blue-eyed grass), *Utricularia subulata* (zigzag bladderwort).

RARE ANIMALS: *Chlidonias niger* (black tern), *Clonophis kirtlandii* (Kirtland's snake), *Dendroica cerulea* (cerulean warbler), *Dendroica discolor* (prairie warbler), *Dendroica dominica* (yellow-throated warbler), *Hesperia ottoe* (Ottoe skipper), *Incisalia irus* (frosted elfin), *Lanius ludovicians* (loggerhead shrike), *Lycaeides melissa samuelis* (Karner blue), *Microtus ochrogaster* (prairie vole).

NATURAL AREAS: State Natural Areas: Crooked Lake Marsh (Allegan State Game Area), Saugatuck; State Nature Study Areas: Warren Woods, Warren Dunes; Michigan Nature Association Preserves: Five Lakes, Wade Memorial, Barvicks Sand Dunes, Pepperidge Dunes, Beck Memorial; The Nature Conservancy Preserves: Grand Beach, Ross, Hofma, Robinson; Other: Sarrett Nature Center, Fernwood Nature Study Area.

PUBLIC LAND MANAGERS: State Game Areas: Grand Haven, Allegan, Muskegon; State Parks: Warren Dunes, Grand Mere, Van Buren, Saugatuck, P.J. Hoffmaster, Holland, Muskegon; National Forests: Manistee.

CONSERVATION CONCERNS: Sub-subsection VI.3.2 contains important tracts of sand dune (as does Subsection IV.4, directly to the north), many of which are protected in dedicated natural areas or as State parks. Residential development, sand mining, and off-road vehicle use remain threats to these dunes. The coastal plain marshes contain some of the highest concentrations of species on Michigan's list of threatened and endangered species; these shallow wetlands are constantly under threat from residential development, dredging and flooding for game management, and off-road vehicle use. Allegan State Game Area, where several of these marshes are being protected, contains more of these marshes than any other area in the State. Allegan State Game Area also contains a large, viable population of federally threatened and endangered Karner blue butterfly; controlled burn management is being conducted to improve and expand habitat for the butterfly.

Disruption of coastal processes along the Lake Michigan shoreline, through creation of marinas and breakwaters, can destabilize other parts of the shoreline. The long-term effects of these processes have not been thoroughly evaluated, except where human lives and residences have been threatened.

SUB-SUBSECTION VI.3.3. Jamestown**; fine-textured end and ground moraine; beech-sugar maple forest.**

DISCUSSION: This small sub-subsection of fine-textured moraine has a climate moderated by Lake Michigan. The presence of fine-textured soils distinguishes it from both Sub-subsection VI.3.1 to the south and Sub-subsection VI.4.2 to the east.

ELEVATION: 640 to 972 feet (195 to 296 m).

AREA: 531 square miles (1,376 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Sub-subsection is entirely underlain by Paleozoic bedrock, primarily Mississippian shale, sandstone, and gypsum (Dorr and Eschman 1984, Milstein 1987). Glacial deposits covering the bedrock are up to 200 feet thick; bedrock is locally exposed in western Ottawa County (Akers 1938).

LANDFORMS: Most of the sub-subsection consists of broad, gently sloping ridges; but a few steep slopes occur, especially in the northeast. The highest steep ridges are approximately 200 feet high.

LAKES AND STREAMS: No large lakes. The Grand River flows through the sub-subsection. The Grand River's flood plain is broad, and the valley walls are steep.

SOILS: Most of the soils are clayey, with high water-holding capacity and low permeability (USDA Soil Conservation Service 1981). Surface soil horizons are generally loamy, and well drained and somewhat poorly drained soils are predominant (Veatch 1953).

PRESETTLEMENT VEGETATION: Fine-textured ground moraine supported a forest of almost equal parts hemlock (43 percent) and beech (41 percent), with some sugar maple, basswood, paper birch, and [red or silver] maple (Comer *et al.* 1993a). On the steeper end-moraine ridges, beech and sugar maple were the dominant tree species. Depressions in the ground moraine were dominated by either black ash or hemlock. Depressions in the steeper end-moraine ridges were dominated by black ash.

NATURAL DISTURBANCE: No mention of natural disturbances for this unit.

PRESENT VEGETATION AND LAND USE: Most of the lands are under agriculture, either row crops or pasture. Woodlots are generally on wet or excessively steep sites.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: *Lanius ludovicians* (loggerhead shrike).

NATURAL AREAS: None to date.

PUBLIC LAND MANAGERS: Grand Haven State Game Area, Riverside County Park.

CONSERVATION CONCERNS: This small sub-subsection has largely been converted to agricultural land. It is also being impacted by residential growth from nearby Grand Rapids.

SUBSECTION VI.4. Ionia**; medium- and coarse-textured moraines; forests of beech-sugar maple (and black maple) and oak-pine, conifer and deciduous swamp forests.**

DISCUSSION: The subsection consists of two sub-subsections.

SUB-SUBSECTIONS: Lansing (VI.4.1), Greenville (VI.4.2).

ELEVATION: 640 to 1,122 feet (195 to 345 m).

AREA: 5,864 square miles (15,192 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from approximately 130 days at the northern edge of the subsection to 160 days at the western edge (Eichenlaub *et al.* 1990). It is the least lake-moderated subsection in Section VI (Albert *et al.* 1986). Average annual precipitation ranges from 30 to 32 inches, and average annual snowfall ranges from 40 to 80 inches, with highest levels in the west near Lake Michigan. Extreme minimum temperature ranges from -24˚F to -36˚F. In general, the extreme minimum temperature becomes lower farther north in the subsection, but there is also a large frost pocket in northern Ingham and Ionia Counties near the center of the subsection.

BEDROCK GEOLOGY: Exposed bedrock is rare; glacial deposits over bedrock are as thick as 350 or 400 feet (Akers 1938). The subsection is underlain primarily by Paleozoic bedrock, primarily Pennsylvanian sandstone, shale, coal, and limestone, with Mississippian shale and gypsum occurring at the western edge (Dorr and Eschman 1984). There are also scattered occurrences of Mesozoic bedrock; these Jurassic red beds consist mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

LANDFORMS: Most of the subsection consists of loamy till plain and narrow bands of loamy end moraine (Sub-subsection VI.4.1); the northern edge of the subsection consists of both sandy ground moraine and sandy, steep end moraines (Sub-subsection VI.4.2) and is considered transitional to Subsection VII.2 to the north.

LAKES AND STREAMS: Lakes are more numerous on the sandy moraines of Sub-subsection VI.4.2 than in Sub-subsection VI.4.1. Many streams are present in both sub-subsections.

SOILS: See sub-subsections.

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VI.4.1. Lansing**; medium-textured ground moraine; beech-sugar maple forest and hardwood swamp.**

DISCUSSION: This broad till plain has rich, loamy soils that have been largely converted to agriculture. This sub-subsection is the largest in Lower Michigan.

ELEVATION: 640 to 1,122 feet (195 to 342 m).

AREA: 5,053 square miles (13,092 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 140 to 160 days and is shortest in the north (Eichenlaub *et al.* 1990). Snowfall ranges from 40 to 70 inches, increasing to the west, closer to Lake Michigan. Annual precipitation is relatively uniform, ranging from 30 to 32 inches. Extreme minimum temperature ranges from -24˚F to -38˚F, lowest in the north and in a large frost pocket near the center of the sub-subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: Sub-subsection consists of gently sloping ground moraine, broken by several outwash channels and also by numerous end-moraine ridges, many of which are a little steeper than the surrounding ground-moraine topography. Most of the gently rolling hills of ground moraine are only 40 to 60 feet high, but hills up to 100 feet are found on the east and west edges of the sub-subsection. The topography is gently rolling; typical slopes on the ridges are within the 0 to 6 percent slope class. Local relief of less than 50 feet is found over areas of several miles. The greatest elevation changes in the sub-subsection, accompanied by steep slopes, are along the outwash channels, which are commonly 50 to 100 feet lower than the adjacent ground moraine.

The end-moraine ridges, which cross-cut the till plain, typically form narrow bands 1 to 3 miles wide. Usually the end moraines do not form single, well-defined ridges, but rather groups of low ridges (less than 50 feet high) and swampy depressions. Most of the ridges are too steeply or irregularly sloping for agriculture.

LAKES AND STREAMS: Three large rivers, the Maple, Grand, and Thornapple, and several smaller rivers flow across the broad till plain. Many of the rivers and creeks occupy glacial outwash channels; these channels presently carry much less water and sediment load than the glacial streams that deposited the outwash. The Grand River, which crosses the sub-subsection, occupies a major glacial outwash channel 150 to 200 feet lower than the surrounding till plain. In parts of the sub-subsection, the post-glacial drainage system is not well developed, resulting in numerous broad swamps and marshes. The largest of these wetlands have been drained and converted to agriculture. There are a few small lakes, both kettle lakes on the end moraines and lakes occupying more linear depressions on the till plain.

SOILS: The undulating topography of the ground moraine forms alternating well and moderately well drained rises and poorly to very poorly drained linear depressions. Approximately 30 percent of the ground moraine is poorly drained. Many of the depressions and glacial drainageways contain very poorly drained soils.

A small area of sandy ground moraine, surrounded by the loam soils more typical of the sub-subsection, occupies southwestern Shiawassee County. Local areas of sandy upland were farmed in the past; but the farms failed, probably due to droughty, sterile soils. The lowlands remain as swamps and marshes.

Soils are classified by the Soil Conservation Service (1967) as gently sloping Hapludalfs plus Argiaquolls.

PRESETTLEMENT VEGETATION: The presettlement vegetation of the upland ground and end moraines was beech-sugar maple forest. Other common species included black maple, basswood, red oak, and white ash. Black maple, now encountered more in this sub-subsection than in any other (possibly because of the wet-mesic conditions and the circumneutral soils on the gently sloping ground moraine), was identified as sugar maple during the original surveys. Some of the drier end-moraine ridges supported oak-hickory forests dominated by red and white oaks. The driest sandy ridges of the outwash deposits supported black oak, white oak, and pignut hickory.

Swamp forests dominated most of the depressions, but wet meadows were also present along streams. Among the common tree species were silver maple, American elm, red ash, and swamp white oak. Hackberry is presently common in the second-growth swamps, but was rarely mentioned by GLO surveyors. Tamarack was also present, especially in very poorly drained outwash channels. A large “wet prairie” was located in Clinton and Shiawassee Counties.

NATURAL DISTURBANCE: Windthrow was probably the most common form of natural disturbance.

PRESENT VEGETATION AND LAND USE: Drainage was necessary for agricultural use of the lowlands and some of the uplands. The number of drainage ditches in the sub-subsection is second only to that of the Maumee Lake Plain and the Saginaw Lake Plain sub-subsections. Tiling was the preferred method of drainage on the moderately well drained soils on uplands, but drainage ditches were necessary on poorly and very poorly drained soils. Organic soils were extensively drained for the production

of mint and other specialty crops. The organic deposits are also extensively mined for sedge peat, used in gardening and landscaping.

Most of the uplands have been converted to crop land, while most of the swamp forest has been converted to pasture. Swamp forest and wet meadow persist locally on the landscape. The largest wet prairies have been drained and converted primarily to agricultural use.

RARE PLANT COMMUNITIES: One of the rarest plant communities in the State, inland salt marsh, occurred in saline seepages along the Maple and Grand Rivers; only one of these marshes remains. All the wet prairies have been badly degraded or destroyed by drainage for agriculture.

RARE PLANTS: *Arabis perstellata* var. *shortii* (rock cress), *Carex typhina* (cattail sedge), *Eleocharis parvula* (dwarf spike-rush), *Scirpus olneyi* (Olney's bulrush), *Trillium nivale* (snow trillium), *Zizia aptera* (prairie golden alexander).

RARE ANIMALS: *Asio otus* (long-eared owl), *Dysnomia triquetra* (snuffbox), *Falco peregrinus* (Peregrine falcon), *Lanius ludovicians* (loggerhead shrike), *Myotis sodalis* (Indiana bat).

NATURAL AREAS: The Nature Conservancy Preserves: Bancroft Floodplain; Other: Baker Woodlot, Scott Woods, Sanford Natural Area, Red Cedar Woods, Toumey Woods, Maher Wildlife Sanctuary, Woldumar Nature Study Area.

PUBLIC LAND MANAGERS: State Game Areas: Rose Lake Wildlife Research Area, Portland, Lowell, Dansville, Mason, Flat River, Oak Grove, Maple River, Barry, Cannonsburg, Shiawassee River, Middleville; State Parks: Seven Lakes, Sleepy Hollow.

CONSERVATION CONCERNS: Because of its fertile soils this sub-subsection was cleared early for farming. Few large tracts of forest exist. The original wet prairies were also drained and farmed. Restoration would be required to develop a functional natural landscape. The least developed portion of the sub-subsection is an area of sandy, poorly drained ground moraine in Clinton and Shiawassee Counties, where there is potential for wet prairie.

SUB-SUBSECTION VI.4.2. Greenville**; coarse-textured end and ground moraine; beech-sugar maple forests and white oak-white pine forests, conifer swamps and bogs.**

DISCUSSION: Sub-subsection is considered transitional from Section VI to Section VII because of its sandy soils and intermediate elevations. The vegetation also reflects this transition, with increased conifer dominance in both uplands and wetlands.

ELEVATION: 800 to 1,122 feet (243 to 342 m).

AREA: 811 square miles (2,100 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 130 to 150 days (Eichenlaub *et al.* 1990). Snowfall ranges from 50 to 70 inches, and annual precipitation ranges from 30 to 32 inches. Extreme minimum temperature ranges from -26˚F to -30˚F.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: Generally hilly terrain, dissected by outwash channels. The hills, up to 140 feet high, are moderately to steeply sloping. Both the ground moraine and end moraine are moderately to steeply sloping, but the ground-moraine ridges are generally smaller than those of the end moraine.

LAKES AND STREAMS: Many small kettle lakes, typically less than 1 square mile in area, on outwash, end moraine, and ground moraine.

SOILS: Soils are well drained and excessively drained sands and loamy sands on the uplands. Sand outwash deposits are common on lower slopes. Most of the outwash soils are poorly drained. Soils are classified by the Soil Conservation Service (1967) as Haplorthods plus Glossoboralfs and Udipsamments.

PRESETTLEMENT VEGETATION: The upland vegetation was a mosaic of beech-sugar maple and oak-hickory forests. Oak-hickory forest was more common at the southern edge of the sub-subsection; beech-sugar maple was more common to the north. This pattern is likely the result of gradual climatic changes that occur as the terrain rises northward into the Highplains subsection (VII.2). White pine was once locally common on the drier upland sites, often growing with white oak in either open forests or savannas.

The lowland vegetation also contained elements of both the deciduous hardwood swamp and hardwood-conifer and conifer swamps. Most of the swamp forests in the outwash channels were hardwood-conifer swamps containing hemlock, balsam fir, northern white-cedar, white pine, trembling aspen, and paper birch.

NATURAL DISTURBANCE: Fires were probably important for maintaining the oak-pine and oak forests and savannas. Windthrows, probably relatively small due to the irregular, small ridges of the sub-subsection, were probably more common in the beech-sugar maple-dominated forests.

PRESENT VEGETATION AND LAND USE: Parts of this sub-subsection were farmed, both for row crops and pasture after logging; but much of the farmland has been abandoned due to low productivity and cold climate. Large parts of the sub-subsection remain forested. Most agricultural activities have been concentrated in uplands with the richest soils. Most wetlands have not been significantly impacted by agricultural activities.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: *Asio otus* (long-eared owl), *Lycaeides melissa samuelis* (Karner blue).

NATURAL AREAS: MacCurdy Ecological Tract.

PUBLIC LAND MANAGERS: State Game Areas: Flat River, Rouge River, Stanton, Lanston; National Forests: Manistee.

CONSERVATION CONCERNS:

SUBSECTION VI.5. Huron**; clay lake plain, reworked till plain, and interlobate; dry-mesic, mesic, and wet-mesic forests, oak savanna, swamp forest, wet and wet-mesic prairie, and emergent marshes.**

DISCUSSION: Subsection VI.5 has a climate moderated by the Great Lakes, but less so than along Lake Michigan or Lake Superior because of the direction of prevailing winds, which are from the west and southwest.

SUB-SUBSECTIONS: the Sandusky Lake Plain (VI.5.1), which is a flat lake plain that slopes gradually to Lake Huron; and the Lum interlobate (VI.5.2), with both end-moraine ridges and outwash deposits.

ELEVATION: 572 to 1,041 feet (175 to 317 m).

AREA: 3,690 square miles (9,564 sq km).

STATES: Michigan.

CLIMATE: Subsection is cooler than most of the rest of southern Lower Michigan. Growing season is 130 to 160 days (Eichenlaub *et al.* 1990). Because most air flows here are from a westerly direction, this subsection experiences less lake moderation than subsections on the west side of the State. Extreme minimum temperature ranges from -24˚F to -28˚F. Average annual precipitation ranges from 28 to 34 inches, and annual snowfall is 40 to 80 inches. The highest rainfall and snowfall occurs at the northeastern edge of the subsection along Lake Huron, where lake-effect precipitation occurs when winds are from the north and east.

BEDROCK GEOLOGY: The bedrock underlying most of the subsection is Paleozoic in age, deposited in marine and near-shore environments

(Dorr and Eschman 1984). Bedrock is covered by glacial deposits, except on lower reaches of some of the streams and small portions of the shoreline of Saginaw Bay and Lake Huron. Bedrock includes Mississippian shale, sandstone, gypsum, and limestone. At the southeastern edge, along the St. Clair River, there is Devonian shale; at the western edge, there is Pennsylvanian sandstone, shale, limestone, and coal. Mississippian sandstone is exposed in the north, along Lake Huron. Pennsylvanian-age coal was mined locally.

LANDFORMS: Subsection VI.5 consists of broad expanses of level lake plain (Sub-subsection VI.5.1), but it also includes steep end-moraine ridges and pitted outwash in the southwest (Sub-subsection VI.5.2). See sub-subsections.

SOILS: See sub-subsections.

LAKES AND STREAMS: See sub-subsections.

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VI.5.1. Sandusky Lake Plain**; clay lake plain and reworked till plain; mesic to wet-mesic forests, swamp forest, wet and wet-mesic prairie, and emergent marshes.**

DISCUSSION: Sub-subsection VI.5.1 is a flat lake plain that slopes gradually to Lake Huron; a narrow moraine that parallels the shore of Saginaw Bay and Lake Huron occupies the center of the narrow sub-subsection. Agricultural development has been intensive as a result of a lake-modified climate and productive loamy soils.

ELEVATION: 572 to 870 feet (175 to 265 m).

AREA: 3,210 square miles (8,319 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: Sub-subsection consists of broad expanses of level lake plain along its margins, but it also includes long, narrow till plains and ridges of end moraine that are parallel with Saginaw Bay or Lake Huron. At the inland margin of the clay lake plain there is a broad sand channel, which is largely poorly drained. The till plain is quite flat and difficult to distinguish from the lake plain. The end moraine is several miles wide and forms a low ridge, which has better drainage conditions than the surrounding lake plain.

SOILS: On the lake plain, slopes are typically in the 0 to 2 percent slope class. Approximately one-third of the soils are poorly drained or very poorly drained; most of the remaining soils are moderately well drained. In the past, the soils of the sandy channels on the lake plain were often poorly drained or very poorly drained. Low dunes within these channels had excessively drained soils. Most of the lacustrine soils were drained to allow agricultural development of the land. Peat soils were also burned. On the end moraines, slopes are gentle to moderate, generally in the 2 to 6 percent slope class, and soils are moderately well and well drained. Soils on the end moraines are classified as Hapludalfs, with some Argiaquolls; those of the lake plain are classified as Haplaquents, with some Haplaquods (USDA Soil Conservation Service 1967).

LAKES AND STREAMS: No lakes. Most of the streams are small, beginning on the moraines and forming relatively straight, shallow trenches across the lake plain before entering Saginaw Bay or Lake Huron. The exceptions are the Cass River and Black River; both flow several miles between parallel moraines before crossing the lake plain.

PRESETTLEMENT VEGETATION: The presettlement vegetation often differed greatly among the clay lake plain, sand lake plain, and end moraine (Comer *et al.* 1993a, b). Almost the entire clay plain was forested. Most of the clay lake plain was dominated by upland conifer forests of eastern hemlock. Topography was flat, with slopes of less than 2 percent. These forests were not generally considered swamps, but the soils were probably wet. Hemlock often made up 40 percent or more of the overstory; other common species were beech, northern white-cedar, sugar maple, [American] elm, balsam fir, paper birch, white pine, white ash, black ash, basswood, [red] maple, and [trembling] aspen. In the wettest parts of the lake plain, lowland hardwoods were prevalent; the common dominants were black ash and American elm. In closed depressions, lowland hardwoods dominated by black ash were common.

On slightly steeper portions of the clay plain, where slopes were generally greater than 2 percent, northern hardwoods forests of beech-sugar maple were numerous, sometimes making up more than 50 percent of the overstory; hemlock was much less common.

The low dunes and relatively flat sand plain supported conifer forests of hemlock and white pine. Small areas of forests dominated by white oak and black oak were also common near the shoreline, both on low beach ridges and sand dunes.

Wetlands within the forested sand plain contained abundant black ash. Along the border with clay lake plain, lowland conifers dominated by tamarack, and occasionally northern white-cedar, were dominant, often forming a dense linear band. Locally, there were extensive emergent marshes one-fourth to one-half mile wide, which occupied depressions within the lake plain, often between beach ridges formed along long-abandoned shorelines of Saginaw Bay.

Extensive Great Lakes marshes occurred along the entire coast of Saginaw Bay and locally along the shore of Lake Huron southeast of Saginaw Bay (Albert *et al.* 1988). The marshes, which extended into water 4 to 5 feet deep, were 1 to 2 miles wide in places. Upland of the marshes there was typically a broad zone of swamp forest; but on large expanses of Saginaw Bay, 1- to 3-mile-wide expanses of wet prairie occurred. Wet prairie was concentrated at the far northwestern edge of the sub-subsection along Saginaw Bay in Tuscola and Huron Counties. The plant composition of the wet prairie changed along with the water level of Lake Huron. Within the coastal marshes and wet prairies were low beach ridges and sand spits that supported scattered white oak and black oak.

Expansive bands of parallel beach ridges and swales occupy some of the embayments along Saginaw Bay. White pine dominated the beach ridges, along with some white oak, black oak, trembling aspen, and paper birch. The wettest swales near Saginaw Bay were dominated by floating and emergent aquatic plants; swales further inland typically supported swamp forests of northern white-cedar, tamarack, and occasionally black ash.

Forests of beech-sugar maple, with lesser quantities of hemlock, basswood, white ash, and red maple, grew on much of the moraines, which generally have better drainage conditions than the lake plain. Black ash dominated many of the wetland depressions within the moraines. Conifer swamps, dominated by northern white-cedar, occupied broad wetlands in footslope positions. These cedar swamps also contained tamarack, balsam fir, hemlock, and some white pine, along with birch, [trembling] aspen, and other hardwoods.

NATURAL DISTURBANCE: Extensive areas of windthrown forest were recorded in the GLO notes. These extensive windthrows are the result of a combination of strong winds off Lake Huron and poorly drained soils. Windthrow appears to have been more common within the wetlands and on the flattest parts of the lake plain. Water level fluctuations of 2 to 3 feet are common along the Great Lakes shorelines, causing tree mortality, shoreline erosion, and major alteration in species composition of marshes and wet prairies. The surveyors noted such water-level fluctuations near the west edge of the subsection.

PRESENT VEGETATION AND LAND USE: Before European settlement, Native American settlements were common along the shorelines of the Great Lakes, primarily upon beach ridges. Indian fires were probably responsible for maintaining oak savannas on the beach ridges near Saginaw Bay.

Most of the clay plain has been ditched and tiled, and these lands are among the most valued for agriculture in the State. Parts of the sand plain were also ditched for agriculture; but the wettest areas remain, either as swamp forest, wet prairie, or marsh. Diking and pumping have allowed vast expanses of wet prairie and some areas of marsh to be farmed, especially along Saginaw Bay. Organic soils were burned to improve their suitability for agriculture (Deeter and Matthews 1931).

The better drained soils on the moraines have also been intensively converted to agriculture. The extensive drainage networks created on the lake plain were not necessary on the end moraines.

Almost no forests remain within the sub-subsection, and the composition of those that do remain has changed considerably. Conifer-dominated forests have been eliminated on both upland and wetland sites. Conifer swamps have converted to lowland hardwoods or brush.

RARE PLANT COMMUNITIES: Wet and wet-mesic prairie were originally extensive, along with oak savannas or "openings," but these now remain as only small remnants, primarily on State-owned lands. Prairies and savannas on the lake plain are called lakeplain prairie or oak opening because of the distinctive flora and fauna. Some of the most extensive upland conifer forests of the lake plain, dominated by either white pine or hemlock, have been virtually eliminated.

RARE PLANTS: Most of the species in this sub-subsection are associated with either Great Lakes marshes or lakeplain prairies. *Agalinis gattingeri* (Gattinger's gerardia), *Agalinis skinneriana* (Skinner's gerardia), *Aristida longespica* (three-awned grass), *Asclepias hirtella* (tall green milkweed), *Asclepias sullivantii* (Sullivant's milkweed), *Astragalus neglectus* (Cooper's milk-vetch), *Astragalus canadensis* (Canadian milk-vetch), *Cacalia plantaginea* (prairie Indian-plantain), *Juncus brachycarpus* (short-fruited rush), *Juncus biflorus* (two-flowered rush), *Platanthera leucophaea* (prairie fringed orchid), *Scirpus clintonii* (Clinton's bulrush), *Trillium undulatum* (painted trillium).

RARE ANIMALS: *Chlidonias niger* (black tern), *Dysnomia torulosa rangiana* (northern riffleshell), *Elaphe vulpina gloydi* (eastern fox snake), *Lanius ludovicians* (loggerhead shrike), *Sterna caspia* (Caspian tern), *Sterna forsteri* (Forster's tern), *Sterna hirundo* (common tern).

NATURAL AREAS: Michigan Nature Association Preserves: Jasper Woods Memorial and Red Wing Nature Sanctuaries, Ray Memorial Plant Preserve.

PUBLIC LAND MANAGERS: State Game Areas: Fish Point, Deford, Rush Lake, Sanilac, Vassar, Port Huron, Minden City, Cass City, Murphy Lake, Tuscola, Verona; State Wildlife Areas: Fish Point, Quanicassee, Wildfowl Bay; State Parks: Lakeport, Port Crescent, Sanilac Petroglyphs, Albert E. Sleeper; Environmental Areas: Fish Point, McKinley, Rose Island, Sebewaing, Thomas, Weale, Bay Port.

CONSERVATION CONCERNS: The GLO surveyors commented on the importance of the wet prairies for waterfowl.

SUB-SUBSECTION VI.5.2. Lum Interlobate**; medium- and coarse-textured end moraine and outwash; oak savanna and oak-hickory forest, hardwood swamps, prairie fens, bogs.**

DISCUSSION: Sub-subsection VI.5.2 is at the extreme northern end of an interlobate area between three glacial lobes that formed approximately 13,000 to 16,000 years B.P. This section of the interlobate, which has a more northerly climate, is about 30 miles long. This sub-subsection is characterized by relatively steep end-moraine ridges surrounded by pitted outwash deposits; kettle lakes and wetlands are common within the outwash.

ELEVATION: 750 to 1,041 feet (229 to 317 m).

AREA: 480 square miles (1,245 sq km).

STATES: Michigan.

CLIMATE: Growing season is 130 to 140 days (Eichenlaub *et al.* 1990). Danger of late spring frosts is great due to numerous lowland depressions (outwash and kettle lakes). Average snowfall is 40 inches, and annual precipitation is 28 to 30 inches. Extreme minimum temperature ranges from -24˚F to -28˚F.

BEDROCK GEOLOGY: The underlying bedrock is primarily Mississippian- and Pennsylvanian-age sandstone (Dorr and Eschman 1984, Milstein 1987). Bedrock is overlain by 250 to 300 feet of glacial drift (Akers 1938).

LANDFORMS: Sub-subsection contains broad expanses of outwash sands that surround sandy and gravelly end moraines and ground moraines. End and ground moraines remain as island-like hills surrounded by flat outwash. Large linear segments of end moraine, broken only by narrow outwash channels, are typically located along the margins of the sub-subsection.

LAKES AND STREAMS: Kettle lakes and ponds are numerous on the pitted outwash and end moraines. Extensive wetlands surround many of the lakes and occupy entire ice-block depressions. Both marl and peat deposits were mined in the past. The headwaters of the Flint River originate here.

SOILS: The soils of the moraines are typically well and excessively well drained. Drainage conditions on the outwash are more variable, ranging from excessively well drained to very poorly drained. Thick outwash deposits are usually characterized by excessively well drained conditions. Shallow outwash deposits are underlain in some places by fine-textured till and lacustrine deposits, causing poor or very poor drainage conditions. On ice-contact topography, soils are typically excessively drained on the upland kames and eskers and poorly or very poorly drained in the kettles and outwash channels. Where the topography is steep, organic soils can be 10 to 15 feet deep in narrow outwash channels.

Soil textures range from sand to clay; the most common soil texture is sandy loam on the moraine ridges and sand on the outwash plains. The circumneutral glacial drift that forms the moraines is largely derived from the local limestone bedrock. Illuviation is responsible for the formation of a clay-rich (argillic) horizon in many of the soils on moraines, providing better water-holding capacity than many of the outwash soils. In the ice-contact areas, soils are sands and gravels. The Soil Conservation Service (1967) classifies the soils of the sub-subsection as Hapludalfs with Argiudolls.

PRESETTLEMENT VEGETATION: Vegetation reflects underlying differences in landform and topography as well as the transition to a more northerly climate. On the sandy moraines at the southern edge, open forests and savannas of black oak and white oak were noted. However, within most of the sub-subsection, forests consisted of a more northerly forest of beech and sugar maple, with large amounts of white pine and often eastern hemlock; white oak commonly occurred with white pine in the southern part of the unit (Comer *et al.* 1993b).

Kettle lakes and swampy depressions on the outwash typically supported alder swamp or conifer swamp; northern white-cedar and tamarack were common species, along with black ash. White pine and eastern hemlock were also common in the swamps.

NATURAL DISTURBANCE: Windthrown forest was mentioned frequently in the GLO notes, but most of these windthrows appeared to be relatively small, probably because of the steep, irregular topography.

PRESENT VEGETATION AND LAND USE: Many of the uplands have been farmed, except the steepest end moraines and ice-contact ridges, which have been maintained as woodlots or are presently either recreational or wildlife management areas. Many of these steep ridges have been pastured in the past. Both residential development and agricultural land use have resulted in rapid eutrophication of lakes and degradation of many wetlands. Road construction and ditching have also modified the hydrology of many wetlands.

RARE PLANT COMMUNITIES: A few oak savannas were present in the southern part of the sub-subsection, but these have been destroyed by agriculture or degraded by fire exclusion.

RARE PLANTS: *Astragalus neglectus* (Cooper's milk-vetch), *Linum sulcatum* (furrowed flax), *Panax quinquefolius* (ginseng), *Polemonium reptans* (Jacob's ladder).

RARE ANIMALS: *Clemmys guttata* (spotted turtle), *Carunculina glans* (purple lilliput).

NATURAL AREAS: None to date.

PUBLIC LAND MANAGERS: State Game Areas: Lapeer, Murphy Lake, Tuscola, and Deford.

CONSERVATION CONCERNS: Residential development is destroying many of the lakes and wetlands, as well as rapidly fragmenting upland forests.

BOUNDARIES: This sub-subsection has soils and physiography similar to the Jackson Interlobate sub-subsection (VI.1.3) to the southwest, but its climate is cooler. The forest vegetation has a major component of white pine and eastern hemlock, reflecting these cooler, more northerly conditions (Albert *et al.* 1986).

SUBSECTION VI.6. Saginaw Bay Lake Plain**; glacial lake plain and reworked till plain; mesic to wet-mesic forests, swamp forest, wet and wet-mesic prairie, and emergent marshes.**

DISCUSSION: Subsection VI.6 consists primarily of flat glacial lake plain. The clay plain is broken by several extensive sand channels. One of the State's largest pineries occurred here on the somewhat poorly to poorly drained sands and clays. Agricultural development has been intensive as a result of the lake-moderated climate and the rich, loamy soils.

ELEVATION: 572 to 800 feet (174 to 244 m).

AREA: 2,390 square miles (6,190 sq km).

STATES: Michigan.

CLIMATE: Growing season is nearly as long (150 to 160 days) as in subsections at the southern boundary of the State. This long growing season differentiates this subsection from the Sandusky Lake Plain sub-subsection (VI.5.1). Extreme minimum temperature is -24˚F to -28˚F. Average annual precipitation is 28 to 30 inches, with 40 inches of snowfall. Both annual precipitation and snowfall are among the lightest in the State, but not low enough to deter agricultural land use. Toward the northern end of the subsection, there is a sharp climatic gradient due to characteristic positions of air masses. The Arenac subsection (VII.1) to the north is separated from the Saginaw Bay Lake Plain subsection (VI.6) on the basis of this gradient; the latter is notably warmer.

BEDROCK GEOLOGY: Bedrock is only locally exposed, with surface glacial lacustrine deposits as thick as 300 feet. Underlying Paleozoic bedrock was important in the economic development of this portion of the Saginaw basin. The subsection is underlain primarily by Paleozoic bedrock, primarily Pennsylvanian sandstone, shale, coal, and limestone (Dorr and Eschman 1984). At the western edge of the subsection, there are scattered occurrences of Mesozoic bedrock; these Jurassic red beds consist mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum. Beneath the Pennsylvanian and Mississippian bedrocks are extensive deposits of Devonian and Silurian shallow marine deposits, which have yielded evaporites and brines important to the chemical industry in Midland and Saginaw. Important oil and gas fields are also associated with marine deposits underlying this sub-subsection.

LANDFORMS: Relatively flat plain of glacial lacustrine origin. The lacustrine deposits, which consist of sands and clays, are thickest along the farthest inland edge of the lake plain (up to 300 feet thick) and thinnest along the present shorelines of Lake Huron, where they are generally 50 feet thick or less along Saginaw Bay.

Clay sediments are generally quite thick on the lake plain, but several broad sand channels were

created by glacial meltwater streams that deposited sand into the shallow proglacial lakes. Many of these sand channels are several miles wide, but the sand in them is generally only 5 to 10 feet thick.

LAKES AND STREAMS: No natural lakes. There are several large rivers, which were important for floating white pine timber to mills along Saginaw Bay. These include the Tittabawassee, Shiawassee, Saginaw, Pine, Flint, and Chippewa. Most of the rivers flow through broad sand plains.

SOILS: Poorly drained mineral soils characterize the clay plain. The sand-channel deposits were reworked by wave action when the Great Lakes were at higher levels, creating small sand dunes and spits and intervening depressions. The resulting features are typically higher and have steeper slopes than any found on the clay lake plain. The soils of the dunes and spits are often excessively well drained; those in the swales are poorly or very poorly drained. Soils of the lake plain are classified as Haplaquents, with some Haplaquods (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Extensive Great Lakes marshes occurred along Saginaw Bay. The marshes, which extended into water 4 to 5 feet deep, were 1 to 2 miles wide in places and extended for miles up major rivers such as the Quanicassee and Saginaw (Comer *et al.* 1993a, b). Along the western shore of Saginaw Bay, the marshes were generally one-eighth to one-half mile wide, much narrower than along the southern edge of the bay.

Shoreward of the marshes were extensive wet and wet-mesic prairies. These prairies extended several miles inland along the Quanicassee and Saginaw Rivers. The wet prairies are probably quite variable in plant composition, ranging from true prairie grasses, such as big blue stem, Indian grass, and cord grass, to blue joint grass and sedges closer to the marsh edges and in wetter depressions. They also contain other aquatic vegetation, including rushes, bulrushes, cattails, reed grass, and willow or other shrubs.

Within the coastal marshes and wet prairies were low beach ridges and sand spits that supported scattered white oak and black oak. Local areas of trembling aspen and other lowland hardwoods were also within the wet prairies.

Inland of the coastal marshes and prairies, there was typically a broad band of lowland forest. Lowland hardwoods were prevalent, with black ash, [American] elm, and [red] maple as common dominants, and often with tamarack, eastern hemlock, and alder present.

Lowland conifer swamps, dominated by tamarack often occurred in broad depressions within the sand lake plain, especially where these depressions were located 1 or more miles inland from the present shoreline.

Flat, inland expanses of sand lake plain supported eastern hemlock, with some white pine as well as black ash, elm, and other hardwoods. There were also hemlock-dominated areas described by the GLO surveyors as swamp. On the flat sand lake plain, a few inches of elevation often results in changes of drainage class, making it difficult to determine whether an area should be called upland or wetland. Flooding is common in both spring and autumn.

On the better drained portions of the clay plain at the southern end of Saginaw Bay, forests were dominated by beech and sugar maple. Many of the upland forests on clay plain were probably fairly moist, as indicated by the abundance of [American] elm, basswood, and black ash. These three lowland hardwood species dominated large expanses of the clay plain, but tamarack and northern white-cedar were also present in the swamps. The flat conditions of the clay lake plain resulted in an intergrading of upland and wetland hardwoods on the landscape. Forests on fine-textured till plain were similar to those found on the clay lake plain.

In the north, forests dominated by hemlock were common on the clay lake plain. These forests also contained hardwood species; beech was often the most common hardwood species, but black ash and [American] elm were sometimes equally common. North of the Saginaw River, balsam fir and white birch became more common.

Swamp dominated by tamarack occurred on the flat, poorly drained clay plain near the boundary with sand lake plain. This was most common

near the Quanicassee River, but also occurred elsewhere.

Fine-textured end moraines generally have slopes greater than 2 percent, resulting in better drainage conditions than typically found on clay lake plain. As a result, forests dominated by beech and sugar maple were common. Associated trees included white oak, [American] elm, basswood, and birch. Hemlock and black ash were generally much less common here than on the upland clay lake plain. At the northern edge, hemlock became increasingly common, even on these well-drained moraine ridges.

NATURAL DISTURBANCE: Although extensive areas of windthrown forest are generally common near the Great Lakes shorelines, GLO surveyors did not note any such areas here, possibly because the location at the southern and western edge of Saginaw Bay provided protection from the prevailing winds. Water level fluctuations of 2 to 3 feet are common along Saginaw Bay shorelines, causing tree mortality, shoreline erosion, and major alteration in species composition of marshes and wet prairies. The surveyors noted such water-level fluctuations near the east edge of the subsection.

PRESENT VEGETATION AND LAND USE: Before European settlement, Native American settlements were common along the shorelines of the Great Lakes. Oak savannas were probably maintained on beach ridges near the shoreline of Saginaw Bay by Indian land management with fire.

Some of the earliest intensive development in the State took place in this part of the Saginaw basin. Billions of board feet of white pine were logged between the 1830's and 1870's. Simultaneously, the salt industry and the Saginaw Bay fishery were developing, resulting in the harvest of oak and ash for barrels to store and ship these valuable commodities. Following logging, drainage began for agricultural use of the clay plain. By 1900, the chemical industry was well developed.

Most of the clay lands have been ditched and tiled, and they are among the most valued agricultural lands in the State. Parts of the sand plain were also ditched for agriculture, but the wettest areas remain, either as swamp forest, wet prairie, or marsh. Diking and pumping have allowed vast expanses of wet prairie and some areas of marsh to be farmed, especially along Saginaw Bay. Organic soils were burned to improve their suitability for agriculture (Wonser 1934, Deeter and Matthews 1931, Moon 1938).

RARE PLANT COMMUNITIES: Wet and wet-mesic prairies were originally extensive, along with oak savannas or "openings," but these now remain only as small remnants, primarily on State-owned lands. Prairies and savannas on the lake plain are called lakeplain prairie or oak opening because of the distinctive flora and fauna. The white pine and hemlock forests of the lake plain have been virtually eliminated.

RARE PLANTS: Most of the species in this subsection are associated with either Great Lakes marshes or lakeplain prairies. *Aristida longispica* (three-awned grass), *Asclepias hirtella* (tall green milkweed), *Asclepias sullivantii* (Sullivant's milkweed), *Cacalia plantaginea* (prairie Indian-plantain), *Juncus brachycarpus* (short-fruited rush), *Juncus biflorus* (two-flowered rush), *Platanthera leucophaea* (prairie fringed orchid), *Scirpus clintonii* (Clinton's bulrush).

RARE ANIMALS: *Asio flammeus* (short-eared owl), *Chlidonias niger* (black tern), *Dysnomia triquetra* (snuffbox), *Elaphe vulpina gloydi* (eastern fox snake), *Rallus elegans* (king rail), *Sterna caspia* (Caspian tern), *Sterna forsteri* (Forster's tern), *Sterna hirundo* (common tern).

NATURAL AREAS: None to date.

PUBLIC LAND MANAGERS: State Game Areas: Crow Island, Gratiot-Saginaw, Tobico Marsh, Shiawassee River (and Shiawassee National Wildlife Refuge); State Wildlife Areas: Nayanquing Point, Quanicassee, Wigwam Bay; State Parks: Bay City; State Forests: Au Sable; Environmental Areas: Coryeon Point, Quanicassee, Pinconning, Nayanquing, Oil Fields.

CONSERVATION CONCERNS: Efforts have begun along Saginaw Bay to restore coastal marshes and prairies, which are important for several rare plant and animal species, as well as for waterfowl, wading birds, and the Lake Huron fishery.

SECTION VII. NORTHERN LACUSTRINE-INFLUENCED LOWER MICHIGAN**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; Great Lakes-moderated climate (Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990); late Wisconsinan-age glaciated landscape underlain by Paleozoic bedrock; northern hardwoods forest, jack pine barrens, white pine-red pine forest, conifer swamp, bog.**

SUBSECTION VII.1. Arenac**; lake plain and fine-textured end and ground moraine; northern hardwood forests, jack pine barrens, white pine-red pine forest, shallow paludified peatland, coastal marsh.**

DISCUSSION: Sub-subsection VII.1.1 is the Standish lake plain, and Sub-subsection VII.1.2 is the Wiggins Lake fine-textured end and ground moraine. The climate and slope class of these sub-subsections differentiate them from the adjacent Highplains subsection (VII.2), which has steeper topography and a colder, more continental climate. Most of the soils of Subsection VII.2 are droughty outwash sands, as opposed to the more poorly drained soils of the lake plain and ground moraine of Subsection VII.1.

ELEVATION: 572 to 1,050 feet (174 to 320 m).

AREA: 1,470 square miles (3,810 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from approximately 120 days at the inland edge of the subsection to 140 days along the Saginaw Bay shoreline (Eichenlaub *et al.* 1990). Frequently the subsection is exposed to cool northern air at the same time the remainder of Saginaw Bay to the south is under an air mass of southern origin (Albert *et al.* 1986); as a result, this subsection's growing season can be up to 20 days shorter and much cooler. In contrast, its growing season can be 20 days longer than that of the Highplains subsection to the west. Average annual precipitation is 28 to 30 inches, and annual snowfall is 40 to 60 inches, increasing at the inland margin of the subsection. Extreme minimum temperature ranges from -26˚F to -40˚F, with coldest values along the inland margin.

BEDROCK GEOLOGY: Subsection VII.1 is underlain by Mesozoic (Jurassic) and Paleozoic (Pennsylvanian and Mississippian) bedrock (Dorr and Eschman 1984, Milstein 1987). Jurassic red beds, consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum, are located beneath the inland margin of the Standish sub-subsection (VII.1.1) and all of the Wiggins Lake sub-subsection (VII.1.2). Pennsylvanian bedrock consists of sandstone, shale, coal, and limestone. Mississippian bedrock is primarily limestone and gypsum.

LANDFORMS: Lake plain characterizes Sub-subsection VII.1.1. A major delta is located at the mouth of the Au Sable River. Sub-subsection VII.1.2 is primarily ground moraine and end moraine. See sub-subsections.

LAKES AND STREAMS: Most of the few lakes in the subsection are concentrated within small areas of end moraine and ice-contact topography. Several large rivers are concentrated on the sand lake plain. See sub-subsections.

SOILS: Soils of the subsection are classified as gently sloping Haplaquepts plus Haplaquods on the lake plain of Sub-subsection VII.1.2 and as gently sloping Glossoboralfs plus Eutroboralfs on the moraines of Sub-subsection VII.1.2 (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VII.1.1. Standish**; lake plain; jack pine barrens, northern hardwoods forest, upland conifer forest, conifer swamps, shallow peatlands, coastal marshes.**

DISCUSSION: Sub-subsection VII.1.1 is a flat clay and sand lake plain, part of the Saginaw lake plain to the south. The sub-subsection is separated from the remainder of the Saginaw lake plain because of its shorter growing season, which results in significant differences in forest vegetation and in human land use.

ELEVATION: 572 to 850 feet (174 to 259 m).

AREA: 1,359 square miles (3,520 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Glacial deposits are up to 250 feet thick, but localized exposures of Mississippian age bedrock occur throughout Arenac County at the northern edge of the sub-subsection (Akers 1938). Glacial drift thicknesses are 50 feet or less along the shoreline throughout the entire sub-subsection.

Sub-subsection is underlain by Mesozoic (Jurassic) and Paleozoic (Pennsylvanian and Mississippian) bedrock (Dorr and Eschman 1984, Milstein 1987). Jurassic red beds, consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum, are located beneath the inland margin of Sub-subsection VII.1.1. Pennsylvanian sandstone, shale, coal, and limestone underlie the southern part of the sub-subsection; Mississippian limestone and gypsum are to the north. Gypsum is mined at Alabaster in the north.

LANDFORMS: Sandy lacustrine deposits far exceed lacustrine silts and clays. The northern third of the sub-subsection is a large glacial delta, which has thick, droughty sand soils. The Au Sable and Rifle Rivers have created deep, steeply eroded gorges through the thick sands (Dorr and Eschman 1984, Burgis 1977).

The lacustrine sand plain to the south is a mosaic of large, poorly drained basins and flat, droughty plains. The elevational differences between the poorly drained basins and excessively well drained plains can be a matter of just a few feet.

The poorly drained basins can be several miles in area. Many of the basins contain thin peat soils, which have probably accumulated in the last 3,000 to 4,000 years. Small, steeply sided, transverse dune ridges occur throughout these embayments; these ridges probably formed when meltwater streams were depositing abundant sands into the shallow embayments of the proglacial lakes.

Intermediate drainage conditions between the very poorly drained basins and the excessively well drained plain occurr over large areas. The soils of these areas are generally poorly drained, with indications that both windthrow and fires were common.

Fine-textured lacustrine deposits and fine-textured moraines, reworked by water, are concentrated along the inland and lake margins of the sub-subsection.

LAKES AND STREAMS: Most of the few lakes in the sub-subsection are concentrated within small areas of end moraine and ice-contact topography. Tawas Lake occupies an old embayment of Lake Huron, separated from Saginaw Bay by numerous beach ridges. Several large rivers are concentrated on the sand lake plain, including the Au Sable, Au Gres, Rifle, Tittabawassee, Molasses, and Pine.

SOILS: Soil drainage conditions are discussed in the LANDFORMS section; most of this discussion concerns the sandy part of the sub-subsection. The predominant drainage classes on the sand lake plain are very poorly, poorly, and excessively well drained. Predominant drainage classes on the clay and clay loam soils of the lake plain include poorly drained, moderately well drained, and well drained. The soils on the small areas of ground and end moraine are primarily moderately well drained or well drained loams and clays. Soils of the sub-subsection are classified as gently sloping Haplaquepts plus Haplaquods (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: On the droughty delta deposits along the Au Sable River, jack pine barrens were the dominant vegetation, with white pine, red pine, and some black oak and white oak on fire-protected sites (Comer *et al.* 1993a, b). Other areas of dry sand plain also supported jack pine-northern pin oak barrens.

Large abandoned embayments, several miles inland from the present Saginaw Bay shoreline, supported bogs or shrub swamps with stunted trembling aspen or jack pine. The transverse dune ridges supported open oak-pine woodlands, with white pine, red pine, white oak, black oak, and bigtooth aspen.

Flat areas of the sand lake plain with poorly drained or somewhat poorly drained mineral soils supported forests of white pine, red maple, and trembling aspen. On the flat, sandy lake plain were numerous swamp types, including swamps dominated by northern white-cedar, tamarack, black ash, hemlock, white pine, and maple, and combinations of these species.

Well-drained sites on the flat clay plain supported forests of hemlock and beech, sugar maple, and basswood. Hemlock and white pine increased on more poorly drained sites. On poorly drained sites on the clay plain, there were also extensive tamarack swamps, cedar swamps, black ash swamps, and maple swamps, as well as shrub swamps dominated by speckled alder and willow.

Loamy or clayey soils on the flat ground or end moraines supported forests of hemlock and northern hardwoods with sugar maple, beech, white pine, and hemlock. The fine-textured end moraine located just west of Tawas has sandy soils on its surface. It supported jack pine barrens and open, burned-over grasslands.

Along the present shorelines of Saginaw Bay were extensive areas of swamp forest, wet prairie, and coastal marsh. The swamp forests supported both hardwood and conifer species. Marshes were most extensive at the mouths of the Rifle and Pine Rivers in Arenac County, where there was also wet prairie. Several of the embayments contained wide complexes of parallel beach ridges and swales. The swales were dominated by aquatic macrophytes or swamp forest; the ridges were dominated by a diverse mix of hardwoods and conifers. The higher beach ridges near the lake shore were dominated by white pine and red oak.

NATURAL DISTURBANCE: Windthrow was common in the forests near the Great Lakes shoreline, resulting from a combination of strong winds off Lake Huron, flat topography, and poor drainage conditions. Water level fluctuations along the Great Lakes shoreline resulted in cyclical floristic variation within the coastal marshes and extensive mortality within the coastal swamp forests.

In the GLO survey, fire was noted as common on the jack pine-dominated barrens of the Au Sable River delta.

PRESENT VEGETATION AND LAND USE: Agricultural land use is less intensive on this part of the lake plain than in sub-subsections further south because of both colder climatic conditions and a prevalence of sandy soils. Drainage ditches have been constructed on both the clay lake plain and on the flat parts of the loamy or clayey ground and end moraines. Clay soils on the lake plain are used as pasture. Moraines are farmed for both row crops and pasture. No examples of mature forest are known in either the clay lake plain or the fine-textured moraines. Sandy soils have been less intensively converted to agriculture than other portions of lake plain further south.

Much of the poorly or excessively drained lake plain is managed for either timber or recreational use. The delta of the Au Sable is managed largely by the Huron National Forest for timber. Both jack pine and red pine plantations cover much of the delta.

A large strip mine is located near Alabaster. Urban development in this sub-subsection is most intensive around Tawas, Standish, and Au Gres.

Native vegetation, bogs and shrub swamp, persists on the poorly drained, abandoned embayments on the lake plain. Upland vegetation on the transverse dune ridges of these embayments has changed considerably; white oak, black oak, and bigtooth aspen persist, but white pine and red pine are generally lacking.

The jack pine-dominated barrens of the Au Sable River delta have been converted to closed-canopy plantations of jack pine or red pine.

Some of the swamps along the Lake Huron shoreline have been converted to agriculture, but those that persist appear to have forest compositions relatively similar to those recorded by GLO surveyors.

Many of the marshes along Lake Huron have been manipulated for waterfowl management, and dikes have been constructed for water control. Small areas of marsh remain intact. Small remnants of prairie may also exist here. Boat slips and channels have also been constructed along many sections of shoreline, resulting in varying degrees of marsh destruction.

RARE PLANT COMMUNITIES: Small areas of wet prairie (lakeplain prairie) may persist.

RARE PLANTS: *Cirsium pitcheri* (Pitcher's thistle).

RARE ANIMALS: *Chlidonias niger* (black tern).

NATURAL AREAS: Michigan Nature Association Preserve: Frink's Pond.

PUBLIC LAND MANAGERS: National Forests: Huron; State Forests: Au Sable; State Parks: Harrisville, Tawas Point; State Wildlife Areas: Wigwam Bay; State Environmental Areas: Rifle River, Pine River, White's Beach.

CONSERVATION CONCERNS: The jack pine plains along the lower Au Sable River have been considered for expansion of habitat for the Kirtland's warbler. A few of the shallow peatlands on the sand lake plain have undergone little intensive forest management and appear to be of potential natural area quality; however, little detailed biological information is available.

SUB-SUBSECTION VII.1.2. Wiggins Lake**; fine-textured end and ground moraine; northern hardwood forest.**

DISCUSSION: This sub-subsection is a narrow band of ground and end moraine that is physiographically a continuation of the Lansing till plain (Sub-subsection VI.4.1), but the growing season of this part of the till plain is shorter.

ELEVATION: 800 to 1,050 feet (243 to 320 m).

AREA: 111 square miles (289 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from approximately 120 to 130 days (Eichenlaub *et al.* 1990). Average annual precipitation is 28 to 30 inches; and annual snowfall is 50 to 60 inches, increasing at the inland margin of the sub-subsection. Extreme minimum temperature ranges from -36˚F to -40˚F, with coldest values along the inland margin. It is primarily this cooler, more northern climate that differentiates this sub-subsection from the Lansing sub-subsection (VI.4.1).

BEDROCK GEOLOGY: Glacial deposits over bedrock are 250 to 450 feet thick; deposits are thickest along the inland edge. The sub-subsection is underlain by Mesozoic (Jurassic) and Paleozoic (Pennsylvanian) bedrock (Dorr and Eschman 1984, Milstein 1987). Jurassic red beds, consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum, are located beneath the entire sub-subsection, as are Pennsylvanian sandstone, shale, coal, and limestone.

LANDFORMS: The topography consists of rolling to moderately sloping ridges, mapped by Farrand (1982) as both end and ground moraine.

LAKES AND STREAMS: Several small branches of the Cedar, Tobacco, and Tittabawassee Rivers flow across the ground moraine and small outwash channels of the sub-subsection. Two small lakes.

SOILS: The soils of the moraines are moderately well to well drained. Soil textures are primarily loams to clay loams. Soils are classified as gently sloping Haplaquepts plus Haplaquods on the lake plain and as gently sloping Glossoboralfs plus Eutroboralfs on the moraines (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The presettlement vegetation was upland beech-sugar maple forest (Comer *et al.* 1993b).

NATURAL DISTURBANCE: No major natural disturbances recorded by surveyors.

PRESENT VEGETATION AND LAND USE: Large parts of the sub-subsection are farmed, both for row crops and pasture. Steeper sections remain forested.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: None.

PUBLIC LAND MANAGERS: None.

CONSERVATION CONCERNS: Most of this small sub-subsection has already been converted to agriculture.

SUBSECTION VII.2. Highplains**; high plateau of outwash plains, sandy end moraines, and ice-disintegration features; jack pine barrens, white pine-red pine forest, northern hardwood forest.**

DISCUSSION: Subsection is a high plateau formed from glacial outwash and end moraines. Relatively high elevation and distance from the lake combine to give the subsection a more continental climate than the rest of the Lower Peninsula of Michigan.

The topography and soils are diverse enough to justify further dividing it into three sub-subsections, which have distinct glacial landforms and soils.

SUB-SUBSECTIONS: The Cadillac sub-subsection (VII.2.1) is sandy end-moraine topography at the southwest end of the subsection; the Grayling sub-subsection (VII.2.2) is an extensive outwash plain at the northeast end, which contains steep ridges of sandy ice-contact topography; and the Vanderbilt sub-subsection (VII.2.3) is a relatively narrow band of sandy end-moraine ridges broken by outwash channels along the northern edge. (See figure 5.)

ELEVATION: 580 to 1,725 feet (177 to 526 m).

AREA: 8,335 square miles (21,604 sq km).

STATES: Michigan.

CLIMATE: Due to its inland location, northern latitude, and relatively high elevations, the subsection has the most severe climate in Lower Michigan. Growing season ranges from 70 days in northern lowland areas to 130 days in the south (Eichenlaub *et al.* 1990). There is a great chance of late spring freezes. Extreme minimum temperatures recorded range from -28˚F to -50˚F. Snowfall is heavy; at the western margin of the high plateau, lake-effect snowfalls are 140 inches. Further east, snowfalls are as low as 60 inches. Average annual precipitation is relatively uniform across the subsection, 28 to 32 inches.

BEDROCK GEOLOGY: There are no bedrock exposures, and glacial drift is 100 to 1,000 feet thick (Akers 1938). Underlying bedrock consists of Jurassic, Pennsylvanian, Mississippian, and Devonian marine and near shore sedimentary rocks, including limestone, dolomite, gypsum, shale, and sandstone (Milstein 1987, Dorr and Eschman 1984). Major oil and gas fields, using underlying Devonian petroleum reservoirs, are found here.

LANDFORMS: A high plateau. Outwash plains cover most of the subsection, but there are also large areas of sandy ground moraine, end moraine, and ice-contact ridges. See sub-subsections.

LAKES AND STREAMS: Several large lakes, primarily in Sub-subsections VII.2.1 and VII.2.2. Several large streams originate within the subsection. See sub-subsections.

SOILS: Almost the entire subsection has sandy surface soils. Sands of the large outwash plains are excessively well drained, except near streams. Depth of sand deposits ranges, from a few feet to several hundred feet. Most of the soils on end moraines are also sands or loamy sands. Soils are classified as Spodosols, primarily Orthods, with some Boralfs and Psamments (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Jack pine barrens, with northern pin oak, dominated most of the outwash plains, but red pine was also present. White pine, red maple, and trembling aspen were major species on poorly drained outwash. Willow swamps, alder swamps, and marshes occupied the wettest outwash. Both northern hardwood forests of beech and sugar maple, with some white pine and eastern hemlock, and forests of white oak and white pine grew on the moraines. See sub-subsections.

NATURAL DISTURBANCE: Both fire and wind were important natural disturbances, but fire impacted a much greater percent of the landscape. See sub-subsections.

PRESENT VEGETATION AND LAND USE: Most of the subsection remains forested and is managed for forest products, wildlife, and recreation. See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VII.2.1. Cadillac**; steep, sandy end moraines; northern hardwood forest, white oak-red oak forest.**

DISCUSSION: Hilly topography characterizes this sub-subsection. Drainage is generally good in the hilly landscape; as a result, lakes and wetlands are not numerous.

ELEVATION: 850 to 1,725 feet (259 to 526 m).

AREA: 2,731 square miles (7,079 sq km).

STATES: Michigan.

CLIMATE: Growing season is 90 to 140 days; the longest growing season is in the south and the shortest is in the north (Eichenlaub *et al.* 1990). Annual precipitation is relatively uniform, 30 to 32 inches. Snowfall is about 100 inches in the west and only 50 inches in the east. Extreme minimum temperature ranges from -28˚F to -44˚F, warmest at the south end of the subsubsection.

BEDROCK GEOLOGY: Bedrock is not exposed; drift thicknesses are 500 to 1,000 feet, some of the thickest in the State (Akers 1938). This subsubsection is underlain primarily by Paleozoic bedrock (primarily Pennsylvanian sandstone, shale, coal, and limestone) and Mesozoic bedrock (Jurassic red beds consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum) (Dorr and Eschman 1984, Milstein 1987).

LANDFORMS: Steep end-moraine ridges. The highest point in Lower Michigan (1,725 feet) is here, near Cadillac. The large sand ridges, 200 to 500 feet high, generally have well-drained

soils. Most depressions between the moraine ridges do not contain wetlands because of the extreme thickness of the coarse, sandy till deposits. The ridges are moderate to steeply sloped; slopes of more than 12 percent are common, and the steepest slope class is 18 to 40 percent (Buchanan 1985).

Outwash channels, relatively common in the sub-subsection, occurr as either narrow deposits between the moraines or as relatively broad plains. The larger outwash plains often consist of several terraces of rolling, excessively drained sand plain.

LAKES AND STREAMS: The Muskegon River occupies the largest outwash channel in the sub-subsection; the present river occupies only a small part of the outwash channel, which is several miles wide. Other rivers are the Pine, Little Manistee, and the Little Muskegon. Modern rivers have typically cut deep gorges through the thick outwash deposits.

Kettle lakes are not common within this sub-subsection, when compared to other areas of end moraine, probably because many of the ice-block depressions are dry. The largest lakes, Mitchell, Cadillac, and Missaukee, are located on either outwash or small lake plains, rather than within the end-moraine topography.

SOILS: Soils are well drained and excessively well drained sands developed from thick deposits of sandy till. An argillic (clay) horizon is seldom encountered, partially due to a lack of a silt or clay fraction in the till. Poorly drained soils, found in depressions at the foot of the steep ridges, occupy only about 10 percent of the end-moraine landscape. Many of the foot slopes are well drained as a result of the sandy soil texture of both surface soils and the thick underlying parent material. Soils are classified as moderately sloping Haplorthods plus Glossoboralfs and Udipsamments (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: GLO surveyors reported oak-pine forest and jack pine barrens, silver maple-dominated flood-plain forest, and hardwood-conifer and conifer swamps. The original vegetation on the end-moraine ridges was northern hardwood forests of beech, sugar maple, red oak, and hophornbeam. Hemlocks were present, in low numbers in moister ravines and on northern-aspect slopes. White pines were scattered in low numbers throughout the hardwood forests. On the excessively drained sandy ridges, there were oak-pine forests, containing red and white pine; red, white, and black oak; red maple; and bigtooth aspen.

The original forests of the outwash were oak-pine forests containing red pine, white pine, red oak, white oak, black oak, red maple, and bigtooth aspen. The droughtiest terraces of the outwash plains originally supported jack pine and northern pin oak; forest structure and dominance changed little in these dry barrens after logging.

Most of the outwash plain through which the Muskegon River flows supported either pine-oak forest or jack pine barrens, but extensive swamp forests and flood-plain forests occur within 2 to 3 miles of the river. The active flood plain is dominated by a forest of silver maple, red ash, and black ash; but the swamps farther away from the river are conifer or hardwood-conifer swamps on peat.

NATURAL DISTURBANCE: Windthrows are common on moraines, but were generally small. Fires also occurred, but these were also small.

PRESENT VEGETATION AND LAND USE: The present forests are oak dominated on outwash plains and beech-sugar maple dominated on moraines. Land is managed primarily for timber. White and red pines were cut in the 1870's to 1890's, and logs were transported by narrow-gauge railroads where river access was poor (Meek 1986, Koch 1979). Pine logging resulted in a major change in overstory dominance; post-logging forests are dominated by oaks, bigtooth aspen, and red maple. Hardwoods were logged later.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Geum triflorum* (prairie-smoke).

RARE ANIMALS: *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey), and *Gavia immer* (common loon) are common on the larger lakes.

NATURAL AREAS: None.

PUBLIC LAND MANAGERS: Manistee National Forest, Pere Marquette State Forest, Haymarsh Lake State Game Area, Houghton Lake Wildlife Research Area.

CONSERVATION CONCERNS: As a result of major changes in forest composition after logging, there are few Forest Service Research Natural Areas in this sub-subsection. The extensive hardwood-dominated forests are probably important for song bird migration and successful nesting. The Muskegon River flood plain and associated wetlands form one of the more extensive wetland forest corridors in the State; it has not been adequately surveyed to determine its full biological significance.

SUB-SUBSECTION VII.2.2. Grayling Outwash Plain**; broad outwash plain including sandy ice-disintegration ridges; jack pine barrens, some white pine-red pine forest, and northern hardwood forest.**

DISCUSSION: Sub-subsection VII.2.2 is a high outwash plain with several large lakes and rivers. Within the plain are several steep ridges surrounded by flat outwash. The climate is the most continental within the section, with extremely low winter temperatures and frosts throughout the summer.

ELEVATION: 900 to 1,580 feet (274 to 482 m).

AREA: 4,061 square miles (10,525 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 80 to 130 days and is longest in the southeast (Eichenlaub *et al.* 1990). Frost danger is extreme throughout the growing season, especially at the northern and southeastern ends. Snowfall ranges from 140 inches in the northwest to 50 inches in the southeast. Heavy snows along the western edge of the sub-subsection are lake-effect snows off Lake Michigan. Annual precipitation is relatively uniform across the sub-subsection, 28 to 32 inches. Extreme minimum temperature ranges from -40˚F to -48˚F, warmest at the southeastern edge.

BEDROCK GEOLOGY: No exposed bedrock; glacial drift is 250 to 800 feet thick, some of the thickest in the State (Akers 1938). Underlying bedrock is primarily of Paleozic age, including Pennsylvanian and Mississippian sandstone, coal, shale, and limestone (Dorr and Eschman 1984, Milstein 1987). In the south, there is also Mesozoic bedrock, Jurassic red beds consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

LANDFORMS: A high outwash plain. Several large ridges of ice-contact sands are surrounded by the outwash; glacial meltwater streams have dissected some of the ice-contact ridges into several steep ridges. Most of the flat outwash plain is at an elevation of 1,050 to 1,300 feet. In contrast, the ice-contact moraines have maximum elevations of 1,450 to 1,580 feet.

Steep-sided ice-block depressions are common locally, both on the ice-contact ridges and on parts of the outwash plains.

There are local lacustrine or till deposits of clay-loam. The two large lakes within the sub-subsection, Houghton and Higgins, are probably perched on lacustrine clay deposits; lacustrine clays were encountered at the southern and western edges of the lakes (Albert 1990).

At the northwestern edge of the sub-subsection are two narrow end-moraine ridges, separated by a narrow outwash channel, which is about 8 miles wide at its widest point. The moraines have soils and vegetation similar to those in Sub-subsection VII.2.3; the outwash channel has soils, vegetation, and severe microclimate similar to the remainder of this sub-subsection.

LAKES AND STREAMS: Large lakes occupying the outwash plains include Houghton Lake, Higgins Lake, Lake Margreth, and Lake St. Helen. Several smaller lakes occupy kettles in abandoned outwash channels. Only one large lake, Bear Lake, is located on an ice-contact ridge. Three major streams, the Manistee, Au Sable, and Muskegon Rivers, originate on the outwash plains. All these rivers are fed by

several small branch rivers or creeks. Large expanses of wetland are located at the margins of the larger lakes, in the Dead Stream Swamp, and in the headwaters of the Muskegon River. Peat depths in the wetlands average between 3 and 7 feet; maximum depths reach 16 feet (LeMasters and Jones 1984).

SOILS: Slopes in the 0 to 2 percent or 3 to 6 percent classes are most common, but slopes as steep as 19 to 25 percent occur. Drainage classes range from excessively drained to somewhat poorly drained; excessively drained soils are prevalent. Most of the soils are sand or sands mixed with gravel, but localized deposits of fine-textured till and lacustrine clays may be exposed at the surface. Soils of the ice-contact ridges are typically well drained to excessively well drained sands on moderately to steeply sloping topography; these soils contain very little silt or clay, and they are mapped as the same association (Graycalm-Montcalm) as those on the moraines of the Cadillac sub-subsection (VII.2.1) (USDA Soil Conservation Service 1981). Soils are classified as gently sloping Haplorthods plus Glossoboralfs (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The vegetation varied on the sandy ice-contact ridges. On the largest deposits, consisting of several large ridges, northern hardwood forests were dominated by beech and sugar maple. They also contained red oak, hemlock, and white pine. In contrast, isolated ridges commonly supported forests of jack pine and northern pin oak similar in composition to the surrounding forests on outwash. Fire frequency, controlled by soil drainage and topographic conditions of both the ice-contact deposits and surrounding outwash deposits, was probably important for determining the species composition of the presettlement forests.

The vegetation on the end moraines at the northwestern edge of the sub-subsection was northern hardwood forests dominated by beech and sugar maple, with little white pine or hemlock. The narrow band of outwash between the moraines also supported northern hardwood forests except in the broadest parts, where forests of white pine and red pine were dominant. Jack pine was also dominant in a large frost pocket.

The excessively drained outwash plains originally supported savannas of jack pine and northern pin oak. Red pines were scattered within the savanna, and white pines were located on moister, less fire-prone sites, such as stream margins. For the outwash plains, GLO surveyors noted burned areas of pine plain or barren covering thousands of acres.

Large and diverse wetlands were found on the poorly drained outwash. Where clay deposits were near the surface, shallow peatlands commonly occupied large areas. The map of original swamp areas in Lower Michigan (Lane 1907) indicates the presence of large tracts of swamp in areas where clay soils are near the surface. Hardwood-conifer swamps contained white pine, red pine, jack pine, trembling aspen, paper birch, balsam poplar, and red maple. In the Dead Stream Swamp, where low sand spits separate large, poorly drained flats, bogs and shrub swamps were the dominant vegetation. The abiotic conditions and vegetation were very similar to those found on lacustrine deposits in Upper Michigan. Typical tree species on the bog mat were black spruce, tamarack, and jack pine. Low sand ridges within the swamp were dominated by red, white, and jack pines. White and red pines were abundant enough in the Dead Stream Swamp area to justify construction of a railroad, which carried the lumber to the nearby Muskegon River (Meek 1986).

Swamp forests occupied the margins of most of the major stream courses; northern white-cedar was the dominant species. Balsam fir, hemlock, trembling aspen, paper birch, and several other swamp species were also found.

The small ice-block depressions on the outwash plains typically contained shrub swamps or sphagnum bogs with highly depauperate flora, probably the result of commonly recurring fires and wet soil. The dominant shrub was usually leatherleaf.

NATURAL DISTURBANCE: Fire is the most important factor shaping the forest composition of both the uplands and wetlands. GLO surveyors noted that more than 3 percent of the land area was recently burned, and several fires covered thousands of acres. Windthrows also occurred, but they were much smaller than the burned areas. Large frost pockets occurred in

depressions on the outwash plain, resulting in high mortality for deciduous tree species and dominance by jack pine; these frost pockets often contained dry prairie openings.

PRESENT VEGETATION AND LAND USE: The jack pine barrens are presently managed for pulp. Many of the wetlands are managed for wildlife. Recreational use of the area is heavy, including fishing, hunting, canoeing, and snowmobiling. Fire suppression has resulted in dangerously high fuel loads within parts of the jack pine plains.

RARE PLANT COMMUNITIES: It appears that there were originally numerous small areas of dry prairie, with a northern flora, in the frost pockets, but most of these have been planted to jack pine as part of the Kirtland's warbler management plan.

RARE PLANTS: *Agoseris glauca* (pale agoseris), *Aster longifolius* (long-leaved aster), *Cirsium hillii* (Hill's thistle), *Dalibarda repens* (false-violet), *Festuca scabrella* (rough fescue), *Lycopodium appressum* (appressed bog clubmoss), *Mimulus glabratus* var. *jamesii* (James' monkey-flower), *Prunus alleghaniensis* (Allegheny or sloe plum), *Scirpus clintonii* (Clinton's bulrush), *Solidago houghtonii* (Houghton's goldenrod), *Sporobolus heterolepis* (prairie dropseed), *Stellaria crassifolia* (fleshy stitchwort), *Viola novae-angliae* (New England violet).

RARE ANIMALS: *Appalachia arcana* (secretive locust), *Brachionyncha borealis* (boreal brachionyncha), *Buteo lineatus* (red-shouldered hawk), *Chlidonias niger* (black tern), *Coturnicops noveboracensis* (yellow rail), *Dendroica discolor* (prairie warbler), *Dendroica kirtlandii* (Kirtland's warbler), *Merolonche dolli* (Doll's merolonche), *Papaipema beeriana* (blazing star borer).

NATURAL AREAS: State Natural Areas: Mason Tract (Au Sable River), Roscommon Red Pines; Michigan Nature Association Preserves: Prairie Chicken, Parsons Memorial, Lost Lake.

PUBLIC LAND MANAGERS: National Forests: Huron, Manistee; State Forests: Au Sable, Mackinac, Pere Marquette; State Parks: Hartwick Pines; State Recreation Areas: Rifle River; State Game Areas: Backus Creek; Kirtland's Warbler Management Areas: Fletcher Road, St. Helen, Staley Lake, Damon, Muskrat Lake, Lovells, Sharon, Warbler Monument, Ogemaw Refuge; Other: Camp Grayling Military Reservation, Sand Lakes Quiet Area (DNR), Houghton Lake Wildlife Research Area.

CONSERVATION CONCERNS: The entire breeding population of Kirtland's warbler, a federally endangered species, is found within the sub-subsection. Management for the warbler consists of clearcutting, burning, and replanting thousands of acres on a set rotation plan. Planting frost pockets to jack pine as part of the Kirtland's warbler management plan may have resulted in the destruction of dry prairies, which are also the habitat for several rare plant species.

The population of the Kirtland's warbler, only about 400 pairs for many years, has increased dramatically largely because of the Bald Hill and Mack Lake wildfires. The Mack Lake burn of May 1980 covered nearly 24,000 acres (Simard *et al.* 1983); about 10,000 acres of the burn proved to be good warbler habitat. Warblers colonized first the warmer, more productive high elevation outwash and ice-contact terrain and then the adjacent low elevation outwash (Zou *et al.* 1992, Barnes 1993).

The Huron-Manistee National Forests are now developing plans for a large corridor of forest to be managed as old growth along the Au Sable River.

Figure 20.—*Sub-subsection VII.2.2: Mack Lake, Oscoda County, Michigan. The extensive jack-pine barrens on the flat outwash plain of this sub-subsection burned frequently. The federally threatened Kirtland's warbler nests in young jack pine in the sub-subsection. Fires are less frequent and less intense on the ridges within the outwash plain; the ridges are consequently dominated by increased amounts of red pine, white pine, and oaks. Photo by B.V. Barnes.*

SUB-SUBSECTION VII.2.3. Vanderbilt Moraines**; steep, sandy end and ground moraine ridges and narrow outwash channels; northern hardwood forest, conifer swamp, some jack pine barrens.**

DISCUSSION: The steep moraine ridges of the sub-subsection connect the high plateau of the Grayling Outwash Plain sub-subsection (VII.2.2) to the lower lacustrine terrain of the Presque Isle subsection (VII.6) to the north (Albert *et al.* 1986). The sub-subsection forms a narrow band around the northeastern and northwestern edge of the Highplains subsection. Topography is some of the steepest in Lower Michigan; changes of more than 200 feet occur over distances of less than a mile. Thick glacial ice in the glacial Great Lakes basins to the north advanced and retreated numerous times, creating a steep and irregular topography of moraines and outwash plains in this subsection.

ELEVATION: 900 to 1,300 feet (274 to 396 m).

AREA: 1,543 square miles (3,996 sq km).

STATES: Michigan.

CLIMATE: Growing season is 70 to 120 days. It is longest near Lakes Michigan and Huron and shortest in outwash channels near the center of the sub-subsection, where elevations drop rapidly to the north (Eichenlaub *et al.* 1990). Frost danger is extreme throughout the growing season. Snowfall ranges from 140 inches in the northwest to 60 inches in the southeast. Heavy snows in the northwest are lake-effect snows off Lake Michigan. Annual precipitation is relatively uniform across the sub-subsection, 28 to 32 inches. Extreme minimum temperature ranges from -36˚F to -50˚F, warmest near Lakes Michigan and Huron and coldest in the outwash channels near the southern edge of the sub-subsection.

BEDROCK GEOLOGY: No exposures of bedrock. Glacial drift ranges from 100 to 800 feet thick and is thickest at the southern edge of the sub-subsection (Akers 1938). Underlying bedrock is of Paleozoic age, Devonian and Mississippian sandstone and shale (Dorr and Eschman 1984, Milstein 1987).

LANDFORMS: Steep moraine ridges surrounded by outwash channels and plains. Outwash deposits occur both as relatively narrow channels between the steep moraines and as broad plains. The broader channels have excessively well drained soils; many of the narrower outwash channels have poorly drained soils.

Most of the moraines have steep slopes and sandy, well-drained soils. Northern hardwood forests of beech, sugar maple, yellow birch, hemlock, and associated species dominate these steep sites. Fires from adjacent outwash plains burned parts of the northern hardwood forests.

LAKES AND STREAMS: Few lakes in the sub-subsection. Most are small kettle lakes on outwash; almost no lakes are on the steep moraines. Several large rivers originate here, including the Black, Sturgeon, Thunder Bay, and Pigeon. These are rapid ground water fed streams, noted for their fine canoeing and trout fishing.

SOILS: Most of the moraines have steep slopes and sandy, well-drained soils. Excessively well drained sands are found on the broader outwash plains; very poorly and poorly drained soils, with sandy or gravelly substrate, occupy narrow channels. Soils are classified as moderately sloping Haplorthods plus Glossoboralfs and Udipsamments (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Northern hardwood forests of beech, sugar maple, yellow birch, hemlock, and associated species dominated most of the steep moraines. Some of the narrower outwash channels have poorly drained soils that supported either conifer or hardwood-conifer swamps. The broader channels have excessively well drained soils that supported jack pine and red pine.

NATURAL DISTURBANCE: GLO maps showed large fires in the larger outwash plains. Fires from outwash plains burned parts of the northern hardwood forests on adjacent moraines.

PRESENT VEGETATION AND LAND USE: Many of the lands are State owned and managed for both timber and wildlife. The area is a favorite for recreation, including hunting, fishing, and canoeing.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Amerorchis rotundifolia* (round-leaved orchis), *Cirsium hillii* (Hill's thistle), *Cypripedium arietinum* (ram's head lady's slipper), *Mimulus glabratus* var. *jamesii* (James' monkey-flower), *Sarracenia purpurea f. heterophylla* (yellow pitcher-plant).

RARE ANIMALS: *Brychius hungerfordi* (Hungerford's crawling water beetle), *Buteo lineatus* (red shouldered hawk), *Martes americana* (marten).

NATURAL AREAS: State Natural Areas: Pigeon River (proposed); Michigan Nature Association Preserves: Lost Lake.

PUBLIC LAND MANAGERS: Mackinaw State Forest, Huron National Forest, Petoskey State Park, Oden State Fish Hatchery.

CONSERVATION CONCERNS: Although the wetlands are recognized as diverse by botanists, there are few threatened and endangered plant records and almost no ecological data on any of the wetlands. Large parts of the sub-subsection are under State forest management, probably because of the steepness of the terrain, which does not allow agricultural development. The large, unbroken tracts of forest are probably important for migratory songbirds, although studies are lacking.

SUBSECTION VII.3. Newaygo Outwash Plain**; outwash plain and sandy end moraines; white pine-white oak forest, jack pine barrens, dry sand prairie.**

DISCUSSION: Subsection VII.3, about 100 miles long, consists of several outwash plains with excessively well drained, sand soils. The climate is intermediate between the highly lake-moderated Manistee subsection (VII.4) to the west and the inland Highplains subsection (VII.2) (Albert *et al.* 1986).

ELEVATION: 700 to 1,210 feet (213 to 369 m).

AREA: 2,023 square miles (5,244 sq km).

STATES: Michigan.

CLIMATE: Intermediate between that of the Manistee subsection (VII.4) and the Highplains subsection (VII.2). Growing season ranges from about 120 to 140 days (Eichenlaub *et al.* 1990). Late spring freezes are a danger because the subsection forms a cold air drainage from the adjacent high plains. Thermal satellite imagery shows a large frost pocket near Baldwin, a town known for its low temperatures. Extreme minimum temperature ranges from -32˚F at the northern and southern edges to -48˚F near the center of the subsection at Baldwin. Average annual precipitation is 32 inches. Average annual snowfall ranges from 70 to 140 inches, decreasing rapidly to the east; these heavy snowfalls are lake-effect snows off Lake Michigan.

BEDROCK GEOLOGY: No bedrock exposures; glacial drift is 300 to 600 feet thick (Akers 1938). Underlying bedrock is primarily of Paleozic age, Pennsylvanian, Mississippian, and Devonian sandstone, coal, shale, and limestone (Dorr and Eschman 1984, Milstein 1987). In the extreme southeast, there is also Mesozoic bedrock, Jurassic red beds consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

LANDFORMS: Subsection consists primarily of outwash plain, but some areas of sand lake plain are in the northern part. Portions of the outwash are pitted with ice-block depressions. These ice-block depressions are frost pockets, which often support dry prairie vegetation rather than forests. Some of the largest ice-block depressions in the outwash are seasonally or permanently flooded.

LAKES AND STREAMS: Several large rivers flow through the subsection, including the Betsie, Manistee, Little Manistee, Big Sable, Pere Marquette, and White. Most of these rivers originate in Subsection VII.2 to the west. Most of these ground water fed streams have trenched deeply into the outwash sand and gravel, creating steep, eroding banks.

Scattered kettle lakes are within the subsection, both on outwash and on end-moraine ridges, which are isolated within the outwash. There are almost no lakes on the sand lake plain.

SOILS: Most of the outwash and lacustrine sands are excessively drained. Somewhat poorly drained and poorly drained soils are more common on the lake plains than on the outwash plains. Soils are classified as gently sloping Haplorthods plus Glossoboralfs (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Forests and savannas of white pine and white oak dominated much of the outwash. Jack pine and northern pin oak grew on the flattest, most fire-prone parts of the outwash and lake plains. Ice-block depressions on the outwash (and occasionally on the lake plain) were often frost pockets that supported either dry sand prairie or, if seasonally flooded, marsh or wet prairie vegetation and localized conifer swamp.

A few portions of sand lake plain in the northern part of the subsection originally supported sugar maple and beech-dominated forests, probably as a result of fire protection.

NATURAL DISTURBANCE: Fire.

PRESENT VEGETATION AND LAND USE: Following logging of the white pine and the severe post-logging fires, white pine regeneration was

generally poor. The resulting forests are dominated by white oak and black oak, often with white pine regeneration forming the understory. The driest jack pine-northern pin oak barrens did not change significantly after logging.

Early settlers attempted to farm some of the sandy outwash and lake plain, resulting in rapid loss of soil fertility and abandonment. Wind erosion also occurred.

Many of the seasonally flooded ice-block depressions on the outwash plain support herbaceous disjunct species of the Atlantic and Gulf Coastal Plains. However, the coastal plain flora is much less diverse than those in Subsection IV.3.

Present land use includes recreation and forest management. Several of the streams are fine trout and canoeing streams.

RARE PLANT COMMUNITIES: Coastal plain marshes and dry sand prairies.

RARE PLANTS: *Cirsium hillii* (Hill's thistle), *Eleocharis tricostata* (three-ribbed spike-rush), *Geum triflorum* (prairie-smoke), *Linum sulcatum* (furrowed flax), *Rhynchospora macrostachya* (tall beak-rush), *Rhexia mariana* (Maryland meadow-beauty), and *Prunus alleghaniensis* (Allegheny or sloe plum).

RARE ANIMALS: *Buteo lineatus* (red-shouldered hawk), *Hesperia ottoe* (Ottoe skipper), *Incisalia irus* (frosted elfin), *Lepyronia gibbosa* (Great Plains spittlebug), *Lycaeides melissa samuelis* (Karner blue).

NATURAL AREAS: Manistee National Forest: Newaygo Prairie Research Natural Area; The Nature Conservancy Preserves: Ore-Ida Prairie; Michigan Nature Association Preserves: Newaygo Prairie; Other: Pere Marquette National Scenic River, South Island Environmental Education Study Area.

PUBLIC LAND MANAGERS: Manistee National Forest, Pere Marquette State Forest.

CONSERVATION CONCERNS: The dry sand prairies and jack pine barrens of the southern half of the subsection provide important habitat for the Karner blue butterfly; the Forest Service is working with The Nature Conservancy and the Michigan Heritage Program to develop management plans for the species and its habitat. The Forest Service is also attempting to protect coastal plain marshes in the subsection.

SUBSECTION VII.4. Manistee**; sand lake plain and end moraine; upland hemlock-white pine forest, northern hardwood forest, conifer swamp.**

DISCUSSION: Subsection VII.4 lies along the west coast of the State. Although it is physiographically diverse, the entire subsection has a climate moderated by Lake Michigan, resulting in intense agricultural use of the lands for vineyards and orchards. The subsection includes five islands: North and South Manitou, North and South Fox, and High. The western edges of all of these islands contain large areas of perched sand dune, and most of each island consists of either dunes or other lacustrine physiographic features.

SUB-SUBSECTIONS: none.

ELEVATION: 580 to 1,150 feet (177 to 350 m).

AREA: 1,435 square miles (3,715 sq km).

STATES: Michigan.

CLIMATE: A strongly lake-modified climate results in a long growing season of 140 to 150 days (Eichenlaub *et al.* 1990). This, coupled with retarded spring warming, makes the climate suitable for commercial fruit production. Extreme minimum temperature ranges from -32˚F at the southern edge of the subsection and along the Lake Michigan shoreline to -42˚F along the eastern edge in Lake County. Lake-effect snowfalls are heavy, averaging 100 to 140 inches. Average annual precipitation is 32 to 34 inches.

BEDROCK GEOLOGY: No exposed bedrock; glacial drift thickness ranges from 400 to 700 feet. The underlying bedrock is Paleozoic, Mississippian gypsum, sandstone, and shale, and

Devonian sandstone, shale, dolomite, limestone, and evaporites (Dorr and Eschman 1984, Milstein 1987).

LANDFORMS: Diverse topography, including sand dunes, sand lake plain, ground and end moraines, and outwash. Morainal bluffs and sand dunes rise abruptly along the shoreline of Lake Michigan. The shoreline is noted for these large sand dunes, which can be as high as 600 feet. Some of the best known dunes are those of the Sleeping Bear Dunes National Lakeshore and Ludington State Park. The high dunes, which date from high Lake Nipissing water levels (Kelley 1962), are also found on North and South Manitou Islands and on South Fox Island. Most of the high dunes are perched on underlying till, which is exposed as steep bluffs along the lakeshore.

Coarse-textured end-moraine ridges are the predominant landforms in the south and also north of Manistee. At Manistee, a broad flat area of lake plain and ground moraine separates the more steeply sloping moraines into northern and southern parts. In the south, the end moraines, 3 to 5 miles wide and 100 to 300 feet high, are separated by wide outwash channels. North of Manistee, the end-moraine ridges are much steeper than ridges in the south and without broad outwash channels between them. Most of the soils on the end moraines are well-drained sands.

Between Manistee and Frankfort, resistant bluffs of medium-textured till rise steeply from the lake, forming moderately to steeply sloping end-moraine ridges. To the east of these ridges are steep ridges of sandy soil.

In the southern half of the subsection, there are small areas of more gently sloping, fine-textured ground and end moraines. Most of the soils are well drained.

Between Ludington and Manistee is a broad expanse of flat sand lake plain and fine-textured ground moraine. Much of the lake plain consists of wet depressions and small, droughty beach ridges. Most of the ground moraine is poorly drained.

LAKES AND STREAMS: Sand bars and low dunes separate several large lakes from Lake Michigan; these lakes were once large bays of Lake Michigan, but as water levels dropped, they became separated. Examples are Manistee Lake on the Manistee River, Portage Lake on the Portage River, Glen Lake on the Crystal River, Pentwater Lake on the Pentwater River, Pere Marquette Lake on the Pere Marquette River, and Hamlin Lake on the Big Sable River. A few small lakes also occur on moraines and outwash.

SOILS: The dune soils are excessively well drained sands that contain no fine silts or clays. Most of the soils on the moraines are sands, but there are both medium-textured and fine-textured soils on the moraines. In the south, the soils are classified as gently sloping Haplorthods plus Glossoboralfs; in the north, soils are moderately sloping and there are also Udipsamments (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The dunes were noted by GLO surveyors as “loose sands” at several places along the coast; they were undoubtedly partially vegetated with dune grasses and shrubs. Farther inland the dunes supported various forests, including upland hemlock, hemlock-white pine, white pine-red pine, and red pine-jack pine-dominated forests. Northern hardwood forests, often with a significant component of hemlock and/or black oak, were also common. Poorly drained interdunal areas often supported northern white-cedar and/or hemlock-dominated swamps and shrub swamps.

On sandy lake plain and sandy moraines, eastern hemlock and American beech were often co-dominants. Other upland parts of the sandy lake plain included forests of white pine, which included significant amounts of white oak, beech, hemlock, black oak, and white ash. Several large complexes of beach ridges and swales, extending as much as a mile inland, supported various upland/wetland plant communities.

Poorly drained parts of the sandy lake plain supported swamps containing various combinations of black ash, elm, trembling aspen, tamarack, northern white-cedar, and hemlock. Thickets of willow, speckled alder, and bog birch, and emergent marshes also occurred on the sandy lake plain. Extensive marshes formed in the shallow inland lakes that formed at the mouths of major rivers, such as the Manistee and Big Sable.

Most of the moraines, regardless of their soil texture, supported forests of northern hardwoods. Dominance of northern hardwoods was probably a result of the increased precipitation and reduced transpiration along Lake Michigan (Denton and Barnes 1987, Eichenlaub 1979), allowing beech, sugar maple, and basswood to dominate sandy soils where oaks and pines would otherwise be expected.

Fine-textured ground moraine supported forests of eastern hemlock. Poorly drained areas with finer textured soils supported black ash, black spruce, and cedar swamps.

Sandy outwash deposits supported forests of white pine, red pine, and white oak, or on more fire prone sites, red pine with jack pine.

NATURAL DISTURBANCE: Although many of the high coastal dunes have been stabilized by forest vegetation, large blowouts are common on the dunes next to Lake Michigan. Some of these blowouts are the product of human disturbance; but many, noted by GLO surveyors, are probably naturally caused. The blowouts are large features, often extending as much as a half mile inland.

Signs of wildfires on sandy outwash deposits were noted several times by surveyors. Occasional, relatively small windthrows were encountered on the moraine ridges of the subsection.

PRESENT VEGETATION AND LAND USE: The dunes are largely managed as recreational lands, including State and federal parks. Residential development is also popular on the dunes.

White pine and red pine were extensively cut from the lake plain. The flat, sandy lake plain supports second-growth forest, used both for timber and recreation. Pine regeneration has generally been poor on the pine plains, with trembling aspen, red maple, and paper birch increasing in dominance after logging. There were attempts to establish orchards and farms on the sand lake plain after logging, but low productivity and easily eroded soils have resulted in high rates of abandonment.

The protection from late spring frosts afforded by Lake Michigan is responsible for the use of the subsection for extensive orchards of apples, cherries, and peaches (Olmsted 1951). Sand mining occurs on the dunes within the subsection, and oil fields tap the underlying Devonian petroleum reservoirs in the south. Urban development has been concentrated along the shoreline in the town of Manistee and several other smaller towns.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Botrychium campestre* (prairie dunewort), *Bromus pumpellianus* (Pumpelly's brome grass), *Cirsium pitcheri* (Pitcher's thistle), *Mimulus glabratus* var. *Michiganense* (Michigan monkey-flower), *Orobanche fasciculata* (fascicled broom-rape), and *Scirpus hallii* (Hall's bulrush).

RARE ANIMALS: *Buteo lineatus* (red-shouldered hawk), *Charadrius melodus* (piping plover), *Clonophis kirtlandii* (Kirtland's snake), *Dendroica discolor* (prairie warbler), *Lanius ludovicians* (loggerhead shrike), *Lycaeides melissa samuelis* (Karner blue), *Trimerotropis huroniana* (Lake Huron locust).

NATURAL AREAS: Wilderness Areas: Nordhouse Dunes (and Research Natural Area, Forest Service), Michigan Islands; The Nature Conservancy Preserves: Betsie River, Point Betsie, Lucia K. Tower.

PUBLIC LAND MANAGERS: State Parks: Charles Mears, Ludington, Silver Lake, Orchard Beach; State Game Areas: Betsie River, Manistee River, Muskegon, Pentwater; State Forests: Pere Marquette; National Forests: Manistee; National Lakeshores: Sleeping Bear Dunes; Other: Beaver Islands Wildlife Research Area, High Island Environmental Area, Central Michigan University Biological Station.

CONSERVATION CONCERNS: Large areas of coastal dune, including both open and forested dunes, have been protected within State parks. Investigation for Michigan monkey-flower continues in seepages along the Lake Michigan shoreline and inland, cold, spring-fed streams.

Figure 21.—*Subsection VII.4: Steep sand dunes, as high as 600 feet, form a narrow band along much of the Lake Michigan shoreline. These dunes, which date from the low-water Nipissing Stage of the Great Lakes from approximately 4,000 years ago, also occur along the shoreline of Lake Michigan and eastern Lake Superior in other subsections and sub-subsections. Near the shoreline, large areas of the dunes have open, shifting sands, but farther inland, where there is protection from offshore winds, forests stabilize the dune sands. Photo by D. Albert.*

SUBSECTION VII.5. Leelanau and Grand Traverse Peninsula**; coarse-textured drumlins on ground moraine, steep end moraine; northern hardwood forest, conifer swamp.**

DISCUSSION: At the inland interior of the subsection, there is a narrow band of steep end-moraine ridges; north of these steep end moraines is a broad drumlin field near Lake Michigan. The subsection is divided into several narrow peninsulas and peninsula-like landscapes by bays of Lake Michigan and several long, narrow inland lakes, including Torch Lake, Lake Charlevoix, and Walloon Lake (Albert *et al.* 1986).

SUB-SUBSECTIONS: Williamsburg (VII.5.1), Traverse City (VII.5.2).

ELEVATION: 580 to 1,220 feet (177 to 372 m).

AREA: 859 square miles (2,225 sq km).

STATES: Michigan.

CLIMATE: Climate is strongly influenced by Lake Michigan; spring and early summer are cooler than in the Highplains subsection to the east (Albert *et al.* 1986). Growing season ranges from 110 days at the inland edge to 150 days along the shoreline of Lake Michigan (Eichenlaub *et al.* 1990). A combination of early last freeze in spring, cool spring temperatures, and less severe thunderstorms creates an excellent setting for commercial fruit production, primarily apples, cherries, and grapes. Lake-effect snowfall is

heavy, averaging 100 to 140 inches annually. Average annual precipitation is 30 to 34 inches. Extreme minimum temperatures are -32˚F along Lake Michigan and -40˚F inland.

BEDROCK GEOLOGY: Drift thicknesses are less than 50 feet for most of the subsection; the thickest drift is about 350 feet, just east of Lake Charlevoix (Akers 1938). Paleozoic bedrock underlies the subsection, but it is only locally exposed near the coast. Bedrock consists of Mississippian shale and Devonian shale, limestone, dolomite, shale, and evaporites (Dorr and Eschman 1984, Milstein 1987).

LANDFORMS: Steep, sandy end moraines occcur at the inland edge; and small areas of sand dune are along the coast. Ground moraine with drumlin ridges characterizes most of the subsection.

LAKES AND STREAMS: See sub-subsections.

SOILS: The end moraines have sandy soils derived from till. The drumlins also have sandy and loamy soils developed on very gravelly till. The dune soils are developed from aeolian-deposited sand. Soils are classified as moderately sloping Haplorthods plus Glossoboralf and Udipsamments (USDA Soil Conservation Service 1967). See sub-subsections.

PRESETTLEMENT VEGETATION: Northern hardwood forests of beech, sugar maple, hemlock, and basswood were found on uplands throughout the subsection. Northern white-cedar dominated the poorly drained depressions between the drumlins.

NATURAL DISTURBANCE: Windthrow was noted in the swamp forests, both inland and along the Lake Michigan shoreline. Fire was noted on the dunes near Lake Michigan.

PRESENT VEGETATION AND LAND USE: GLO surveyors noted that Native Americans had small agricultural fields and sugar bushes near the Lake Michigan shoreline (Comer *et al.* 1993a). The drumlin fields are presently intensively used for agriculture, both orchards and pasture. The steep end moraines and dunes remain forested.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VII.5.1. Williamsburg**; coarse-textured end-moraine ridges; northern hardwood forest and white pine-red pine forest.**

DISCUSSION: Sub-subsection VII.5.1 is a small area of steep end-moraine ridges between the drumlins of the Traverse City sub-subsection (VII.5.2) to the north and the outwash plains of the Newaygo Outwash Plain subsection (VII.3) and the Grayling Outwash Plain sub-subsection (VII.2.2) to the south. It is distinguished from the Vanderbilt sub-subsection (VII.2.3) to the east because it has lower elevations and is not part of the high plateau.

ELEVATION: 750 to 1,220 feet (229 to 372 m).

AREA: 110 square miles (284 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: The narrow band of steep, sandy ridges at the southern edge of the sub-subsection supports northern hardwood forests dominated by beech and sugar maple. This portion of the Williamsburg sub-subsection is very similar to the steep ridges of the Vanderbilt sub-subsection (VII.2.3) to the south, but its ridges are separated from the Vanderbilt by outwash.

LAKES AND STREAMS: No lakes in the sub-subsection; the only major stream is the Boardman River.

SOILS: Soils on the end moraines are well-drained sands. There are few poorly or very poorly drained soils.

PRESETTLEMENT VEGETATION: The vegetation on the well-drained soils of the end-moraine ridge was northern hardwood forest dominated by sugar maple, beech, and hemlock. More xeric sandy moraines supported white and red pines intermixed with white and red oaks.

NATURAL DISTURBANCE: No mention of disturbances.

PRESENT VEGETATION AND LAND USE: Most of the sub-subsection remains forested because of the steepness of the landscape.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: Skegemog Swamp.

PUBLIC LAND MANAGERS: State Forests: Pere Marquette, Mackinaw; State Game Areas: Petobego; Wildlife Areas: Skegemog Swamp.

CONSERVATION CONCERNS:

SUB-SUBSECTION VII.5.2. Traverse City**; coarse-textured drumlin fields on ground moraine; northern hardwood forest and northern white-cedar swamps.**

DISCUSSION: Sub-subsection VII.5.2 consists primarily of narrow drumlins. It is divided into several peninsulas by Grand Traverse Bay of Lake Michigan and several large lakes, including Torch, Charlevoix, and Walloon. Lake Michigan has moderated the climate, providing excellent conditions for orchards and vineyards.

ELEVATION: 580 to 1,095 feet (177 to 334 m).

AREA: 749 square miles (1,940 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORMS: The drumlins are long, narrow ridges, about one-fourth mile wide, a mile long, and less than 100 feet high. The slopes are moderate or steep. Narrow depressions between the drumlins account for 6 to 26 percent of the land surface in Leelanau, Charlevoix, and Antrim Counties (Albert 1990).

Narrow, relatively low sand dunes border the western shorelines of the Leelanau Peninsula and Mission Peninsula and those of Charlevoix and Antrim Counties. This dune border is typically less than a mile wide, accounting for only a small percentage of the sub-subsection's surface area.

Small complexes of parallel beach ridges and swales occupy the sandy lake plain along Grand Traverse Bay and at Bowers Harbor; beach ridges are well drained, and the swales vary in drainage condition, from shallow ponds to shallow organic soils supporting swamp forest.

LAKES AND STREAMS: Bays of the lake and several long, narrow inland lakes divide the sub-subsection into narrow peninsulas. Two of the long, narrow lakes, Torch and Elk, were bays of Lake Michigan until they were cut off by sand deposition during Nipissing time (Dorr and Eschman 1984). Other large narrow lakes include Lake Leelanau, Lake Charlevoix, Lake Skegemog, Six Mile Lake, and Walloon Lake. Large streams flowing into these lakes are the Boardman, Jordan, and Boyne Rivers.

SOILS: Most of the soils on the drumlins are well-drained gravelly sand and gravelly sandy loam. Most of the gravel is local limestone. Most of the soils in the narrow depressions between the drumlins are peats rather than poorly drained mineral soils. Although swamps and small lakes are found in depressions between

many of the drumlins, some depressions are relatively well drained. In western Charlevoix County, where the drumlin ridges are closely spaced, narrow deposits of thick organic soils, less than 1,000 feet wide, separate adjacent drumlins.

PRESETTLEMENT VEGETATION: The original vegetation of the drumlins was northern hardwood forests of beech, sugar maple, yellow birch, hemlock, basswood, white ash, and hophornbeam. Northern white-cedar was common in the wetlands between the drumlins.

Upland areas of sand lake plain along Grand Traverse Bay supported forests of white pine and red oak (Comer *et al.* 1993a). Northern white-cedar was dominant on the sandy lake plain bordering many inland lakes and wetter parts of Grand Traverse Bay. Other wetland species present included balsam fir, hemlock, white pine, white spruce, red maple, American elm, and trembling aspen. Shrub swamps were also found on the sandy lake plain.

The northern hardwood forests that dominated the dunes contained more red maple, red oak, hemlock, and white pine than did the northern hardwoods on the drumlin fields.

NATURAL DISTURBANCE: Windthrows were noted in several swamps close to the shoreline. Surveyors noted wildfires near the shore along the eastern Leelanau Peninsula and behind sand dunes along the east shore of Grand Traverse Bay.

PRESENT VEGETATION AND LAND USE: The drumlin fields have been extensively used for orchards, and many of the depressions between the drumlins have been pastured. Residential development is rapid throughout the sub-subsection.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Bromus pumpellianus* (Pumpelly's brome grass), *Cirsium pitcheri*

Figure 22.—*Sub-subsection VII.5.2: Small, steep-sided drumlin ridges remain forested or are converted to pasture land. The larger, more gently sloping drumlin ridges and ground moraine (till plain) have been converted to pasture or crop land. Poorly drained outwash plain surrounds many of the drumlins; poorly drained outwash remains as swamp forest or pasture, whereas well drained outwash is converted to crop land. Photo by D. Albert.*

(Pitcher's thistle), *Tanacetum huronense* (Lake Huron tansy).

RARE ANIMALS: *Charadrius melodus* (piping plover), *Falco columbarius* (merlin).

NATURAL AREAS: Michigan Nature Association Preserves: Green River, Cedar River; The Nature Conservancy Preserves: Palmer-Wilcox-Gates, Skegemog Swamp; Other: Oyster Bay Nature Preserve, Leffingwell Forest Preserve.

PUBLIC LAND MANAGERS: State Parks: Fisherman Island, Leelanau, Young, Old Mission Peninsula; State Forests: Pere Marquette, Mackinaw; State Game Areas: Petobego; National Lakeshores: Sleeping Bear Dunes; County Parks: Marion Island.

CONSERVATION CONCERNS: Few areas of natural area quality persist; these are primarily wetland areas along lake shores or upland forests on very steep end moraines. Because of the scenic beauty, the orchards and agricultural lands are under tremendous development pressure for second homes.

SUBSECTION VII.6. Presque Isle**; drumlin fields and ground moraine, steep sand ridges, sandy lake plain; northern hardwood forest, white pine-red pine forest, hardwood-conifer swamp, northern fen, coastal marsh, open sand dunes.**

DISCUSSION: This subsection, located at the extreme northern end of Lower Michigan, is topographically diverse. Along the inland margin is a broad drumlin field. At the western edge, there are large steep moraines. Along the shoreline is a 3- to 18-mile-wide band of sand lake plain.

SUB-SUBSECTIONS: Onaway (VII.6.1), Stutsmanville (VII.6.2), Cheboygan (VII.6.3).

ELEVATION: 580 to 1,330 feet (177 to 405 m).

AREA: 2,985 square miles (7,730 sq km).

STATES: Michigan.

CLIMATE: The climate of the entire subsection is moderated by Lake Michigan and Lake Huron, but the northern latitude shortens the growing season (Albert *et al.* 1986). Growing season ranges from approximately 110 days on the southern, inland margin to 150 days along the Lake Huron shoreline (Eichenlaub *et al.* 1990). At the inland margin, the climate is less moderated by the Great Lakes. Atlanta, a town near this inland border, has a growing season of only 108 days. Extreme minimum temperatures are also moderated by Lake Michigan and Lake Huron; minimum temperatures are as high as -28˚F along the lakes, can be as low as -46˚F along the inland margin. Heavy, lake-effect snowfall (140 inches) occurs along the western edge, but drops off fairly rapidly to 70 inches in the east. Annual precipitation is relatively uniform, ranging from 28 to 32 inches.

BEDROCK GEOLOGY: Glacial drift is as thick as 500 feet at the inland margin of the subsection and is discontinuous within 30 miles of the shorelines of Lake Michigan and Lake Huron (Akers 1938). The underlying bedrock consists of Mississippian and Devonian marine and nearshore sedimentary deposits (Milstein 1987, Dorr and Eschman 1984). Limestone, dolomite, and gypsum are locally exposed and mined. Devonian bedrock in the subsection is a source for salt, brine, and major petroleum reservoirs (Dorr and Eschman 1984).

LANDFORMS: Drumlins are the predominant landform in Sub-subsection VII.6.1; steep, sandy end moraines are prevalent in Sub-subsection VII.6.2; and sandy glacial lake plain covers most of Sub-subsection VII.6.3. See sub-subsections.

SOILS: Soils are generally sandy throughout the subsection. Soils are locally rocky on the drumlin fields and thin near the Lake Huron shoreline, where bedrock is locally exposed. Extensive peat deposits occur in the depressions between the drumlins and in old embayments and swales on parts of the sand lake plain.

PRESETTLEMENT VEGETATION: Northern hardwood forest was common on drumlins and

sandy end moraines (Comer *et al.* 1993a). White pine and red pine forests grew on thin, rocky soils near Great Lakes shoreline. Conifer swamps covered large areas; northern white-cedar was a common dominant of the swamps along poorly drained Great Lakes shorelines. See sub-subsections.

NATURAL DISTURBANCE: Both fires and windthrow noted. See sub-subsections.

PRESENT VEGETATION AND LAND USE: Most of the subsection is managed for forest products or wildlife. Agriculture is most intensive on the loamier drumlins and broad ground-moraine ridges on the lake plain. There are several important State parks and natural areas, primarily on the Lake Huron and Lake Michigan shoreline. Limestone and gypsum are quarried on or near the present shoreline at several locations.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VII.6.1. Onaway**; drumlin fields on coarse-textured ground moraine; northern hardwood forest and conifer swamp.**

DISCUSSION: Ground moraine, supporting localized drumlin fields, occupies the eastern three-quarters of the sub-subsection. The western quarter contains several large lakes and sandy lake plain interspersed with small areas of ground moraine.

ELEVATION: 595 to 1,100 feet (181 to 335 m).

AREA: 1,931 square miles (5,005 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from approximately 100 days at the inland edge in the south to 130 days in the north along Lake Huron (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from approximately -46˚F inland to -34˚F closer to Lake Huron. Average annual precipitation is 30 to 32 inches. Annual snowfall is 140 inches in the west near Lake Michigan and only 70 inches at the eastern edge of the sub-subsection.

BEDROCK GEOLOGY: Glacial drift is as thick as 500 feet at the inland margin of the sub-subsection and is discontinuous within 30 miles of the shorelines of Lake Michigan and Lake Huron (Akers 1938, Haag 1976). The underlying bedrock consists of Mississippian and Devonian marine and near-shore sedimentary deposits (Milstein 1987, Dorr and Eschman 1984). Limestone, dolomite, and gypsum are locally exposed and mined. Devonian bedrock in the sub-subsection is a source for salt, brine, and major petroleum reservoirs (Dorr and Eschman 1984).

LANDFORMS: Rolling to moderately sloping ground-moraine topography. Drumlins are common on the ground moraine of the eastern three-quarters. Readvancing glaciers sculpted the southeastward-trending drumlin fields. Most of the drumlins are less than 60 feet high, one-eighth to one-fourth mile wide, and about 1 mile long. Individual drumlins are typically separated by poorly drained outwash. The western quarter contains several large lakes and large areas of lake plain interspersed with small ground-moraine deposits. The lacustrine deposits are from early Algonquin time, when the small ground-moraine deposits remained as “islands” above the level of Glacial Lake Algonquin (Burgis and Eschman 1981, Dorr and Eschman 1984).

Elevations are generally lower to the northeast near Lake Huron and higher to the southwest along the boundary with the Vanderbilt sub-subsection (VII.2.3). Small areas of exposed limestone bedrock are common in the ground moraine, and karst topography is also present. The ground moraine is broken by a broad outwash channel west of the town of Hawks.

LAKES AND STREAMS: Several large lakes are located here, including Burt, Douglas, Mullett, and Black Lakes. Major rivers are the Maple, Sturgeon, Black, Cheboygan, and Pigeon.

SOILS: The rolling hills and drumlins of the eastern section of ground moraine, characterized by slopes in the 0 to 12 percent slope class, have highly variable drainage and soil texture. Gravelly sandy loams are common. The gravel and angular rock fragments are predominantly limestone, derived from bedrock at the northern edge of the drumlin fields (Burgis and Eschman 1981). The glacial deposits within the drumlin fields are primarily brown, sandy tills, but these are overlain locally by red, sandy till or lacustrine deposits. Moderately well to well drained sands and sandy loams typify the drumlins. The depressions between the drumlins are generally poorly drained and constitute more of the landscape than the drumlin ridges.

Soils of the outwash channels vary from sand to gravel, and drainage conditions vary from excessively well drained to very poorly drained. The outwash contains several kettle lakes.

PRESETTLEMENT VEGETATION: Most of the drumlins supported northern hardwood forest, dominated by sugar maple, beech, basswood, hophornbeam, white ash, and hemlock (Comer *et al.* 1993a). In the southeast and near Black Lake, some sandy drumlins surrounded by droughty outwash supported red pine forest, with red oak and bigtooth aspen. Some of the smaller, low drumlin ridges were dominated by hemlock or a mix of hemlock and white pine; similar to vegetation found on the smaller drumlins in Menominee County (Sub-subsection VIII.3.1).

The poorly drained outwash and ground moraine surrounding the drumlins typically supported forested wetlands of northern white-cedar. Cedar was commonly the dominant at the upland margins of wetlands, but increasing amounts of tamarack and black spruce occurred in the center of the wetlands. Other species observed in these forested wetlands included trembling aspen, balsam poplar, paper birch, black ash, white pine, hemlock, willow, and speckled alder.

NATURAL DISTURBANCE: Windthrows were noted along the boundary with the Cheboygan sub-subsection (VII.6.3), but most of these windthrows occurred on that lake plain, not on the moraines of this sub-subsection.

PRESENT VEGETATION AND LAND USE: Most of this sub-subsection remains forested and is either part of State forest or commercial forest lands. Most of the drumlin ridges were cleared for agriculture, primarily for pasture, but also for some row crops and potatoes. The soils are very rocky; the rocks removed from fields form huge mounds on the landscape, and many have been built into fieldstone houses. Some of the wetlands have also been drained for pasture, but most remain intact.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Armoracia aquatica* (lake cress), *Carex nigra* (black sedge), *Cirsium pitcheri* (Pitcher's thistle), *Iris lacustris* (dwarf lake iris), *Juncus militaris* (bayonet rush), *Mimulus glabratus* var. *michiganensis* (Michigan monkey-flower), *Tanacetum huronense* (Lake Huron tansy).

RARE ANIMALS: *Brychius hungerfordi* (Hungerford's crawling water beetle), *Buteo lineatus* (red-shouldered hawk), *Charadrius melodus* (piping plover), *Lanius ludovicians* (loggerhead shrike).

NATURAL AREAS: Little Traverse Conservancy Preserves: Swift, Raunecker, W. Wequetonsing, Bartley, Schachinger, Bissell, James, Fischer, Sandford, Meadowgate, Fairbairn, Morley, Burley, Fisk, Goldman, Rockwell, Menonaqua Woods, Round Lake, L'Arbre Croche, Rocky Point, Orchis Fen, McCune, Bryan; Other: Colonial Point Forest Preserve (University of Michigan Biological Station).

PUBLIC LAND MANAGERS: State Forests: Mackinaw; State Parks: Harrisville, Negwegon, Onaway; National Forests: Huron; Other: University of Michigan Biological Station.

CONSERVATION CONCERNS: Partially because of insufficient biological surveys, little natural area protection has been achieved for this inland sub-subsection.

SUB-SUBSECTION VII.6.2. Stutsmanville**; steep sand ridges; northern hardwood forest.**

DISCUSSION: This small sub-subsection consists of steep sand ridges deposited by the glaciers, as well as some high sand dunes near the present Lake Michigan shoreline. It is almost entirely forested.

ELEVATION: 750 to 1,330 feet (229 to 405 m).

AREA: 219 square miles (566 sq km).

STATES: Michigan.

CLIMATE: Growing season is approximately 140 days along the Lake Michigan shoreline and as short as 110 days at the eastern, upland edge of the sub-subsection. Extreme minimum temperature ranges from -30˚F to -34˚F, with coldest temperatures inland. Average annual precipitation is 30 to 32 inches. Average snowfall is 80 to 120 inches; lake-effect snow off Lake Michigan that increases rapidly with elevation.

BEDROCK GEOLOGY: Glacial drift is several hundred feet thick over the underlying Devonian shale, sandstone, limestone, dolomite, and evaporites (Dorr and Eschman 1984, Milstein 1987).

LANDFORMS: Large, broad ridges of sandy ground moraines, some nearly 500 feet high. Glacial drift is generally several hundred feet thick.

LAKES AND STREAMS: No major lakes or streams.

SOILS: Primarily well drained sands and sandy loams. The moderate to steep slopes of the sub-subsection account for the well-drained soils. The narrow, often steep valleys between the ridges are poorly or very poorly drained, but they account for only a small part of the sub-subsection's surface area.

PRESETTLEMENT VEGETATION: The predominant vegetation of the sub-subsection was northern hardwood forest dominated by beech, sugar maple, hemlock, basswood, hophornbeam, and yellow birch. Lowlands, restricted to relatively narrow valleys between the ridges, were dominated by northern white-cedar, or occasionally tamarack or mixed conifers. The largest wetland noted was approximately 1.5 square miles in area.

NATURAL DISTURBANCE: No natural disturbances noted.

PRESENT VEGETATION AND LAND USE: Several Native American fields were noted on the sloping ridges of this sub-subsection within 1 to 2 miles of the shoreline. After European settlement, most of the forests were logged; but little agricultural development has occurred on the large, steep ridges.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Cirsium pitcheri* (Pitcher's thistle), *Iris lacustris* (dwarf lake iris), *Mimulus glabratus* var. *michiganensis* (Michigan monkey-flower), *Tanacetum huronense* (Lake Huron tansy).

RARE ANIMALS: *Buteo lineatus* (red-shouldered hawk), *Charadrius melodus* (piping plover), *Sterna caspia* (Caspian tern), *Trimerotropis huroniana* (secretive locust).

NATURAL AREAS: Little Traverse Conservancy Preserves: M. Shrotleff, E. Johnston, Sims-Moffat.

PUBLIC LAND MANAGERS: State Forests: Mackinaw; State Parks: Wilderness.

CONSERVATION CONCERNS: Sub-subsection contains part of Wilderness State Park, which supports many characteristic landscapes found along the northern Great Lakes shoreline.

SUB-SUBSECTION VII.6.3. Cheboygan**; lake plain; pine-oak forest, hardwood-conifer and conifer swamp, bog, coastal marsh, coastal fen.**

DISCUSSION: Much of this relatively flat area of calcareous glacial lake plain is wetland, largely dominated by northern white-cedar. Broadly diverse lacustrine features are present, supporting vegetation characteristic of the northern Great Lakes shoreline.

ELEVATION: 580 to 750 feet (177 to 229 m).

AREA: 836 square miles (2,158 sq km).

CLIMATE: Growing season ranges from 130 days near the inland edge to 140 days along much of the Lake Huron and Michigan shorelines. The longest growing season is about 150 days at the extreme southeast edge near Alpena (Eichenlaub *et al.* 1990). Extreme minimum temperatures are approximately -28˚F at the southern edge and -36˚F further to the north, where Lake Huron does not appear to modify the extreme low temperature to any great extent. Average annual precipitation is 28 to 30 inches, and average snowfall is 80 inches along the entire length of the sub-subsection.

BEDROCK GEOLOGY: Glacial drift is discontinuous near the shorelines of Lake Michigan and Lake Huron. The underlying bedrock consists of Mississippian and Devonian marine and near-shore sedimentary deposits (Milstein 1987, Dorr and Eschman 1984). Limestone, dolomite, and gypsum are locally exposed and mined. Devonian bedrock in the subsection is a source for salt, brine, and major petroleum reservoirs (Dorr and Eschman 1984).

LANDFORMS: Sub-subsection VII.6.3 forms a narrow band of sandy lake plain, 2 to 10 miles wide, along the shoreline of Lake Huron (Comer *et al.* 1993a). Although a veneer of sand covers a large part of the sub-subsection's surface, limestone bedrock is near the surface of almost the entire sub-subsection; and exposed bedrock and cobble beaches are common.

Similar to other sand lake plains in the State, much of the topography is a series of beach ridges and adjacent wet depressions, extending locally several miles inland. These dune and swale complexes are well developed in Sturgeon Bay of Lake Michigan and east of Cheboygan and along Hammond Bay of Lake Huron. Near the present lake shore, the depressions are typically poorly drained and sometimes ponded. Farther inland, the depressions become better drained; in some places they are excessively drained, as are adjacent beach ridges. Sand dunes, low foredunes, sand spits, and beach ridges line much of the shoreline. The Original Swamp Map of Michigan (Lane 1907) shows most of the sub-subsection as swamp.

Inland from the beach ridges and depressions are extensive flat, featureless areas of sand lake plain that are usually poorly drained. Within these broad tracts occur low sandy rises with slightly better drainage.

West of Rogers City, the surface soil is primarily sand. Sand depth and the surface features are quite variable. The Ocqueoc River in northwestern Presque Isle County cuts through thick sand deposits that extend landward for more than a mile. These deposits are relatively flat, and their origin is unclear.

Large Nipissing-age dunes are located near Sturgeon Bay on Lake Michigan (Dorr and Eschman 1984). Most of the dunes on Lake Huron are much smaller; the largest of these are 30 to 40 feet high near 40 Mile Beach.

Exposed limestone bedrock and thick deposits of cobbles are common southeast of Rogers City. Waves have eroded the limestone bedrock into steep bluffs. At one time, organic soils covered the cobbles; but fire, which was widespread throughout this part of the lake plain at the time of the GLO surveys, has destroyed much of the organic cover, leaving bare cobbles. Karst depressions occur around Long Lake and elsewhere in Presque Isle and Alpena Counties of the eastern end of the sub-subsection.

LAKES AND STREAMS: Three major lakes: Carp, Grand, and Long. Long, Grand, and Grass Lakes have long, linear basins formed by glacial erosion of the underlying bedrock; the orientation of these lakes is similar to that of the drumlins in

adjacent Sub-subsection VII.6.1. Large rivers: Thunder Bay, Ocqueoc, Black, and Cheboygan.

SOILS: Most of the soils are lacustrine sands, ranging from excessively drained to very poorly drained. It is more useful to discuss the soils in context of the diverse lacustrine features. See the LANDFORMS section.

PRESETTLEMENT VEGETATION: Large areas of flat, poorly drained sand lake plain were dominated by lowland conifer forests; the most common species was northern white-cedar. Northern white-cedars were dominant in areas where there was lateral water movement and they formed dense stands at the seepy, calcareous margins of adjacent Sub-subsection VII.6.1. Tamarack was also a common dominant and often was found growing with cedar; it was more common where drainage conditions were more impeded. Other wetland species common in the extensive wetlands of the sub-subsection included balsam fir, black spruce, eastern hemlock, white pine, balsam poplar, trembling aspen, paper birch, speckled alder, and shrub willows.

White pine and red pine were common co-dominants on the well-drained, low sand ridges of the lake plain, especially near the Lake Michigan and Lake Huron shorelines. These pines also grew together on gravelly or rocky sites near the Lake Huron shoreline.

Hemlock and white pine were also common co-dominants, often where the drainage conditions were slightly poorer than where white pine and red pine grew together. Paper birch and trembling aspen also grew on flat to rolling parts of the sand lake plain.

Near the Ocqueoc River, where droughty outwash sands extended for several miles inland from the shore, there were extensive stands of jack pine and red pine-jack pine. These stands also contained red oak and some white pine.

The complexes of beach ridges and swales near Sturgeon Bay and Cheboygan contained ridges of white pine and red pine and swales dominated by either northern white-cedar and other conifers, or if they were flooded, by emergent marsh. A similar complex at Hammond Bay, where the swales were narrow, was drier; the ridges were dominated by white pine and red pine near the shoreline, with jack pine and northern pin oak becoming more common farther inland. The drier swales supported balsam fir, aspen, and other upland species; and the wetter ones supported cedar, tamarack, and other lowland conifers or hardwoods.

Calcareous ponds occurred near the shoreline; these ponds were sometimes dominated by emergent marsh or small-diameter tamarack, cedar, and occasional black spruce.

Although northern hardwoods were not generally extensive in the sub-subsection, some large tracts were located around Long and Grand Lakes, along the Cheboygan and Black Rivers, and locally along the Lake Michigan and Lake Huron shorelines.

NATURAL DISTURBANCE: Several windthrows were noted; the largest of these was less than 2 square miles in area. The windthrows were concentrated near the boundary of the lake plain with the drumlins of Sub-subsection VII.6.1. Windthrows were also recorded on Hog, Garden, and High Islands.

There were also two large areas of burned timber. These burns were not noted in the first GLO survey (of the township lines); they may have been the result of early logging operations near Cheboygan, where log mills were already noted in the first survey. Several square miles of timber were burned near Cheboygan, and several more were burned near Thompson's Harbor and Grand Lake. Mixed stands of white pine and red pine appeared to be the forest type most impacted by the fires. Wildfires were also noted on Garden and Hog Islands.

PRESENT VEGETATION AND LAND USE: Early European activity was apparent at Cheboygan, an early logging and fishing settlement, at the time of the GLO surveys. Limestone in this sub-subsection has been quarried at several locations, including near Alpena, Grand Lake, Adams Point, and Rogers City. Residential development is concentrated along the shoreline, especially in the Straits of Mackinac, from Wilderness State Park in the west, to east of Cheboygan. Many seasonal residences and second homes have been built around the larger inland lakes.

Logging has greatly altered the forest composition of many upland forest types, especially those dominated by white pine, red pine, or hemlock. Most of the wetlands have also been logged. No major changes of wetland forest composition have been noted; northern white-cedar has generally regenerated well on the calcareous soils of the lake plain.

RARE PLANT COMMUNITIES: High-quality fens are common along the shoreline of Lake Huron.

RARE PLANTS: *Cirsium pitcheri* (Pitcher's thistle), *Iris lacustris* (dwarf lake iris), *Mimulus glabratus* var. *michiganensis* (Michigan-monkey flower), *Pterospora andromedea* (pine-drops), *Solidago houghtonii* (Houghton's goldenrod), *Tanacetum huronense* (Lake Huron tansy).

RARE ANIMALS: *Charadrius melodus* (piping plover), *Chlidonias niger* (black tern), *Sterna caspia* (Caspian tern), *Sterna hirundo* (common tern), *Trimerotropis huroniana* (secretive locust).

NATURAL AREAS: Wilderness Area and National Wildlife Refuges: Michigan Islands (U.S. Fish and Wildlife Service); State Natural Areas: Besser, Sturgeon Bay-Sucker Creek, Thompson's Harbor, Waugoshance Point Nature Study Preserve, Wilderness State Park (proposed); The Nature Conservancy Preserves: Grass Bay, Squaw Bay; Michigan Nature Association Preserves: Grass Lake, Gull Island, Bird Island, Grass Island; Other: Peter Nature Sanctuary.

PUBLIC LAND MANAGERS: State Forests: Mackinac; State Parks: Wilderness, Cheboygan, Thompson's Harbor, Onaway, Negwegon, P.H. Hoeft; State Environmental Areas: Black River, Duncan Bay, Jensen Harbor, Hat Island, Squaw Bay, Whitefish Bay, Wilderness, Grape, Sacajawea; Other: University of Michigan Biological Station, Beaver Island Wildlife Research Area.

CONSERVATION CONCERNS: Sub-subsection VII.6.3 contains several large State parks and nature preserves along the Great Lakes shoreline, offering protection to high-quality coastal ecosystems and large populations of both dwarf lake iris and Pitcher's thistle. Mature forests of white pine and red pine, among the best remaining in the State, are protected at Wilderness State Park. Several areas of high-quality, undeveloped Great Lakes shoreline remain unprotected.

SECTION VIII. NORTHERN LACUSTRINE-INFLUENCED UPPER MICHIGAN AND WISCONSIN**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; Great Lakes-moderated climate (Denton 1985, Eichenlaub 1979, Eichenlaub *et al.* 1990); late Wisconsinan-age glaciated landscape; northern hardwoods forest, jack pine barrens, white pine-red pine forest, conifer swamp, bog.**

SUBSECTION VIII.1. Niagaran Escarpment and Lake Plain**; bedrock escarpment, sand and clay lake plain and lacustrine landforms, ground moraine; upland forests of northern hardwoods, conifers, and hardwood-conifers, extensive conifer-dominated wetlands, Great Lakes coastal wetlands, open sand dunes, and alvar (grasslands on bedrock).**

DISCUSSION: Various landforms of glacial lacustrine origin characterize the subsection, including flat lake bed, deltaic deposits of sand, parabolic dune fields, and shallow embayments containing transverse dunes. Ground moraine is locally present. Exposures of limestone and dolomite bedrock occur along the shorelines of both Lakes Michigan and Huron, and locally several miles inland.

SUB-SUBSECTIONS: St. Ignace (VIII.1.1), limestone bedrock and sand lake plain along northern Lake Michigan; Rudyard (VIII.1.2), clay lake plain in eastern Upper Michigan; Escanaba/Door Peninsula (VIII.1.3), limestone bedrock and sand lake plain along Lake Michigan, with a more moderate climate than Sub-subsection VIII.1.1; and Green Bay Till Plain and Lake Plain (VIII.1.4), silt- and clay-rich tills and lacustrine deposits along the western Lake Michigan shoreline in Wisconsin. (See figures 4 and 6.)

ELEVATION: 580 to 1,040 feet (177 to 317 m).

AREA: 5,356 square miles (13,883 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: With a climate typified by lake-effect moderation, this is the warmest subsection in Upper Michigan and northern Wisconsin. Growing season ranges from 128 days in the north to 175 days along the southern boundary (Eichenlaub *et al.* 1990, Wisconsin Agricultural Statistics Service 1987). Extreme minimum temperature ranges from -28˚F in the southwest along Lake Michigan to -46˚F at the inland edge of the subsection in Upper Michigan. Average annual precipitation ranges from 28 to 34 inches. Average annual snowfall ranges from less than 50 inches in Wisconsin (Wisconsin Agricultural Statistics Service 1989) to 120 inches near Sault Ste. Marie, Michigan, at the extreme northeastern edge.

BEDROCK GEOLOGY: The entire subsection is underlain by Silurian and Ordovician sedimentary bedrock, principally limestone and dolomite, but also including less resistant shale and gypsum (Dorr and Eschman 1984). The resistant Niagaran series dolomite and limestone of Silurian age form the Niagaran Escarpment, which is locally exposed as cliffs and limestone pavement (alvar) along the Lake Michigan and Lake Huron shorelines from the Door Peninsula in northeastern Wisconsin, to Drummond Island at the far eastern edge of the Upper Peninsula of Michigan, and eastward to Cockburn Island, Manitoulan Island, and the Bruce Peninsula of Ontario. Little Bay de Noc and Big Bay de Noc, Michigan (Sinclair 1960), and Green Bay, Wisconsin, occupy depressions where soft gypsum and shales were eroded, probably by both glacial and lacustrine erosional processes. The underlying bedrock is typically less than 50 feet below the surface of the glacial drift in Michigan (Vanlier and Deutsch 1958; Sinclair 1959, 1960; Vanlier 1963b). It is exposed or near the surface on the Door Peninsula, but is more deeply buried inland (Hole 1976).

LANDFORMS: Most of the subsection consists of lacustrine sand or clay deposits that have flat to

gently undulating surfaces. On this topography, only a few inches of elevation change can greatly alter drainage conditions.

Along the shoreline and several miles inland in Sub-subsections VIII.1.1 and VIII.1.3, either bedrock or sand is at the surface. Local landforms on the sand plain include transverse and parabolic dunes, deltas, and beach ridges and swales. See sub-subsections.

At the northeastern edge of the subsection in Michigan and at the southwestern edge in Wisconsin (Sub-subsections VIII.1.2 and VIII.1.4), there are broad clay plains consisting of lacustrine deposits and water-reworked till.

LAKES AND STREAMS: Large lakes are not common, but those that occur (Indian Lake and the Manistique Lakes in Michigan) are near the junction between Ordovician and Silurian marine bedrock. They may be the result of chemical or physical erosion of less resistant bedrock. Streams are numerous on the flat lake plain. See sub-subsections.

SOILS: Soils on the lake plain itself are generally lacustrine sands or lacustrine clays. Most of the clay soils were calcareous and either somewhat poorly drained or poorly drained. The sandy soils ranged from very poorly drained to excessively drained, depending on slope and depth to underlying bedrock or fine-textured soils. Many of the sands are calcareous, but often deeply leached. Thin soils over bedrock are common throughout Sub-subsections VIII.1.1 and VIII.1.3, especially near the Lake Michigan or Lake Huron shoreline.

Calcareous sandy and sandy loam tills are locally common, often immediately adjacent to bedrock.

PRESETTLEMENT VEGETATION: The original vegetation of the subsection was diverse, reflecting the local diversity of landforms, soil texture, and drainage class on the lake plain (Comer *et al.* 1994). See sub-subsections.

Conifer swamps were extensive throughout. On the clay plain, a diverse forest of swamp hardwoods and conifers was found. Northern white-cedar dominated wetlands over limestone; tamarack and black spruce were common dominants on sandy soils. Near the shores of the Great Lakes were extensive marshes and wet meadows where there was adequate protection from wave action.

Northern hardwoods, including sugar maple, beech, American elm, basswood, and yellow birch, were locally common on better drained sites. White pine and red pine were locally common on sand dunes and beach ridges; white pine also occurred within the swamp forests.

NATURAL DISTURBANCE: Winds off Lakes Michigan and Huron resulted in many small areas of windthrown trees, most concentrated within a mile or two of the shoreline (Comer *et al.* 1993a). Such a localized storm along the north shore of Lake Michigan was observed in the summer of 1995, destroying large numbers of white and red pine. Poorly drained soils and the resulting shallow rooting increase the number of windthrown trees.

Water levels of the Great Lakes regularly fluctuated 2 to 3 feet over a period of 7 to 8 years, with a longer cycle of even more extreme fluctuation (Thompson 1992), resulting in dynamic vegetation conditions within a mile of the shoreline. Beaver ponds and resulting tree mortality are common in this flat, poorly drained landscape.

Fire, caused by lightning, has destroyed large areas of conifer forest. Conifer forests are also regularly affected by insect vectors, including jack pine budworm, spruce budworm, and larch sawfly.

PRESENT VEGETATION AND LAND USE: The clay lake plains (Sub-subsections VIII.1.2 and VIII.1.4) have been converted to crop or pasture land. Pasture is prevalent in Sub-subsection VIII.1.2, where the growing season averages only 125 days (Denton 1985); and crop land is prevalent in Sub-subsection VIII.1.4, where the growing season can be up to 160 days long (Hole 1976, Hole and Germain 1993). On most of these flat, lacustrine landscapes, some form of drainage is necessary for agriculture. Ditches 6 to 8 feet deep are common on the clay plain. In Michigan, much of this pasture has been abandoned and is slowly reverting to forest. Most of the remaining sandy lake plain is forested, and large portions are publicly owned. The Lake Michigan and Lake Huron shorelines are also popular for recreational use and for vacation homes. Limestone and dolomite are quarried locally.

Excellent examples of numerous types of wetlands occur along the shoreline. The Great Lakes marshes of the subsection are large and of high quality. The importance of these marshes for habitat of water fowl, wading birds, small mammals, and fish cannot be overstated.

RARE PLANT COMMUNITIES: Alvar, grassland on thin soils over dolomite or other marine bedrock, is a globally rare plant community. In Michigan, alvar is found only in this subsection. Although alvar is well represented in adjacent Ontario, many of these grasslands in Michigan are of extremely high quality. Calcareous fens are probably best represented along the shorelines within this subsection (Subsection VII.6 also has excellent examples), where they can extend several miles inland on Nipissing-age clay lake beds.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: The primary areas of concern within the subsection are the sensitive Great Lakes shorelines, both the wetlands and dunes, and alvar (grassland on limestone bedrock). All are extremely sensitive to damage by off-road vehicles. Remaining private areas of shoreline are rapidly being developed for retirement homes and second homes. Degradation of shorelines by off-road vehicles almost always follows soon after home development.

Subsection VIII.1 contains high-quality habitat for several threatened and endangered plants and animals, most of which are associated with Great Lakes shorelines. These include the following federally threatened: Pitcher's thistle, dwarf lake iris, Houghton's goldenrod, and Michigan monkey-flower. It also contains high-quality examples of many ecosystems associated with either present or past shorelines of the Great Lakes.

SUB-SUBSECTION VIII.1.1. St. Ignace**; limestone bedrock and sand lake plain; conifer-dominated upland and wetland forests, northern hardwoods, fens, coastal emergent marshes, alvar.**

DISCUSSION: Sub-subsection VIII.1.1 is typified by sandy lake plain and limestone bedrock at or near the surface. Limestone bedrock is exposed along the Lake Huron shoreline in the east, especially on Drummond Island. Lacustrine features include sand dunes, embayments with complexes of parallel beach ridges and swales, and extensive conifer-dominated wetlands on sand or bedrock.

ELEVATION: 580 to 1,040 feet (177 to 317 m).

AREA: 1,578 square miles (4,088 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 130 to 140 days, longest along the Lake Michigan and Lake Huron shorelines (Eichenlaub *et al.* 1990). Extreme minimum temperatures are coldest inland, where they can be as low as -46˚F, and warmest along the Lake Michigan shoreline, where they are as high as -30˚F. Average annual precipitation is 30 to 32 inches across the entire sub-subsection. Annual snowfall averages 60 to 80 inches, uniform across the sub-subsection.

BEDROCK GEOLOGY: The entire sub-subsection is underlain by Silurian- and Ordovician-age sedimentary bedrocks, principally limestone and dolomite, but also including less resistant shale and gypsum (Dorr and Eschman 1984). The resistant Niagaran series dolomite and limestone of Silurian age form the Niagaran Escarpment, which is locally exposed as cliffs and limestone pavement along the Lake Michigan shoreline from the Stonington Peninsula in the west to Drummond Island at the far eastern edge of the Upper Peninsula of Michigan, and eastward to Cockburn Island, Manitoulan Island, and the Bruce Peninsula of Ontario. The underlying bedrock is typically less than 50 feet below the surface of the glacial drift (Vanlier and Deutsch

1958; Sinclair 1959, 1960). Limestone is mined in several places within the sub-subsection; large limestone quarries are located on Drummond Island and at Cedarville.

LANDFORMS: Various landforms of glacial lacustrine origin characterize the sub-subsection, including flat lake bed, deltaic deposits of sand, parabolic dune fields, and shallow embayments containing transverse dunes.

Large areas consist of lacustrine sand deposits that have flat to gently undulating surfaces. On this topography, only a few inches of elevation change can greatly alter drainage conditions. Drainage conditions also depend on depth to underlying bedrock or fine-textured substrate.

Ground moraine is locally present. Exposed limestone and dolomite bedrock forms flat, pavement-like areas, and breccia chimneys are locally exposed.

LAKES AND STREAMS: Several large lakes. The largest are on ground moraine, including Manistique and South Manistique Lakes. On the sandy lake plain, there are two large lakes, Millecoquins and Brevoort, and several smaller lakes. On bedrock, or where limestone and dolomite bedrock is near the surface, there are numerous lakes, including Merwin, Gulliver, McDonald, Caribou, and East. Several other small, highly calcareous lakes are located on the dolomite of Drummond Island.

Rivers are not numerous. Two of the larger are the Pine and Carp, which originate in other sub-subsections farther to the north.

SOILS: Soils are diverse. Lacustrine soils are primarily sands, but there are small, local areas of lacustrine clays. The clays are primarily poorly drained. The sands are generally either excessively drained or poorly drained. Excessively drained sands are on beach ridges or dunes. Poorly drained sands are more common, occupying much of the flat lake plain or depressions between dunes and beach ridges. Soils of the ground moraine range from loamy sands to loams; they are often stony. Where bedrock is near the surface, soils are often calcareous and poorly drained. The most common soil orders here are Alfisols (Boralfs), Histosols, and Entisols (Aquepts), with some Orthods and Aquods (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Along the Lake Huron and Lake Michigan shorelines, there were many broad coastal marshes in protected coves and embayments. These were most numerous on Lake Huron where there was more protection from wave action. They were especially common in and around the Les Cheneaux Islands. The substrate in these marshes was often clay or marl (Albert *et al.* 1989).

The forests of the flat lake plain were generally dominated by conifers, especially on the poorly drained or excessively drained portions (Comer *et al.* 1993a). The most common swamp conifers were northern white-cedar, tamarack, balsam fir, and black spruce. The most common upland conifers were white pine and hemlock, with increased red pine on dry sand ridges and localized areas of jack pine on droughtiest sites.

Extensive complexes of beach ridges and swales were in large embayments; these supported forests of white pine, red pine, red oak, and other hardwoods on the driest ridges and conifer swamp and shrub swamp in the drier swales. Emergent vegetation grew in the swales near the present Great Lakes shoreline. The largest area of beach ridges and swales is at Pointe Aux Chenes, west of St. Ignace.

In some of the embayments, there were extensive fens, dominated by stunted white pine, northern white-cedar, tamarack, and black spruce. GLO surveyors noted marly pools in these fens. Much of the coastal zone along northern Lake Huron and Lake Michigan, where soils were thin overlay bedrock, was dominated by balsam fir-spruce-cedar forests and northern hardwoods.

The flat, sandy lake plain supported diverse swamp forest types, including extensive cedar swamps, tamarack swamps, and mixed conifer swamps. Hemlock and northern hardwood forest also dominated many uplands on sandy lake plain.

On the low parabolic dunes along the sandy lake plain of Lake Michigan, the moist air and presumably higher precipitation and soil moisture caused most of the dunes to be dominated by northern hardwood forests of sugar maple, beech, hemlock, red oak, yellow birch, paper birch, and basswood. The Brevoort Lake dunes, located near the Lake Michigan shore, are a good

example of this forest type. In contrast, the dunes located near Round Lake, several miles inland from Lake Michigan, support forests dominated by red and jack pines; this possibly indicates the lack of local microclimatic influence bringing moisture from Lake Michigan.

Ground-moraine ridges were dominated by northern hardwoods, hemlock-beech, and hemlock-white pine forests.

NATURAL DISTURBANCE: GLO surveyors recorded many occurrences of fire in upland and swamp forests on both sand and bedrock. There were both wildfires and windthrows on Little St. Martin Island and the beach ridges near the mouth of the Crow River were burned off at the time of the surveys.

Many windthrows were noted by surveyors on both the uplands and wetlands along the shorelines of both Lake Michigan and Lake Huron, especially on the islands. Thin soils over bedrock and poorly drained soils, common along the shoreline, combined with the strong lake winds to produce extensive windthrow areas. White pine appears to be especially susceptible to coastal wind storms.

PRESENT VEGETATION AND LAND USE: European settlements were well established at St. Ignace, Bois Blanc Island, and at Gros Cap at the time of the GLO surveys in the 1840's. The 1829 survey of Mackinac Island showed only small second-growth timber over the entire island, probably as a result of firewood cutting. A British military outpost was established at the southwest end of Drummond Island. Fishing camps were based at various locations along the shoreline from Epoufette west to Seul Choix Point. Native American settlements were also located on Bois Blanc Island and St. Martins Island. Native American sugar camps were also located throughout the area where northern hardwoods dominated. Limestone has been quarried at several locations within this subsubsection, including Drummond Island, inland areas northeast of Hessel, Millecoquins Lake, and Seul Choix Bay. Upland areas dominated by pines and northern hardwoods were cut, and often burned, by the early 20th century. Roads and highways have probably had the most enduring negative impact on coastal wetlands, by disrupting wetland hydrology and facilitating shoreline development. Several emergent marshes along northern Lake Huron have been degraded by coastal highway construction. Residential development is increasing along Lake Huron. Residential development is quite dense on many of the Les Cheneaux Islands, which are connected to the mainland by roads. Ground moraine has been cleared for agriculture and pasture use.

RARE PLANT COMMUNITIES: Some of the more resistant dolomites and shales, when exposed at the surface, proved to be too droughty for successful forest establishment; instead, they support alvar communities. As a result of severe droughtiness, alvar contains grasses, herbs, and occasional shrubs as well as stunted clones of trembling aspen on thin soil. Thin organic soils develop, but they appear to be subject to destruction by fire. Some of the best remaining alvar, globally, is found today on the northern Maxton Plains of Drummond Island and south of Gulliver Lake in Schoolcraft County.

RARE PLANTS: *Amerorchis rotundifolia* (round-leaved orchid), *Asplenium rhizophyllus* (walking fern), *Asplenium scolopendrium* var. *americana* (Hart's-tongue fern), *Asplenium viride* (green spleenwort), *Calypso bulbosa* (Calypso orchid), *Carex richardsonii* (Richardson's sedge), *Carex scirpoidea* (bulrush sedge), *Cirsium pitcheri* (Pitcher's thistle), *Cypripedium arietinum* (ram's-head lady's-slipper), *Eleocharis compressa* (flattened spike-rush), *Empetrum nigrum* (black crowberry), *Erigeron hyssopifolius* (hyssop-leaved fleabane), *Iris lacustris* (dwarf lake iris), *Juncus stygius* (moor rush), *Mimulus glabratus* var. *Michiganense* (Michigan monkey-flower), *Muhlenbergia richardsonis* (mat muhly), *Piperia unalascensis* (Alaska orchid), *Ranunculus lapponicus* (Lapland buttercup), *Scutellaria parvula* (small skullcap), *Solidago houghtonii* (Houghton's goldenrod), *Sporobolus heterolepis* (prairie dropseed), *Stellaria longipes* (stitchwort), *Sterna forsteri* (Forster's tern), *Sterna hirundo* (common tern), *Tanacetum huronense* (Lake Huron tansy).

RARE ANIMALS: *Alces alces* (moose), *Canis lupus* (gray wolf), *Charadrius melodus* (piping plover), *Chlidonias niger* (black tern), *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus*

(osprey), *Sterna caspia* (Caspian tern), *Trimerotropis huroniana* (Lake Huron locust).

NATURAL AREAS: The Nature Conservancy Preserves: Bois Blanc Island, Maxton Plains, Voight Bay, Dudley Bay-Trout Lake, Poe Point, Little LaSalle Island, Northern Lake Huron Bioreserve; Michigan Nature Association Preserves: Purple Coneflower, Michigan Monkey-Flower, Green Spleenwort, Rare Fern, Beaver Dam, Beavertail Point, Three Wilderness Islands, Carlton Lake Wetlands, Lake Huron Sand Dunes, Drummond Island, Harvey's Rocks; Proposed Research Natural Areas (Hiawatha National Forest): Summerby Swamp, Pointe aux Chenes Marsh; Wilderness Areas (Hiawatha NF): Horseshoe Bay, Round Island, Government Island; State Natural Areas: Maxton Plains, Snake Island, Mixed Forest Nature Study Area, North Shore, Northern Lake Michigan (proposed), Seiners Point (proposed), Little Brevoort Lake Scenic Area.

PUBLIC LAND MANAGERS: Michigan: National Forests: Hiawatha; National Wildlife Refuges: Seney; State Forests: Lake Superior, Mackinac; State Parks: Detour, Mackinac Island; State Forest Campgrounds (Lake Superior State Forest): Big Knob, DeTour; Environmental Areas: Little St. Martin Island, Voight Bay, Goose Island, Pointe Aux Chenes Bay, Mismer Bay, Carp River, St. Helena, Crow River, Scammon, Epoufette, Crow Island, Cedar Island, Paw Point, Search Bay, Lone Susan, Pontchartrain, Seiners Point, Naubinway Island, Scotty Bay, Seymour Bay, Duck Bay, Gravel Island.

CONSERVATION CONCERNS: Low sand dunes and beach ridges along the shoreline support healthy populations of Pitcher's thistle (federally threatened), a Great Lakes endemic, as well as Lake Huron tansy. Three other Great Lakes endemics are found near the shoreline: dwarf lake iris (federally threatened) is found on calcareous till or sand deposits near the shoreline, Houghton's goldenrod (federally threatened) grows in moist interdunal swales along the shore, and Michigan monkey-flower (federally threatened) grows in cold, spring fed streams near the Great Lakes shoreline.

Figure 23.—*Sub-subsection VIII.1.1: Seaman's Point, Drummond Island, Chippewa County, Michigan. Paleozoic marine bedrock underlies all of section VIII, and is exposed along the shoreline of Lakes Huron and Lake Michigan. The dolomite pavement at Seaman's Point tilts very gradually toward the center of the Michigan basin to the south. Photo by P. Comer.*

SUB-SUBSECTION VIII.1.2. Rudyard**; clay lake plain; conifer and hardwood-conifer-dominated uplands and wetlands; coastal marshes.**

DISCUSSION: This small sub-subsection of lake plain with fine-texture soils has been more intensively managed for agriculture than any other part of Upper Michigan.

ELEVATION: 580 to 800 feet (177 to 244 m).

AREA: 666 square miles (1,725 sq km).

STATES: Michigan.

CLIMATE: Average growing season ranges from 120 days in the north to 140 days in the south (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -32˚F over most of the sub-subsection to -38˚F in the north and northeast along the St. Marys River. Average annual precipitation is 32 to 34 inches. Annual snowfall ranges from 120 inches in the north (lake-effect snows) to 80 inches in the south.

BEDROCK GEOLOGY: Sub-subsection is underlain by Silurian- and Ordovician-age sedimentary bedrock, principally limestone and dolomite, capped with lacustrine clays. The underlying bedrock is typically less than 50 feet below the surface of the lake clays for much of the sub-subsection, but is 100 to 200 feet thick where preglacial valleys dissected the bedrock surface; such valleys underlie the present valleys of the Pine and Carp Rivers (Vanlier and Deutsch 1958; Sinclair 1959, 1960).

LANDFORMS: Almost the entire sub-subsection is a broad clay lake plain. A small area of sand lake plain is present in the center of the sub-subsection. Within this small area of sand plain, there is a series of ancient beach ridges and swales, many miles from the present Great Lakes shorelines.

Sandy ground moraine occurs on Sugar and Neebish Islands and on the mainland at the north end of Munuscong Bay.

LAKES AND STREAMS: No lakes. Several rivers, including the Carp, Pine, Waiska, Little Munuscong, and Munuscong, cut deep, narrow valleys across the lake plain.

SOILS: The clay soils are somewhat poorly drained to poorly drained. The flat lake bed becomes more poorly drained closer to the St. Marys River along the eastern edge of the sub-subsection. Soils are generally well drained on the ground moraine of Sugar and Neebish Islands.

PRESETTLEMENT VEGETATION: Somewhat poorly drained to poorly drained clay soils originally supported a hardwood-conifer forest of balsam fir, balsam poplar, hemlock, northern white-cedar, tamarack, trembling aspen, white pine, black spruce, and white spruce (Comer *et al.* 1993a). Northern hardwoods, including sugar maple, beech, American elm, basswood, and yellow birch, were locally common on slightly better drained sites. The extensive poorly drained areas along the St. Marys River were primarily dominated by conifers; large peatlands near Munuscong Bay and Izaak Walton Bay on the St. Marys River were dominated by cedar, spruce, and tamarack.

The poorly drained shorelines of the clay plain support some of the most extensive marshes of Michigan. The emergent marsh zone can be a mile wide, and the wet meadow zone along the shoreline is often another quarter- to half-mile wide.

The sandy ground moraine of Sugar and Neebish Islands supported northern hardwood forests of beech and sugar maple. Poorly drained portions of these ground moraines supported speckled alder-willow swamps.

NATURAL DISTURBANCE: Poor drainage conditions cause widespread windthrow. GLO surveyors noted large windthrows south and west of Sault St. Marie and on the south side of Sugar Island.

PRESENT VEGETATION AND LAND USE: Europeans had already settled at Sault St. Marie when the area was surveyed in 1845. Forests had been cleared for several miles around the settlement. Native American settlements and trails were also present.

In subsequent development, forests were cleared and swamps were drained extensively for agriculture. Swamps near the Great Lakes shoreline have been modified less than those elsewhere in the sub-subsection. Many emergent marshes along the St. Marys River were hayed for marsh hay by creating shallow ditches in the marsh. All these ditches have now been abandoned. A large part of the marsh at the mouth of the Munuscong River has been diked for waterfowl management.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Ranunculus lapponicus* (Lapland buttercup).

RARE ANIMALS: *Alces alces* (moose), *Chlidonias niger* (black tern), *Sterna hirundo* (common tern).

NATURAL AREAS: Michigan Nature Association Preserves: Beaver Dam, Lapland Buttercup, Three Wilderness Islands, Carlton Lake Wetlands, Roach Point; Other: Osborn Preserve.

PUBLIC LAND MANAGERS: Michigan: National Forests: Hiawatha; State Forests: Lake Superior; Environmental Areas: Frog Bay, Roach Point, Pickford, Shingle Bay, Kemps, Rock Island, Duck Lake, Muskrat, Neebish, Gogomain, Hiawatha, Sand Island, Birch Point, Winter, Round Island (Chippewa County), Gem Island, Dike.

CONSERVATION CONCERNS: The wetlands along the St. Marys River are extremely important for waterfowl migration.

SUB-SUBSECTION VIII.1.3. Escanaba/Door Peninsula**; limestone bedrock and sand lake plain, ground moraine; conifer swamps, northern hardwoods forest, coastal marshes.**

DISCUSSION: The primary basis for separating this sub-subsection from the St. Ignace sub-subsection (VIII.1.1) is the milder climate in this sub-subsection. Rocky ground moraine is locally extensive.

ELEVATION: 580 to 1,040 feet (177 to 317 m).

AREA: 1,256 square miles (3,254 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Growing season is approximately 140 days in both sub-subsections in Michigan, but increases to 160 days at the southern edge of VIII.1.3 in Wisconsin (Eichenlaub *et al.* 1990, Hole and Germain 1993). Sub-subsection VIII.1.3 also receives less snowfall than Sub-subsection VIII.1.1, 60 inches and 80 inches respectively. Average precipitation is 30 to 32 inches, almost identical to that of Sub-subsection VIII.1.1. Extreme minimum temperatures are lowest inland, where they can be as cold as -46°F, and highest along the Lake Michigan shoreline, where they are as high as -30°F.

BEDROCK GEOLOGY: The entire sub-subsection is underlain by Silurian- and Ordovician-age sedimentary bedrock, principally limestone and dolomite, but also including less resistant shale and gypsum (Dorr and Eschman 1984, Morey *et al.* 1982). The resistant Niagaran series dolomite and limestone of Silurian age form the Niagaran Escarpment, which is locally exposed as cliffs and flat limestone pavement along the Lake Michigan shoreline of the Stonington, Garden, and Door Peninsulas. Little Bay de Noc and Big Bay de Noc in Michigan and Green Bay in Wisconsin occupy depressions where soft gypsum and shales were eroded, probably by both glacial and lacustrine processes (Sinclair 1960). Devonian limestone, dolomite, and breccia are locally exposed at the southern edge of the sub-subsection. The underlying bedrock is typically less than 50 feet below the surface of the glacial drift (Vanlier and Deutsch 1958; Sinclair 1959, 1960; Vanlier 1963b). Limestone is mined in several places within the sub-subsection.

LANDFORMS: Various landforms of glacial lacustrine origin characterize the sub-subsection, including flat lake bed, deltaic deposits of sand,

parabolic dune fields, and shallow embayments containing transverse dunes. Beach-ridge and swale topography, consisting of dozens of low, linear beach ridges alternating with shallow depressions (swales), commonly forms a narrow 1- to 2-mile-wide band along the shorelines of protected embayments of Lake Michigan.

There are large areas of lacustrine sand deposits that have flat to gently undulating surfaces; regional slope is typically only 8 to 10 feet per mile. On this topography, only a few inches of elevation change can greatly alter drainage conditions. Drainage conditions also depend on depth to underlying bedrock or fine-textured substrate.

Ground moraine is quite extensive on the Door Peninsula in Wisconsin and locally present in Michigan south of Escanaba along the Lake Michigan shoreline and north of the Garden Peninsula. Throughout the sub-subsection, ground-moraine deposits are often quite thin over bedrock; cobbles and boulders of dolomite are common within the sandy loam till. Bedrock is commonly exposed near the shoreline, either as cliff or flat pavement.

Outwash deposits are located near the Lake Michigan shore just northeast of Escanaba. Small barchan dunes (crescent shaped) are scattered on the outwash plain.

LAKES AND STREAMS: Many rivers. The larger include the Menominee, Whitefish, Escanaba, Ford, and Sturgeon, but there are many more small rivers draining the flat outwash and lake plain of Michigan's eastern Upper Peninsula. Where these rivers flow over bedrock, they are typically shallow and broad. Where they flow across sand lake plain, they have steep banks and generally meander considerably, forming numerous oxbow lakes. There are only two large lakes, Indian and Moss.

SOILS: Diverse soils. Lacustrine soils are primarily sands, but the sands are often underlain by lake clays or bedrock within only a few feet of the surface. The sands are generally either excessively drained or poorly drained. Excessively drained sands are on beach ridges or dunes. Poorly drained sands are more common, occupying much of the flat lake plain or depressions between dunes and beach ridges. Soils of the ground moraine are stony, with textures ranging from loamy sands to loams. Where bedrock is near the surface, soils are often calcareous and poorly drained. The most common soil orders here are Alfisols (Boralfs), Histosols, and Entisols (Aquepts), with some Orthods and Aquods (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Extensive swamps of northern white-cedar grew on the poorly drained soils of the lake plain, extending inland several miles from the present shoreline (Albert 1990, Comer *et al.* 1993a). These cedar swamps were interrupted by narrow, low beach ridges, which often supported upland conifer forests of hemlock, white pine, or a mixture of the two. These upland conifer types also occurred locally on narrow beach ridges along the Lake Michigan shoreline. Low broad upland areas of lacustrine sands supported the same upland conifer forests or occasionally, northern hardwood forest dominated by beech and sugar maple. Although cedar was the tree species most commonly referenced by GLO surveyors, other common wetland species included tamarack, balsam fir, [red] maple, [paper] birch, black ash, [black] spruce, hemlock, [trembling] aspen, and balsam poplar. Depressions within the extensive wetlands of the lake plain were often dominated by low productivity tamarack swamps or black spruce swamps.

Along embayments of Lake Michigan were extensive complexes of dunes and swales, where the drier ridges were dominated by forests of white pine or red pine, along with white spruce, balsam fir, and hardwoods. Lower ridges were often dominated by northern white-cedar, as were some of the drier swales. The wetter swales supported emergent marsh or sedge meadow.

Along the sandy shoreline of Lake Michigan, marshes were generally narrow because of severe wave action. The only extensive marshes within the sub-subsection were near Escanaba, at Portage Bay, and in Little Bay de Noc at the mouth of the White River.

Extensive flood-plain forest occurred along the Sturgeon River and along the Menominee River. The flood-plain forest along the Sturgeon River was dominated by silver maple, and it also contained abundant butternut; both of these species are rare in the Upper Peninsula. Most of the flood plains this far north were dominated by conifers, especially northern white-cedar.

Northern hardwood forest of beech and sugar maple grew on ground moraine and on thin soils over limestone bedrock. Where bedrock was exposed at the surface, as on portions of the Garden, Stonington, and Door Peninsulas, open cedar glades were common, and alvar was locally present.

Jack pine barrens, containing scattered red pine, occurred on the outwash sands near Rapid River. GLO surveyors noted large portions of the pine barrens as burned over.

NATURAL DISTURBANCE: Windthrow is the most common type of disturbance. Along the Lake Michigan shoreline between Menominee and Escanaba, 18 windthrows (mostly under a square mile in area) were noted within 1 to 2 miles of the shore by GLO surveyors. Occasionally surveyors noted that windthrows burned later. Windthrows destroyed both upland and wetland forests.

Fires were also noted on pine plains near Native American settlements near Menominee, Escanaba, and Rapid River in Michigan. Other Native American settlements were on the Stonington and Garden Peninsulas, where sugar bushes and gardens were also noted. Indian trails were commonly noted, especially along major rivers and the Lake Michigan shoreline.

The dynamic water level fluctuations of Lake Michigan cause changes in the vegetation of coastal marshes, wet meadows, and swamps. In other parts of the Great Lakes, these water level fluctuations were documented by the original surveyors.

PRESENT VEGETATION AND LAND USE: After European settlement, logging began, first for white and red pines, then for northern white-cedar and hemlock, and finally for hardwoods and pulp. Logging mills were located along many of the rivers near the Lake Michigan shoreline. Most of the sub-subsection remains forested, but the composition of the forests has changed from predominantly conifer to a much greater proportion of hardwoods, both on the uplands and in swamps. The species most affected by logging were white pine, red pine, hemlock, and northern white-cedar. Post-logging fires reduced regeneration of the pines, and severe deer browse has reduced regeneration of hemlock and cedar.

Agricultural land use has been limited to pasturing on the ground moraine and occasionally on small areas of sand lake plain. Few of the wetlands have been greatly altered for agricultural purposes.

Major roads are located along much of this shoreline. Urban development is concentrated along the shoreline; major cities here are Menominee, Escanaba, Gladstone, Rapid River, and Manistique.

RARE PLANT COMMUNITIES: High quality areas of alvar occur on the Garden Peninsula. In both Michigan and Wisconsin, conifer-dominated upland forests are present and have been called boreal forest. These forests also contain many species with a more southerly distribution that are not typically considered boreal. In Wisconsin, cobble beaches, sand dunes, and interdunal wetlands are all restricted to the Door Peninsula. Great Lakes estuaries also occur on the Mink River.

RARE PLANTS: Michigan only: *Amerorchis rotundifolia* (round-leaved orchid), *Iris lacustris* (dwarf lake iris), *Ranunculus lapponicus* (Lapland buttercup), *Solidago houghtonii* (Houghton's goldenrod), and *Sporobolus heterolepis* (prairie dropseed). **Wisconsin only:** *Calamintha arkansana* (low calamint), *Calamovilfa longifolia* (sand reed), *Elymus lanceolatus* ssp. *psammophilus* (thick-spike wheatgrass), *Festuca occidentalis* (western fescue), *Orobanche uniflora* (one-flowered broomrape), *Parnassia parviflora* (small-flowered grass-of-Parnassus), *Solidago ohioensis* (Ohio goldenrod), *Solidago simplex* var. *gillmanii* (dune goldenrod). **Michigan and Wisconsin:** *Asplenium viride* (green spleenwort), *Calypso bulbosa* (Calypso orchid), *Carex richardsonii* (Richardson's sedge), *Cirsium pitcheri* (Pitcher's thistle), *Cypripedium arietinum* (ram's-head lady's-slipper), *Juncus stygius* (moor rush), *Tanacetum huronense* (Lake Huron tansy).

RARE ANIMALS: Michigan only: *Charadrius melodus* (piping plover). **Wisconsin only:** *Somatochlora hineana* (Ohio emerald). **Michigan and Wisconsin:** *Haliaeetus leucocephalus* (bald eagle), *Sterna caspia* (Caspian tern), *Trimerotropis huroniana* (Lake Huron locust), *Chlidonias niger* (black tern), and *Sterna hirundo* (common tern).

NATURAL AREAS: Michigan: Michigan Nature Association Preserves: Two Wilderness Islands, Garden Peninsula, Escanaba River; Proposed Research Natural Area's (Hiawatha NF): Nahma, Sturgeon River. **Wisconsin:** State Natural Areas: Peninsula Park Beech Forest, Peninsula Park White Cedar Forest, The Ridges Sanctuary, Sister Islands, Two Creeks Buried Forest, Seagull Bar, Toft Point, Newport Conifer-Hardwoods, Jackson Harbor Ridges, Mud Lake, Whitefish Dunes, Marshall's Point, Moonlight Bay Bedrock Beach, Coffey Swamp; The Nature Conservancy Preserves: Mink River Estuary.

PUBLIC LAND MANAGERS: Michigan: National Forests: Hiawatha; State Forests: Lake Superior, Escanaba River; State Parks: Fayette, Palms Book, Wells; Environmental Areas: Portage Point, Rapid River, St. Vital Island, Fishdam River, Ford River, Round Island (Delta County), Ogontz River. **Wisconsin:** U.S. Fish and Wildlife Service: Spider, Gravel, Fish Islands; State Parks: Newport, Peninsula, Whitefish Dunes, Rock Island, Potawotami, State Wildlife Areas: Mudlake.

CONSERVATION CONCERNS: In Wisconsin, the sensitive shoreline areas have deservedly been the focus of virtually all protection efforts, while the rich mesic forests of the Door Peninsula interior have been largely destroyed and severely fragmented. Some of the larger remnant forests in Peninsula State Park are currently severely overbrowsed by deer.

Low sand dunes and beach ridges along the shoreline support healthy populations of Pitcher's thistle (federally threatened), a Great Lakes endemic, as well as Lake Huron tansy. Two other Great Lakes endemics are found near the shoreline: dwarf lake iris (federally threatened) is found on calcareous till or sand deposits near the shoreline, and Houghton's goldenrod (federally threatened) grows in moist interdunal swales along the shore.

SUB-SUBSECTION VIII.1.4. Green Bay Till Plain and Lake Plain; **clay loam and silt loam soils on till plain; northern hardwood forests with beech and some hemlock, conifer swamps, riverine marshes.**

DISCUSSION: Sub-subsection VIII.1.4 has been separated from adjacent mapping units (Sub-subsections VIII.1.3 and VIII.3.1) on the basis of its clay soils; the prevalent soil textures in those sub-subsections are loams and sandy loams.

ELEVATION: 580 to 935 feet (177 to 285 m).

AREA: 1,855 square miles (4,808 sq km).

STATES: Wisconsin.

CLIMATE: Growing season is approximately 120 days farthest from Lake Michigan and as long as 180 days near the lake (Hole and Germain 1993). Average minimum temperature is 6 to 10˚F (Wendland *et al.* 1992). Extreme minimum temperature is approximately -30˚F along the Lake Michigan shoreline and closer to -35˚F inland. Annual precipitation is 30 to 32 inches, with 44 to 52 inches of snowfall. Snowfall increases with latitude, but does not appear to be greatly affected by Lake Michigan.

BEDROCK GEOLOGY: The entire sub-subsection is underlain by Silurian- and Ordovician-age sedimentary bedrock, principally limestone and dolomite, but also including less resistant shale and gypsum (Dorr and Eschman 1984, Morey *et al.* 1982). The resistant Niagaran series dolomite and limestone of Silurian age form the Niagaran Escarpment, which underlies this sub-subsection as a broad, flat cuesta from the east side of Green Bay on the Door Peninsula to the eastern shore of Lake Winnebago. The west edge of the sub-subsection is underlain by Ordovician limestone and dolomite. Green Bay occupies a depression where soft gypsum and shales were eroded, probably by both glacial and lacustrine processes (Sinclair 1960).

LANDFORMS: A relatively flat plain. The western edge consists of lacustrine clays, and the remainder is primarily clayey ground and end moraines (Farrand *et al.* 1984).

LAKES AND STREAMS: Major rivers include the Fox and Manitowac. No large inland lakes.

Many drainage ditches have been constructed on the flat lake plain and ground moraine to facilitate farming.

SOILS: The soils are somewhat leached (but not podsolized), red calcareous clays. The primary soils are silty clay loam to clay loam in texture, classified as Typic Hapludalfs (Hole 1976). Slopes range from level to rolling. Gullying, from geological and agricultural erosion, occurs on some of these clay soils. Carbonate materials make up about 30 percent of the soils.

PRESETTLEMENT VEGETATION: The dominant vegetation was northern hardwood forest, dominated by beech and sugar maple, with basswood and some oaks, including red, white, and black. Hemlock was present, but much less prevalent than in Sub-subsections VIII.3.1 to the west and VIII.1.3 to the east. There were several areas of wetland, primarily dominated by northern conifers. Northern white-cedar was common on the lake plain. There was a large area of marsh and wet meadow where the Fox River meets Green Bay as well as extensive areas of conifer swamp along the Green Bay shoreline.

NATURAL DISTURBANCE: Windthrows, noted by the GLO surveyors, were most common near the Lake Michigan shoreline; many were probably the result of storm winds off the lake.

PRESENT VEGETATION AND LAND USE: Approximately 60 percent of the landscape is cropland, 15 percent pasture, and 25 percent woodland and wetland (Hole 1976).

RARE PLANT COMMUNITIES: Sand dunes are found at two locations. There were very localized tallgrass prairie and oak savanna near the Fox River; both have been destroyed by agriculture. Dolomite glade is in northeastern Brown County, and interdunal wetlands are along the Lake Michigan shoreline.

RARE PLANTS: *Cirsium pitcheri* (Pitcher's thistle), *Iris lacustris* (dwarf lake iris).

RARE ANIMALS: None identified to date.

NATURAL AREAS: Cedarburg Bog, Cedar Grove Hawk Research Station, Wilderness Ridge, Maribel Caves, Two Creeks Buried Forest, Fairy Chasm, Kohler Park Dunes, Point Beach Ridges.

PUBLIC LAND MANAGERS: Point Beach State Forest, Kohler-Andrae State Park.

CONSERVATION CONCERNS: Sub-subsection VIII.1.4 is part of a major migratory bird corridor, especially for raptors and waterfowl.

BOUNDARIES: This sub-subsection can be further subdivided into an eastern unit of till plain and a western unit of lake plain.

SUBSECTION VIII.2. Luce**; poorly drained sand lake plain, sandy end moraine, shoreline, and outwash plain; northern hardwood forest, upland conifers, conifer swamps, bogs, patterned peatlands.**

DISCUSSION: The subsection consists of two sub-subsections, both with sandy soils and high lake-effect snowfall.

SUB-SUBSECTIONS: Seney (VIII.2.1) is a broad expanse of poorly drained outwash plain, deltas, and sand lake plain. Grand Marais (VIII.2.2) consists primarily of well-drained outwash, end moraine, and lake plain. (See figure 6.)

ELEVATION: 602 to 1,240 feet (183 to 378 m).

AREA: 3,427 square miles (8,910 sq km).

STATES: Michigan.

CLIMATE: Growing season ranges from 130 days on Lake Superior to less than 100 days in the interior (Eichenlaub *et al.* 1990). The center of the subsection is a frost pocket and has extreme minimum temperatures as cold as -46°F. Minimum temperatures along Lake Superior are as high as -30°F. Average annual precipitation is 32 to 34 inches. Average snowfall ranges from 180 inches along the ridges south of Lake Superior to 80 inches at the southern edge of the subsection.

BEDROCK GEOLOGY: An east-west-trending sandstone escarpment of Cambrian age is exposed in several waterfalls, including

Tahquamenon Falls, Au Train Falls, Miner's Falls, and Laughing Whitefish Falls, and along the Lake Superior shoreline at Pictured Rock National Lakeshore (Dorr and Eschman 1984). Farther inland, there are local bedrock exposures, but most of the surface consists of either glaciofluvial or lacustrine deposits that are as thick as 200 feet (Vanlier 1963a). Farther inland, Ordovician sandstone and dolomite are the underlying bedrock (Reed and Daniels 1987).

LANDFORMS: See sub-subsections.

LAKES AND STREAMS: See sub-subsections.

SOILS: Soils are sands, loamy sands, and in Sub-subsection VIII.2.1, primarily organic soils. See sub-subsections.

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION VIII.2.1. Seney Sand Lake Plain**; very poorly or excessively drained sand lake plain, transverse dune, outwash; shallow, paludified peatlands (many patterned), jack pine barrens, hardwood-conifer and conifer swamp.**

DISCUSSION: This sub-subsection of sand lake plain contains the largest expanses of wetland in the State. Landforms of lacustrine origin typify the sub-subsection.

ELEVATION: 600 to 880 feet (183 to 268 m).

AREA: 1,662 square miles (4,307 sq km).

STATES: Michigan.

CLIMATE: The climate is dominated by lacustrine influences near its margins, but an extreme frost pocket is near the center of the broad wetlands. Growing season ranges from less than 100 days in the center of the frost pocket to approximately 130 days at the northern and southern edges (Albert *et al.* 1986, Eichenlaub 1990). The growing-season heat sum (1,800 degree C-days) is one of the lowest in the State (Albert *et al.* 1986, Denton 1986). Extreme minimum temperature is -46˚F near the center and -36˚F at the north and south edges. Average annual precipitation is 32 to 34 inches. Annual snowfall is between 80 and 160 inches; the greatest amount is in the north nearer Lake Superior, and the least is at the southern edge (Eichenlaub *et al.* 1990).

BEDROCK GEOLOGY: Bedrock is typically covered by 100 to 200 feet of glacial drift, but is near the surface along the western edge. Ordovician- and Silurian-age limestone, dolomite, and other sedimentary rocks of marine or near-shore environments underlie the entire sub-subsection (Sinclair 1959, 1960; Reed and Daniels 1987).

LANDFORMS: Landforms of lacustrine origin. Broad, poorly drained embayments contain beach ridges and depressions (swales), sand spits, transverse sand dunes, and sand bars. Deltaic deposits occur along the northern margins of the embayments, where glacial meltwater streams carried massive amounts of sand into the shallow waters.

LAKES AND STREAMS: Many rivers originate in the wetlands here. All these rivers meander,

creating broad oxbows on the flat landscape. Most of the rivers, including the Manistique, Fox, Driggs, Creighton and Sturgeon, flow to the southeast, perpendicular to the regional bedrock slope.

SOILS: Peats, poorly drained sands, excessively drained sands. Excessively drained sand soils occur on level lake plain, outwash plains, and transverse dune ridges.

PRESETTLEMENT VEGETATION: Marshes, peatlands, and low productivity swamps were the predominant vegetation on the very poorly drained topography, as noted by GLO surveyors (Albert 1990, Comer *et al.* 1993a). Many of the broad wetlands occupy embayments of Glacial Lake Algonquin (10,000 years B.P.), but peat began to accumulate only during the moister, cooler climatic conditions of the last 3,000 to 4,000 years (Futyma 1982). Jack pine dominated the droughtiest outwash plains; red pine, white pine, and bigtooth aspen occupied the seasonally moist lake plains and the transverse dunes (Comer *et al.* 1994).

NATURAL DISTURBANCE: Based on the surveyors' notes, fires occurred regularly on both the extensive peatlands and on the transverse dunes within the peatlands. The fires were probably not extreme on the dunes because of their steep slopes. Beaver floodings were quite common, with several noted within a single peatland.

PRESENT VEGETATION AND LAND USE: Much of the land here is part of either a State or national forest or Wildlife Refuge; land management is primarily for timber or wildlife. The original logging occurred shortly after 1900 for much of the area; white pine and red pine were logged from the uplands, and northern white-cedar was logged from margins of the wetlands.

In the early 20th century, attempts were made to drain and farm parts of the wetlands that are now the Seney National Wildlife Refuge. These attempts failed due to low soil productivity, soil erosion, and the extremely short growing season. During the Seney fire in the 1970's, the peat fire was difficult to extinguish along the drainage ditches, where the peat was dry enough to smoulder and burn to great depths.

RARE PLANT COMMUNITIES: Almost all the State's patterned peatlands occur here.

RARE PLANTS: *Amerorchis rotundifolia* (round-leaved orchid), *Danthonia compressa* (flat oatgrass), *Eleocharis nitida* (slender spike-rush), *Juncus vaseyi* (Vasey's rush), *Oryzopsis canadensis* (Canada rice-grass), *Petasites sagittatus* (sweet coltsfoot), *Vaccinium cespitosum* (dwarf bilberry).

RARE ANIMALS: *Coturnicops noveboracensis* (yellow rail).

NATURAL AREAS: Research Natural Areas (Hiawatha National Forest): Northern Hardwoods, Betchler Tamarack Swamp (proposed), Shingleton Bog (proposed); Wilderness Areas: Delirium (Hiawatha NF); Michigan Nature Association Preserves: Huntington Memorial, Walker Memorial, Cedar Lake.

PUBLIC LAND MANAGERS: National Forests: Hiawatha; National Wildlife Refuges: Seney; State Forests: Superior; State Environmental Areas: Duck Lake, Rock Island.

CONSERVATION CONCERNS: The peatlands of the sub-subsection are among the largest and least developed wetlands of the State. At present, there appears to be little threat of development, but some have proposed drainage for planting of hybrid larch. Parts of the Seney National Wildlife Area have been hydrologically altered in the past, and there are proposals to dynamite potholes into some of the peatlands of the sub-subsection to create areas for waterfowl breeding. Many of the large patterned peatlands have been inadequately surveyed for biotic diversity. The large, shallow peatlands are breeding habitat for sandhill cranes.

BOUNDARIES: This sub-subsection is further divided into several finer mapping units in the Hiawatha National Forest's Ecological Classification System.

Figure 24.—*Sub-subsection VIII.2.1: Indian River Pines, Schoolcraft County, Michigan. Poor drainage characterizes much of the sand lake plain and outwash of this sub-subsection. Here, red pine and white pine form small groves on islands of drier outwash surrounded by sedge-dominated wet meadows and shallow peatlands. Many of the wetlands are quite young; they were dominated by upland conifers until 3,000 to 4,000 years ago, when cooler, wetter climatic conditions resulted in the transformation of upland forests to wetlands. Photo by D. Albert.*

SUB-SUBSECTION VIII.2.2. Grand Marais Sandy End Moraine and Outwash**; sandy end-moraine ridges and outwash aprons, Lake Superior shoreline features, transverse dunes, sand spits; white pine-red pine forest, jack pine barrens, red pine forest, northern hardwood forest, and patterned peatlands.**

DISCUSSION: Sandy ridges of end moraine and pitted outwash are characteristic of the sub-subsection. Lacustrine deposits of glacial and postglacial origin are also located along the northeastern edge.

ELEVATION: 602 to 1,300 feet (184 to 396 m).

AREA: 1,765 square miles (4,562 sq km).

STATES: Michigan.

CLIMATE: Average growing season ranges from 140 days very close to Lake Superior to less than 100 days farther inland (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -30˚F along Lake Superior to -40˚F or less at the southern inland edge. Average annual precipitation is relatively uniform, between 32 and 34 inches. Annual snowfall is as high as 180 inches on the uplands near Lake Superior, decreasing to approximately 100 inches in the south.

BEDROCK GEOLOGY: An east-west-trending sandstone escarpment of Cambrian age is exposed in several waterfalls, including Tahquamenon Falls, Au Train Falls, Miner's Falls, and Laughing Whitefish Falls, and along the Lake Superior shoreline at Pictured Rocks National Lakeshore (Dorr and Eschman 1984,

Reed and Daniels 1987). Farther inland, Ordovician sandstone and dolomite are the underlying bedrock (Reed and Daniels 1987). Bedrock is locally exposed, but drift can be at least 200 feet thick, both on the outwash plains and on the moraine ridges (Vanlier 1963a).

LANDFORMS: Sandy ridges of end moraine and pitted outwash. Lacustrine deposits of glacial and postglacial origin are also located along the northeastern edge. The recent geomorphological interpretation is that many of the end moraines (as originally interpreted by Leverett 1929) are actually heads of outwash and related stagnation landforms (Blewett and Rieck 1987).

Lacustrine deposits within the sub-subsection can be broken into two major types: the droughty sand dunes and beach ridge deposits and the poorly and very poorly drained glacial lacustrine deposits. Along the Lake Superior shoreline, sand dunes, sand spits, and beach ridges form a broad zone characterized by vast expanses of excessively drained sand soils, unlike most shorelines of the Great Lakes.

The Grand Sable Dunes, west of the town of Grand Marais, are large, steep dunes perched upon till. The dunes are active, supporting only local areas of forest. At their protected east end, they support a small area of northern hardwood forest. A few small pockets of jack pine also persist within the dunes.

The poorly drained deposits are concentrated in northern Luce County. These are of the same age and support vegetation similar to that of the more extensive peatlands of Sub-subsection VIII.2.1. An extensive complex of sandspits at Whitefish Point in northwestern Chippewa County produced hundreds of alternating swales and sandspits.

Outwash plains are concentrated along the southern edge of the sub-subsection, and a relatively small area of poorly drained outwash is at the extreme west edge. Along the shoreline, outwash is restricted to areas west of Munising and west of Grand Marais.

Most of the moraine ridges and pitted outwash have well-drained, sandy soils. Kettles within the pitted outwash and moraines contain bogs with thick deposits of sphagnum peat. At the far western edge of the sub-subsection, where sandstone bedrock is only thinly covered by till, soils are moderately well drained. The soils are classified as Histosols and Entisols (Aquepts), with some Orthods and Aquods (USDA Soil Conservation Service 1967).

LAKES AND STREAMS: Numerous kettle lakes in local areas of the pitted outwash.

SOILS: Most of the moraine ridges and pitted outwash have well-drained, sandy soils.

PRESETTLEMENT VEGETATION: Sandy lake plain along Lake Superior supported several wetland and upland communities. Emergent marshes, bogs, and speckled alder-willow swamps were common in the swales associated with the shoreline and small lakes immediately inland.

Peatlands were dominated by stunted black spruce, northern white-cedar, and tamarack; narrow beach ridges within the peatlands were dominated by white and red pine (Comer *et al.* 1993a). Excessively drained, fire-prone portions of the lake plain supported forests dominated by jack pine and red pine-jack pine. Jack pine-dominated forests were extensive along the shoreline between Grand Marais and Whitefish Point. Upland portions of the lake plain that were better protected from wildfires were extensive along the shoreline west of Grand Marais. These areas supported forests dominated by hemlock, northern hardwoods, and hemlock-white pine.

Extensive complexes of beach ridges and swales occurred on the sandy lake plain along Lake Superior. Most examples were excessively drained throughout and supported jack pine and red pine. However, the complex at Tahquamenon Bay was mostly spruce and tamarack-dominated swamp, and the swales at Au Train and Whitefish Point included tamarack swamp and shrub swamp.

The Grand Sable Dunes were active, supporting only local areas of forests. At their protected east end, they supported a small area of northern hardwood forest and a few, small pockets of jack pine.

GLO surveyors noted extensive emergent marshes near the mouth of the Au Train River and at the southeast end of Grand Island. The

Au Train marsh is best described as a fresh water estuary or drowned river mouth created when dunes restricted the river's flow into Lake Superior.

Small areas of clay lake plain at Tahquamenon Bay supported spruce and tamarack-dominated swamps. Narrow strips of clay lake plain along the shore in Luce County supported hemlock-white pine forests.

Coarse-textured moraines, most common south of Tahquamenon and Pendills Bays, supported northern hardwoods, often with significant amounts of hemlock. Forests of red pine and white pine and red pine "openings" were also common on these moraines; and small swamps dominated by northern white-cedar, tamarack, and spruce were also found in depressions on these moraines. On somewhat poorly drained tills, where bedrock is near the surface, hemlock and white pine were dominant species. Small cedar and tamarack-dominated swamps also occurred on the end moraines east of Munising.

Poorly drained outwash was uncommon in this sub-subsection. Where it did occur, just west of Munising, there was cedar-dominated swamp. Well-drained outwash supported northern hardwood forest. Somewhat poorly drained outwash near the edges of wetlands often supported hemlock. Droughty, flat outwash plains supported open jack pine barrens, or where conditions were not quite so fire prone, forests of jack pine, red pine, and occasionally, white pine.

NATURAL DISTURBANCE: GLO surveyors mentioned fires in the pineries on the sand ridges between Whitefish Point and Grand Marais and at the mouth of the Tahquamenon River. A large windthrow was noted in the cedar-tamarack swamps near the Lake Superior shoreline.

PRESENT VEGETATION AND LAND USE: Surveyors noted several Native American trails, fields, and sugar camps west of Tahquamenon Bay and near Munising. Early European settlements were established on Grand Island and west of Munising at the time of the surveys.

The dominant use of this sub-subsection has been for commercial timber production. Urban development has been limited mainly to the Munising area. Although most of the wetlands in this region persist, they were probably altered by logging and post-logging fires. Roads and small dams have had the most significant impact on wetland hydrology.

The upland forests have also been greatly affected by logging-era activities. On the droughty Raco Plains, jack pine dominance expanded, but areas of white and red pine have had poor regeneration. The Kingston Plains were originally dominated by forests of red and white pine, and northern hardwoods with white pine. On the areas of these plains most severely burned by post-logging fires, the only existing vegetation consists of lichens, sedges, and scattered understory black cherries. Subsequently, parts of both plains have been planted to red pine or jack pine.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Botrychium acuminatum* (acute-leaved moonwort), *Botrychium campestre* (prairie moonwort), *Botrychium hesperium* (western moonwort), *Cirsium pitcheri* (Pitcher's thistle), *Elymus mollis* (American dune wild-rye), *Empetrum nigrum* (black crowberry), *Littorella americana* (American shore-grass), *Potamogeton confervoides* (alga pondweed).

RARE ANIMALS: *Charadrius melodus* (piping plover), *Falco peregrinus* (Peregrine falcon), *Gavia immer* (common loon), *Haliaeetus leucocephalus* (bald eagle), *Lycaeides idas nobokovi* (northern blue), *Martes americana* (marten), *Pandion haliaeetus* (osprey), *Sterna hirundo* (common tern), *Trimerotropis huroniana* (secretive locust).

NATURAL AREAS: Research Natural Areas: Betsy Lake (State), Betsy Lake River (State), Grand Island (Hiawatha NF), Au Train Gorge (proposed, Hiawatha NF); Wilderness Areas: Rock River Canyon (Hiawatha NF); State Scenic Sites: Wagner Falls; The Nature Conservancy Preserves: McMahon Lake, Swamp Lakes; Michigan Nature Association Preserves: Lake Superior, Twin Waterfalls; Other: Whitefish Point Bird Observatory.

PUBLIC LAND MANAGERS: National Park Service: Pictured Rocks National Lakeshore, including Grand Sable Dunes, Grand Island; National Forests: Hiawatha; State Forests: Lake Superior; State Parks: Tahquamenon Falls, Muskallonge Lake; State Environmental Areas: Tahquamenon Island, Williams Island.

CONSERVATION CONCERNS: Parts of the Lake Superior shoreline support some of the most extensive natural stands of red pine in the State; none of these red pines have special designation. Two areas of wetland within the sub-subsection are being protected: McMahon Lakes patterned peatland and the extensive shallow peatlands surrounding Betsy Lake. Old-growth northern hardwoods and some white pine are protected within the Tahquamenon Falls State Park. Whitefish Point on Lake Superior is a famous migratory route for hawks, owls, and other birds. The Grand Sable Dunes and coastal sandstone cliffs of the Pictured Rocks National Lakeshore are protected.

Protection should be considered for some areas of the "pine stump plains" for scenic and educational value. Identification of potential future natural areas where white pine is successfully regenerating should also be considered; our present natural areas of white pine are overmature stands that may not survive long into the future.

BOUNDARIES: The Hiawatha National Forest's Ecological Classification System further subdivides this sub-subsection into several finer mapping units.

SUBSECTION VIII.3. Dickinson**; till plain, poorly drained sandy outwash, sandstone bedrock and high, sandy ridges; northern hardwood forest, conifer swamp.**

DISCUSSION: This subsection is transitional between the low elevation lake plain and outwash of this section (Section VIII) and the steeper, higher elevation bedrock ridges and moraines of Section IX.

SUB-SUBSECTIONS: Northern Lake Michigan (Hermanville) Till Plain (VIII.3.1), a loamy till plain over limestone bedrock; Gwinn (VIII.3.2), a broad, poorly drained outwash plain; and Deerton (VIII.3.3), broad ridges of thin soil over sandstone and steep ridges of deep sand. (See figures 4 and 6.)

ELEVATION: 602 to 1,300 feet (183 to 396 m).

AREA: 4,385 square miles (11,366 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Temperature is moderated by Lake Michigan. In Wisconsin, the growing season is nearly 150 days along Lake Michigan, but only 120 days at the west edge of the subsection (Hole and Germain 1994). To the north, in Michigan, the growing season can be shorter than 100 days (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from about -40˚F inland to -30˚F along the Lake Superior shoreline. At the southern edge of the subsection, snowfall is relatively light, 60 to 80 inches annually in Michigan (Eichenlaub *et al.* 1990) and 40 to 60 inches in Wisconsin (Wisconsin Statistical Reporting Service 1967); to the north along Lake Superior, snowfall is as high as 140 inches. Total annual precipitation is relatively uniform, from 30 to 34 inches.

BEDROCK GEOLOGY: Surface deposits of glacial drift reflect the local bedrock from which the till was derived. The bedrock in the northern third of Michigan is Cambrian sandstone, and bedrock in the remainder of Michigan and Wisconsin is Paleozoic (Ordovician) limestone and dolomite. Bedrock is generally within 40 feet of the surface in Michigan (Vanlier 1963b, Sinclair 1960), probably at least partially accounting for the high percentage of wetland within the subsection.

LANDFORMS: See sub-subsections.

LAKES AND STREAMS: See sub-subsections.

SOILS: Soils are classified as moderately sloping Haplorthods plus Fragiorthods and gently or moderately sloping Psammaquents plus Sideraquods and Histosols (USDA Soil Conservation Service 1967). See sub-subsections.

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

SUB-SUBSECTION VIII.3.1. Northern Lake Michigan (Hermanville) Till Plain**; sandy and loamy ground moraine, drumlin fields; northern hardwood forest (with large amounts of hemlock and northern white-cedar), northern white-cedar swamp, hardwood-conifer swamp.**

DISCUSSION: The topography of the sub-subsection consists of a broad plain of loamy ground moraine. Soils are rocky, and limestone bedrock is generally less than 50 feet below the surface. Drumlin ridges, trending northeast-southwest, characterize most of the sub-subsection in Michigan; but they are uncommon in Wisconsin, where the landscape consists of a gently sloping till plain.

ELEVATION: 580 to 1,250 feet (177 to 381 m).

AREA: 3,880 square miles (10,057 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: The temperature is moderated by Lake Michigan. In Wisconsin, the growing season is nearly 150 days along Lake Michigan, but only 120 days at the west edge of the sub-subsection (Hole and Germain 1994). In Michigan, the growing season ranges from 140 days in the south, to shorter than 100 days in the north (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -32˚F in the south, near Lake Michigan to -40˚F in the north, farther inland. Influence of the Great Lakes is less here than in the rest of the subsection; snowfall is relatively light, 60 to 80 inches annually in Michigan (Eichenlaub *et al.* 1990) and 40 to 60 inches in Wisconsin (Wisconsin Statistical Reporting Service 1967). Average annual precipitation is relatively uniform, from 28 to 32 inches.

BEDROCK GEOLOGY: Paleozoic limestone and dolomite are generally within 30 feet of the surface, accounting for the rocky nature of the glacial drift and also the nutrient-rich, sandy loam soils (Vanlier 1963b, Sinclair 1960). Surface deposits of glacial drift reflect the local bedrock from which the till was derived; the bedrock in the northern third of Michigan is Cambrian sandstone, and bedrock in the remainder of Michigan and Wisconsin is limestone and dolomite. Bedrock close to the surface in Michigan accounts for the high percentage of wetland within the sub-subsection.

LANDFORMS: A broad till plain (ground moraine). In Michigan, drumlins oriented northeast-southwest cover much of the plain, but there are few drumlins on the undulating till plain in Wisconsin. Drumlin ridges are typically one-eighth to one-fourth mile wide, less than a mile long, and 20 to 60 feet high (Albert *et al.* 1986). The highest drumlins are less than 100 feet high. Wetlands are extensive throughout the sub-subsection, but they have been more extensively drained for agriculture to the south in Wisconsin than elsewhere.

LAKES AND STREAMS: A few small, linear lakes, trending southwest-northeast; many large, shallow wetlands also trending southwest-northeast. Many small rivers and creeks drain the numerous linear wetlands of the sub-subsection. Large rivers: Oconto, Peshtigo, and Menominee.

SOILS: Dominant soils are rocky, podzolized, pink sandy loams. Peat and muck soils are common. Soils on the drumlins are generally well to moderately well drained; but some of the smaller, more gently sloping drumlins can have poorly drained soils (Albert 1990). Soils are classified primarily as Spodosols and Alfisols

(Hole 1976). In Wisconsin, Typic Hapludalfs are common; farther north in Michigan, Haplorthods and Fragiorthods are predominant (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: On the loamy drumlins and undulating ground moraine were northern hardwood forests of sugar maple, beech, hemlock, northern white-cedar, and yellow birch (Albert 1990). Hemlock and white pine were much more common here than on the clay plain of Sub-subsection VIII.1.4 to the southeast. In Michigan, hemlock and occasionally northern white-cedar formed upland stands. Small drumlins within wetlands were often dominated by either hemlock, white pine, or a mix of the two.

In Michigan, wetlands covered all but the drumlin ridges, accounting for 30 to 70 percent of the land surface. A cross section of the flat plain between the drumlins had northern white-cedar and tamarack at the margins of the drumlins (on poorly drained mineral soil or shallow organic soils) and black spruce and open bog or wet meadow at the center of the plain (on very poorly drained peats or mucks).

At the northern edge of the sub-subsection in Michigan, where the texture of the drumlin ridges was sand, the dominant vegetation was originally a mixed red, jack, and white-pine forest. Logging followed by fire converted most pine forests to bigtooth aspen.

NATURAL DISTURBANCE: Windthrow was common, both in Michigan and Wisconsin, occurring both on the isolated drumlin ridges and within the vast wetlands (Comer *et al.* 1993a, Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: Early logging of white pine occurred in the sub-subsection; later, agriculture predominated. Until the early 1980's, pasture was the primary agricultural use, but hybrid corn is now being planted on many uplands.

RARE NATURAL COMMUNITIES: None identified to date.

RARE PLANTS: Michigan and Wisconsin: *Ranunculus cymbalaria* (seaside crowfoot). **Michigan only:** *Danthonia intermedia* (wild oatgrass), *Linum sulcatum* (furrowed flax). **Wisconsin only:** *Carex formosa* (handsome sedge), *Trillium nivale* (snow trillium).

RARE ANIMALS: Michigan and Wisconsin: *Alces alces* (moose). **Wisconsin only:** *Ophiogomphus howei* (pygmy snaketail), *Acipenser fulverscens* (lake sturgeon).

NATURAL AREAS: Michigan: Michigan Nature Association Preserves: Daubendiek Memorial (Escanaba River alvar). **Wisconsin:** State Natural Areas: Poppy's Rock, Tellock's Hill Wood, Mukwa Bottomland Forest, Charles Pond, Hortonville Bog, Bloch Oxbow, Shaky Lake.

PUBLIC LAND MANAGERS: Michigan: State Forests: Escanaba River, Copper Country; National Forests: Ottawa, Upper Peninsula Experimental Forest. **Wisconsin:** State Wildlife Areas: Green Bay Shores, Navarino.

CONSERVATION CONCERNS: Very little biological survey has been done within the sub-subsection. The calcareous substrate should provide habitat similar to that found along the Great Lakes shorelines, but there are few or no records of many of the threatened plants one would expect in such habitats. This sub-subsection is considered very important to the deer herd of northern Michigan, due to the excellent juxtaposition of upland and wetland conifers for winter cover and food. Commercial forestry logging practices destroyed most of the mature upland hemlock stands during the 1980's, causing public concern. The logging of mature conifers may have also been detrimental to migratory song birds, especially some of the warblers. The large amounts of remote conifer swamp in the northern part of the sub-subsection may provide significant habitat for large mammals and migratory song birds.

SUB-SUBSECTION VIII.3.2. Gwinn**; poorly drained and excessively drained sandy outwash; conifer swamp, jack pine barrens.**

DISCUSSION: This small sub-subsection consists primarily of a poorly drained, broad outwash plain, but also includes areas of droughty outwash.

ELEVATION: 1,030 to 1,240 feet (314 to 378 m).

AREA: 277 square miles (719 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: See subsection.

LANDFORM: A large outwash plain. In the north, the outwash is locally quite thin over bedrock. Near Gwinn, there are many kettle lakes and depressions, some containing ponds and bog vegetation. Farther to the south, the outwash slopes gradually to the southeast.

LAKES AND STREAMS: No lakes on the poorly drained outwash; several small kettle lakes on the pitted outwash near Gwinn. The Escanaba River flows through the wetland.

SOILS: The southern part of the sub-subsection has thick, acidic, organic soils over sand or sandy loam. The northern part has excessively drained sand soils. Bedrock is exposed at the margins of the outwash plain in the west.

PRESETTLEMENT VEGETATION: The extensive conifer swamps contained abundant northern white-cedar at the upland margins, with increased amounts of black spruce and tamarack dominant in the wetland interior. Swamp hardwoods included balsam poplar, red maple, paper birch, and black ash.

The excessively drained outwash supported open stands of jack pine. White pine and red pine, along with some northern hardwoods, were located on steeply sloping channels on the outwash. White pine and hemlock stands were locally dominant on the margins of kettle lakes.

NATURAL DISTURBANCE: Windthrow and fire, as mentioned by GLO surveyors.

PRESENT VEGETATION AND LAND USE: The wetlands remain dominated by conifer swamp. Jack pine remains the dominant vegetation on the droughty outwash. White pine and hemlock remain locally among the kettle lakes, but many of these stands were logged and replaced by trembling aspen and paper birch.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date; little biological survey done.

RARE ANIMALS: None identified to date; little biological survey done.

NATURAL AREAS: None to date.

PUBLIC LAND MANAGERS: State Forests: Lake Superior, Escanaba River.

CONSERVATION CONCERNS:

SUB-SUBSECTION VIII.3.3. Deerton**; sandstone bedrock and high sandy ridges; northern hardwood forest, conifer swamp.**

DISCUSSION: This small sub-subsection consists of two distinctive areas of sand ridges: the first is an area of steep, highly dissected sand hills, and the second is an area of broad bedrock-cored ridges.

ELEVATION: 602 to 1,300 feet (185 to 395 m).

AREA: 228 square miles (590 sq km).

STATES: Michigan.

CLIMATE: Minimum temperatures are moderated along Lake Superior, ranging from -28 to -32˚F; but they are -38˚F at the inland edge.

Growing season ranges from 140 days along Lake Superior to less than 100 days along the inland margin. Average precipitation is 32 to 34 inches, and annual snowfall ranges from 120 to 140 inches.

BEDROCK GEOLOGY: The bedrock knobs along the eastern edge are 100 to 200 feet high and have steep sides and relatively flat tops. Exposed at the surface or underlying the glacial drift are Cambrian-age Munising and Jacobsville sandstones (Dorr and Eschman 1984, Hamblin 1958). Most of the bedrock is covered with a veneer of sand or rocky till. However, bedrock is occasionally exposed in roadcuts, or more dramatically, in steep ravines, such as the one at Laughing Whitefish Falls.

LANDFORMS: The eastern part of the sub-subsection has large, rounded, sandstone knobs typically covered with a mantle of sandy glacial drift. Drainage conditions, which range from well to poorly drained, are poor where bedrock is near the surface. The western part has irregular, steep sand ridges that have been deeply eroded by postglacial streams so that steep stream valleys, only 300 to 400 feet wide, are up to 150 feet deep.

Along the Lake Superior shoreline, at the western edge of the sub-subsection, there is also a narrow band of outwash and sand lake plain. The lake plain consists of a broad complex of low beach ridges and adjacent swales, extending more than a mile inland.

LAKES AND STREAMS: Only two lakes, Deer Lake and Howe Lake; both in the east where bedrock is near the surface. Several streams originate in this sub-subsection, including the Rock, Laughing Whitefish, Sand, and Chocolay Rivers. Waterfalls and rapids occur in the east. The streams flowing off the steep sand ridges in the west are small, but have eroded steep ravines.

SOILS: Where glacial drift is thick, as in the west, soils are well drained; where drift is thin, as in the east, drainage is poor, and large swampy areas occur. The drift is very rocky. West of Munising, large boulders, several feet in diameter, are common on the surface.

The soils on the lake plain and outwash are sands. In the complex of dunes and swales, both the dunes and swales are prone to drought.

PRESETTLEMENT VEGETATION: Cedar, spruce, and hemlock dominated many of the small swamps associated with these thin soils over bedrock. Hemlock was especially common on many of the poorly drained bedrock ridgetops and in the steeper ravines. Well-drained sand ridges were occupied by northern hardwoods forests of sugar maple, hemlock, yellow birch, and white pine. Beech was generally absent from the steep ridges.

The long, narrow complex of beach ridges and swales in the west along Lake Superior mostly had dry swales dominated by red pine and jack pine. Inland from these complexes, however, there were extensive swamps of black ash, alder, elm, and northern white-cedar along the Chocolay River.

The western extreme of this sub-subsection included an outwash plain that supported forests of jack pine and red pine, mixed with aspen.

NATURAL DISTURBANCE: No major natural disturbances recorded.

PRESENT VEGETATION AND LAND USE: The dominant land use in this sub-subsection has included logging and, more recently, recreation and intensive residential development, especially along the shoreline.

The impact of logging-era activities probably decreased the relative dominance of hemlock and white pine in upland forests. Several small rivers were dammed, affecting wetlands in their drainage. Urban development and road construction along the shoreline have significantly altered upland and wetland vegetation in the area.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: The Nature Conservancy Preserves: Laughing Whitefish Lake.

PUBLIC LAND MANAGERS: State Forests: Escanaba River, Lake Superior; State Scenic Sites: Laughing Whitefish Falls; National Forests: Hiawatha.

CONSERVATION CONCERNS:

SECTION IX. NORTHERN CONTINENTAL MICHIGAN, WISCONSIN, AND MINNESOTA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; Precambrian Shield bedrock, late Wisconsinan-age glaciated landscape; northern hardwood forest, white pine-red pine forest, jack pine barrens, hardwood-conifer and conifer swamp, bog.**

SUBSECTION IX.1. Spread Eagle-Dunbar Barrens**; Precambrian bedrock knobs surrounded by outwash, some sandy ground moraine; jack pine barrens, white pine-red pine forest, balds.**

DISCUSSION: The topography of the subsection consists of steep bedrock knobs, which rise 200 feet or more from the surrounding outwash plains. Jack pine barrens and white pine-red pine forests grow on both the shallow soils of the bedrock knobs and on the broad outwash plains.

SUB-SUBSECTIONS: None.

ELEVATION: 670 to 1,970 feet (204 to 600 m).

AREA: 2,065 square miles (5,353 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Intermediate between the lake-moderated Subsection VIII.3 and more continental Subsection IX.3. Average annual precipitation is 28 to 32 inches. Annual snowfall is 52 to 80 inches; snowfall is approximately 70 to 80 inches north of the Wisconsin/Michigan boundary, less than 70 inches south of the boundary, and continuously decreasing to the south (Wendland *et al.* 1992, Eichenlaub *et al.* 1990, Wisconsin Statistical Reporting Service 1967). Growing season ranges from 100 to 130 days, increasing to the east closer to Lake Michigan. Extreme minimum temperature ranges from -35˚F to -45˚F.

BEDROCK GEOLOGY: Although much of the subsection is blanketed with outwash sands and till, there are many exposed bedrock knobs of Precambrian bedrock. In Wisconsin, these are primarily basalts and rhyolites, but also granites (Ostrom 1981); in Michigan they are granite and quartzite knobs, including iron-bearing rocks of the Vulcan Formation of the Menominee Range (Dorr and Eschman 1984, Cannon 1986). Other bedrock types include slate, metagraywacke, greenstone, and amphibolite (Morey *et al.* 1982).

LANDFORMS: Bedrock knobs surrounded by extensive outwash plains. Some of the outwash plains are pitted, containing many ice-block depressions, which frequently contain wetlands. Steep end-moraine ridges are common along the Michigan side of the Menominee River, and inclusions of sandy ground moraine and end moraine are in both Wisconsin and Michigan.

Steep, rounded bedrock knobs rise 200 feet or more from the surrounding outwash plain and smaller ground-moraine hills. The elevation of the ridges increases to the south, from 1,530 feet in southern Michigan to 1,970 feet at the southern edge of the subsection in Wisconsin. In Michigan, many of the ridges are sand capped, but both the shape of the ridges and localized bedrock outcrops indicate that all the ridges have bedrock cores.

The outwash plains of the subsection are extensive, especially along the Menominee River.

LAKES AND STREAMS: Many kettle lakes within the pitted outwash plains, both in Michigan and Wisconsin. Large rivers flowing across the outwash include the Paint, Michigamme, Brule, and Menominee.

SOILS: Droughty outwash sands, thin sandy soils on bedrock, sandy loams and loamy sands on ground moraine and end moraine. The plains are excessively well drained in most areas. Depressions in the outwash contain peat deposits.

PRESETTLEMENT VEGETATION: The excessively well drained outwash plains supported jack pine and northern pin oak barrens. Depressions in the outwash contained either depauperate bog-like wetlands or wet meadows. Bedrock knobs and thin soils supported red pine, white pine, jack pine, bigtooth aspen, and red oak. Where the knobs are covered with sandy till, northern hardwoods with white pine dominated.

NATURAL DISTURBANCE: Fires common on outwash plains and bedrock knobs (Finley 1976).

PRESENT VEGETATION AND LAND USE: Iron was mined within the subsection, but all the mines have now been abandoned. The pineries were logged at the turn of the century, and jack pine, aspen, and paper birch are presently harvested for pulp.

Aspen and paper birch presently dominate many of the sites originally dominated by red pine and white pine. Jack pine remains dominant on the outwash plains.

RARE PLANT COMMUNITIES: Several large jack pine barrens, concentrated near the Menominee River.

RARE PLANTS: Michigan only: *Asclepias ovalifolia* (dwarf milkweed), *Camptosorus rhizophyllus* (walking fern), *Cystopteris laurentiana* (Laurentian fragile fern), *Pellaea atropurpurea* (purple cliff-brake), *Woodsia obtusa* (blunt-lobed woodsia). **Michigan and Wisconsin:** *Amerorchis rotundifolia* (round-leaved orchis), *Arabis missouriensis* var. *deamii* (Missouri rock cress), *Cypripedium arietinum* (ram's head lady's-slipper), *Dryopteris expansa* (expanded woodfern), *Vaccinium cespitosum* (dwarf bilberry). **Wisconsin only:** *Carex backii* (Rocky Mountain sedge), *Carex gynocrates* (northern bog sedge).

RARE ANIMALS: Michigan and Wisconsin: *Erebia discoidalis* (red disked alpine), *Lycaeides idas nabokovi* (northern blue butterfly).

NATURAL AREAS: Michigan: State Natural Areas: Shakey Lakes Barrens (proposed); Michigan Nature Association Preserves: Rock Ridge Plant Preserve. **Wisconsin:** State Natural Areas: Miscauno Cedar Swamp, Dunbar Barrens.

PUBLIC LAND MANAGERS: Michigan: State Forests: Copper Country, Escanaba River. **Wisconsin:** National Forests: Nicolet.

CONSERVATION CONCERNS: The vegetation of this subsection has not been extensively surveyed. Further surveys of the area could possibly locate other rare species typically found growing on bedrock. Much of the Michigan part of the subsection is in State forest. Parts of the jack pine barrens of both States are being managed with fire, both for game and non-game species.

BOUNDARIES: The eastern boundary of the subsection in Wisconsin is based upon the boundary between ground moraine and pitted outwash, as shown on the Glacial Deposits of Wisconsin Map (Land Resources Analysis Program 1976). This boundary agrees relatively well with the distribution of white and red pine forest and jack pine barrens, but there are also some large wetlands along this boundary. The boundary between this subsection and Subsection VIII.3.1 to the east is also based on my interpretation of Hole's (1968) soils map; Hole maps outwash soils (H1-6) within the subsection. The modifications along the east edge are discussed within Sub-subsection VIII.3.1. Subsection IX.1 was extended to the south to include sandy outwash deposits dominated by either jack pine barrens or white pine-red pine forest.

The western boundary is less concise, but includes all of the large ridges with exposed bedrock and also agrees closely with the distribution of pine-dominated uplands. This boundary was modified at the northern edge to reflect Clayton's treatment of Florence County (1986). Bedrock was at or near the surface within Subsection IX.1, while loess-covered till was at the surface in Sub-subsection IX.3.1 to the west.

SUBSECTION IX.2. Michigamme Highland**; Precambrian granitic and sandstone bedrock knobs, rocky ground moraine, bedrock lakes, localized outwash plains; northern hardwood forest, white pine-red pine-red oak on bedrock, balds, localized jack pine barrens.**

DISCUSSION: Subsection IX.2 is defined by the uplands of exposed Precambrian bedrock. Elevations rise rapidly from Lake Superior at 602 feet to 1,980 feet at Mount Curwood, the highest point in Michigan (Albert *et al.* 1986).

ELEVATION: 602 to 1,980 feet (184 to 604 m).

AREA: 1,182 square miles (3,061 sq km).

STATES: Michigan.

CLIMATE: Continental; extreme snowfall along the Lake Superior shoreline, extremely cold winters. Growing season ranges from 75 days in the interior to 150 days along the Lake Superior coast; most of the variation occurs within 10 to 15 miles of the coast (Albert *et al.* 1986, Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -28˚F along the coast to -46˚F inland (Eichenlaub *et al.* 1990). Snowfall is heaviest inland, averaging 200 inches, and is least along the coast, averaging 120 to 140 inches. Average annual precipitation is 32 to 36 inches; the heaviest precipitation falls at high elevations inland. The extreme climatic gradient from the Lake Superior shoreline to the inland parts of the subsection has an influence on the biota. One example of this is the presence of scattered American beech near the shoreline, but not further inland.

BEDROCK GEOLOGY: Large areas of exposed Precambrian-age bedrock, consisting of diverse types of metamorphic, igneous, and sedimentary bedrock, including sandstone and shale, gneiss, amphibole, slate, metagraywacke, quartzite, mafic volcanic rocks, and iron formation (Morey *et al.* 1982). The iron formations were once heavily mined in the Michigamme Range, but most mines are no longer operating.

LANDFORMS: Although bedrock generally controls topography, the character of the topography is variable. In some areas, the terrain is a mosaic of low rocky ridges less than 50 feet high, with many small lakes and swamps (Albert *et al.* 1986). In other areas, like the Huron Mountains, large, exposed ridges of granite or sandstone can be 500 to 800 feet high.

There are local areas of sandy till deposits. These can be extremely steep, as between the Yellow Dog plain and Lake Superior. Two large outwash plains occur within the subsection, the Yellow Dog and the Mulligan plains, which are separated by only a few miles.

LAKES AND STREAMS: Lakes occupy depressions in the bedrock created by glacial erosion. These bedrock lakes are common throughout. Some of the larger lakes are Lake Michigamme, Craig Lake, Crooked Lake, Beaufort Lake, Mountain Lake, Rush Lake, Ives Lake, Conway Lake, Lake Margaret, Bulldog Lake, and the Silver Lake Basin, but there are many more. Some of these large lakes (Ann, Howe, Rush, Trout, and Pine) were created or deepened by severe late glacial-era flooding (Drexler 1981).

Rivers and smaller streams are also numerous. Most of these streams have steep gradients, and many have waterfalls near Lake Superior. Some of the larger streams are the Peshekee, Huron, Little Huron, Dead, Yellow Dog, and Salmon Trout Rivers.

SOILS: Mostly sands. The sands of the outwash plain are excessively drained. The sandy tills near Lake Superior are not as well sorted as those of the outwash and are well drained rather than excessively drained. Local silt caps of aeolian origin cover some of the rock knobs (Pregitzer and Barnes 1984). The tops of the bedrock knobs have little or no soil. All the soils are very acidic. Soils of the entire subsection are classified as Spodosols, primarily Orthods (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Northern hardwoods (lacking beech, except along the Lake Superior shoreline) were dominant on tills and also on those thin soils over bedrock that did not burn frequently. Hemlock was often the dominant species, growing along with northern hardwoods and white pine. The sandy soils of the

gullied ridges north of the Yellow Dog plain supported northern-hardwoods forest. On sandy ground moraine, northern hardwood forests dominated the well-drained soils, and red pine-white pine forests dominated the more excessively drained soils.

Scattered white pine, red pine, and red oak were the dominant trees on exposed bedrock ridges. On the most heavily burned ridges, lichens and juniper dominated.

Hemlock and hemlock-white pine forests dominated the outwash deposits around Marquette. Jack-pine forests dominated the droughty outwash sands of the Yellow Dog and Mulligan plains.

Balsam fir, tamarack, and black spruce were the most common species in the wetlands, which were often in relatively small drainages located between the steep-sided bedrock uplands.

The largest wetlands were along the shoreline on sandy lake plain. Extensive emergent marsh was noted along the Iron River near its mouth. Complexes of forested beach ridges and swales are located at Little Presque Isle, Big Bay, Iron River, the mouth of the Salmon Trout River, and at the Pine River mouth. The drier complexes supported upland forests of hemlock-white pine, or on droughtier sites, jack pine and red pine. The wetter complexes were mostly "open swamp" dominated by spruce and cedar or speckled alder and shrub willows.

NATURAL DISTURBANCE: Extensive burned forests were reported by GLO surveyors around Marquette, and many fires have been noted within the Huron Mountain Club, especially on rocky ridges or lake margins (Simpson *et al.* 1990). Lightning-strike fires occur on ridge tops, as I observed in 1989. No major windthrow areas were recorded by surveyors in this subsection, but small areas of windthrow presently occur in old-growth forests here.

PRESENT VEGETATION AND LAND USE: Native American encampments and trails were noted by GLO surveyors at Big Bay. By 1846, when this area was surveyed, iron mining activities by European companies had already begun. Furnaces and forges were already established in and around Marquette. Roads were established leading west and southwest of Marquette, and some rivers had already been diverted for use in mining.

Logging and mining have been a major part of land use activities in the subsection. Mining for iron in the Michigamme Range created many large open-pit mines. The diversion of creeks and rivers has undoubtedly had an impact on associated wetlands, either by flooding or removal of water sources. Some impoundments are highly polluted by mine tailings and chemical products of mining.

Urban development is concentrated around Marquette. Recreation is an important land use, both along the shoreline and inland.

Old-growth forests persist in the Huron Mountain Club and parts of the McCormick Tract, where detailed ecological mapping and classification have been conducted (Simpson *et al.* 1990, Pregitzer *et al.* 1983).

RARE PLANT COMMUNITIES: The open bedrock ridges, which have not been completely explored, may be floristically different from those of other parts of Michigan.

RARE PLANTS: Many of the rare plants of the subsection are found on either cliffs or bedrock balds. *Asplenium viride* (green spleenwort), *Collinsia parviflora* (small blue-eyed Mary), *Cryptogramma stelleri* (slender cliff-brake), *Danthonia compressa* (flat oatgrass), *Draba arabisans* (rock whitlow-grass), *Dryopteris fragrans* (fragrant cliff woodfern), *Dryopteris expansa* (expanded woodfern), *Gentiana linearis* (narrow-leaved gentian), *Nuphar pumila* (small yellow pond-lily), *Opuntia fragilis* (fragile prickly-pear), *Ribes oxyacanthoides* (northern gooseberry), *Salix pellita* (willow), *Senecio indecorus* (rayless mountain ragwort), *Vaccinium cespitosum* (dwarf bilberry), *Woodsia alpina* (northern woodsia).

RARE ANIMALS: *Falco columbarius* (merlin), *Lycaeides idas nobokovi* (northern blue butterfly), *Martes americana* (marten).

NATURAL AREAS: Wilderness Areas: Huron Islands (Seney National Wildlife Refuge),

McCormick Tract (Ottawa National Forest); Research Natural Areas: McCormick Tract (Ottawa NF); Michigan Nature Association Preserves: Willow Creek, Braastad Memorial; Huron Mountain Club: Nature Reserve Area.

PUBLIC LAND MANAGERS: State Forests: Escanaba River, Copper Country; State Parks: Craig Lake; National Forests: Ottawa; Experimental Forests: McCormick, Upper Peninsula; State Environmental Areas: Squaw Bay.

CONSERVATION CONCERNS: The privately owned Huron Mountain Club manages a large tract (8,000 acres) of northern hardwoods and open pine-oak dominated bedrock knobs as a Nature Reserve Area, with access for scientific study only. The McCormick Research Natural Area also protects a large tract of northern hardwoods, including some mature areas of white pine. Remaining old-growth hardwood and conifer forests are on private land and are not protected. In the remainder of the subsection, biological survey is incomplete. Aerial photo surveys show there are probably high-quality bedrock knobs worthy of biological investigation throughout the subsection.

Figure 25.—*Subsection IX.2: Huron Mountain Club, Marquette County, Michigan. Glacial ice scoured the granitic and sandstone bedrock of this subsection, creating a landscape of lakes and exposed bedrock knobs. White pine and red pine cling to the thin soils of the knobs, while eastern hemlock and northern hardwoods occupy areas with thicker, better developed soils. Photo by B.V. Barnes.*

SUBSECTION IX.3. Upper Wisconsin/Michigan Moraines**; drumlinized ground moraine, ice-stagnation moraines, localized outwash; northern hardwood forest, bog.**

DISCUSSION: The subsection consists primarily of end and ground moraines. Northern hardwood forests characterize most of the uplands, but differences in landform and soil texture among the sub-subsections cause differences in overstory and groundcover vegetation and differences in land management. The sub-subsections also support different wetland types.

SUB-SUBSECTIONS: Brule and Paint Rivers sub-subsection (IX.3.1); Winegar Moraine sub-subsection (IX.3.2); Central Wisconsin Loess Plains sub-subsection (IX.3.3); Chippewa-Green Bay Lobes sub-subsection (IX.3.4). (See figures 4 and 6.)

ELEVATION: 600 to 1,952 feet (183 to 595 m).

AREA: 14,295 square miles (37,024 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Climate of Sub-subsection IX.3 is less modified by the Great Lakes than any other subsection in Michigan (Albert *et al.* 1986). Growing season is short, 87 days in Michigan (Albert *et al.* 1986) and 100 to 128 days in Wisconsin (Wisconsin Agricultural Statistics Service 1987). The chance of late spring frosts is greater here than in any other subsection in Michigan. Winters are cold; extreme minimum temperature ranges from -45˚F to -50˚F (Wisconsin Statistical Reporting Service 1967, Eichenlaub *et al.* 1990). Annual snowfall ranges from 40 to 140 inches (Eichenlaub *et al.* 1990, Wisconsin Statistical Reporting Service 1967); snowfall amounts are greatest in the northern part of the subsection but less than along the Lake Superior shoreline (Albert *et al.* 1986). Severe winds associated with squall lines and thunderstorms may have a strong impact on forests.

BEDROCK GEOLOGY: Precambrian bedrock within this large subsection is quite diverse and includes granite, gabbro, basalt, gneiss, amphibolite, felsic and mafic metavolcanic rock, quartzite, slate, and iron formations (Morey *et al.* 1982). Bedrock is generally overlain by glacial drift, but is locally exposed throughout the subsection. Glacial drift is up to 300 feet thick.

LANDFORMS: End and ground moraine. Kettle depressions and steep ridges make up the irregular end-moraine lobes of the northern part of the subsection. See sub-subsections.

LAKES AND STREAMS: See sub-subsections.

SOILS: Rocky, red, sandy loams and sands make up the subsoil. A reddish silt cap of loess is common in Sub-subsections IX.3.1, IX.3.3, and IX.3.4. Fragipans are often present. Soils are Spodosols. Peat deposits can be several feet thick.

PRESETTLEMENT VEGETATION: Northern hardwoods dominated all sub-subsections. Hemlock was common, both within the hardwood stands and as pure stands.

NATURAL DISTURBANCE: Windthrow is probably most important. Large windthrows were common in Sub-subsections IX.3.1 and IX.3.3 due to the relatively flat topography. Smaller windthrows characterized the irregular topography of Sub-subsection IX.3.2. Fire was an important factor along more droughty lake margins.

PRESENT VEGETATION AND LAND USE: Forest management for timber and pulp is the primary land use. Some agriculture, primarily pasture, is in the south in Sub-subsection IX.3.3.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: The entire subsection is important for timber and pulp production. It provides very important habitat for large mammals and migratory song birds. Present land management is generally compatible with these habitat needs. Parts of this subsection have been considered for wolf management.

BOUNDARIES: Subsection IX.3 includes lands of the Ottawa, Nicolet, and Chequamegon National Forests, which have been mapped in detail by ECS teams.

SUB-SUBSECTION IX.3.1. Brule and Paint Rivers**; drumlinized ground moraine; silt-loam-capped (loess) ground moraine, long linear lakes; northern hardwood forests.**

DISCUSSION: Silt-loam-capped ground moraine and outwash with linear lakes characterize the landscape. The silt cap results in a diverse groundcover flora as well as tree species not commonly occurring on the more prevalent sandy loam soils in this part of the State.

ELEVATION: 1,350 to 1,875 feet (411 to 572 m).

AREA: 1,801 square miles (4,667 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Continental, with heavy snows and extremely cold winters. See subsection.

BEDROCK GEOLOGY: Glacial drift covers bedrock, which is only locally exposed. The predominant bedrock types are Precambrian basaltic to rhyolitic metavolcanic rock with some metasedimentary rock. In Michigan, the western part of the Menominee Iron Range is within the sub-subsection.

LANDFORMS: Drumlin ridges and adjacent swampy depressions that are oriented northeast-southwest. The ridges are typically one-third to one-half mile wide, 1 mile long, and 80 to 140 feet high (Albert *et al.* 1986). Glaciofluvial deposits of sand and gravel surround many of the drumlins; but these are often covered with a thin silt cap, resulting in vegetation dominated by northern hardwoods.

LAKES AND STREAMS: Most large lakes here are linear, with the same general trend as the adjacent drumlins; the lake basins were eroded by glacial ice. Among the larger lakes are North Twin, Big Sandy, Long, and Smoky in Wisconsin, as well as Smoky, Brule, Golden, Chicagon, Stanley, Ottawa, and James in Michigan. Smaller kettle lakes are also scattered throughout.

Many small creeks and rivers drain the numerous linear wetlands between the drumlins. Larger rivers include the Paint and Brule.

SOILS: Soils are generally well drained, derived from rocky, red, sandy loam till or gravelly, loamy sand outwash. Often the soils have a silt cap of loess. In Wisconsin, the silt-loam loess is as much as 30 inches deep (Hole and Germain 1994); in Michigan, the loess cap is generally thinner. At the northern edge of the sub-subsection in Michigan, the loess is localized; often one side of an outwash channel will have a thin loess cap, while the other will not. Fragipans are common, often resulting in poor drainage conditions on flat ridge tops. The soils are reddish from the abundance of iron in the local bedrock. This sub-subsection is distinguished from Sub-subsections IX.3.3 and IX.3.4, which have thicker, more continuous loess caps. Nevertheless, the thin loess cap has an important effect on the vegetation here.

PRESETTLEMENT VEGETATION: Northern hardwoods dominated this unit, but with higher amounts of white ash, American elm, yellow birch, and basswood than on sandy loam soils in adjacent Sub-subsection IX.3.2. Larix and black spruce dominated most depressions between the drumlin-like ridges, and the centers of some of these depressions supported bogs and wet meadows. Black ash, yellow birch, and American elm dominated better drained depressions.

NATURAL DISTURBANCE: Windthrows were large and relatively common on broad ridges, as

noted by GLO surveyors and more recent field studies (Albert 1990). I observed that the surface of the drumlins is in most cases almost completely covered with windthrow mounds (cradle-knoll).

PRESENT VEGETATION AND LAND USE: Sub-subsection IX.3.1 is managed primarily for forest, but local areas of the broad ridges are pastured. Iron mining was once important near the city of Iron River on the Menominee Iron Range. Northern hardwoods are dominant on both sandy loam and silt loam soils. American elm, basswood, white ash, and yellow birch are much more common on silt loams than on the sandy loams of Sub-subsection VIII.3.2 (Albert 1983, Goff in Milfred *et al.* 1967). Ground layers are ephemeral rich, unlike those of Sub-subsection IX.3.2. Within the Nicolet National Forest, the best saw timber comes from this sub-subsection.

Where the linear depressions between the drumlinized ridges are drained by streams, American elm and balsam fir are common. In linear depressions undrained by streams, poor fen or bog dominated by sedges and sphagnum mosses is common; tamarack is dominant along the edges of these depressions and is gradually replaced by black spruce toward the center. Northern white-cedar is occasionally present at the edges of depressions, but the ground and end moraines generally contain little of this species.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Michigan and Wisconsin: *Carex assiniboinensis* (Assiniboia sedge), *Juncus stygius* (moor sedge), and undescribed species of *Botrychium*. **Wisconsin only:** *Polemonium occidentalis* (western Jacob's ladder), and *Valeriana sitchensis* (marsh valerian). **Michigan only:** *Botrychium hesperium* (western moonwort), *Botrychium pseudopinnatum* (grapefern), *Carex arcta* (sedge), *Petasites sagittatus* (sweet colts-foot).

RARE ANIMALS: *Gavia immer* (common loon), *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey), *Martes americana* (marten).

NATURAL AREAS: Michigan: Iron River State Roadside Rest (old-growth northern hardwoods). **Wisconsin:** State Natural Areas: Giant White Pine Grove, Bose Lake Hemlock-Hardwoods, Marinette County Beech Forest, Scott Lake-Shelp Lake; Wilderness Areas (Nicolet National Forest): Whisker Lake, Headwaters; Research Natural Areas (Nicolet NF): Grandma Lake, McCaslin Mountain, Bose Lake Hemlock-Hardwoods.

PUBLIC LAND MANAGERS: Michigan: State Forests: Copper Country; National Forests: Ottawa. **Wisconsin:** National Forests: Nicolet.

CONSERVATION CONCERNS: There are no Forest Service Research Natural Areas and few nature preserves in the highly productive northern hardwoods of this sub-subsection. The forests are probably important for breeding songbirds. Breeding bird habitat is probably secure because most of the lands will remain under forest management. However, the impact of present logging practices on songbird breeding success is not known; this question is now being investigated in a Wisconsin Department of Natural Resources research project. In Wisconsin, this area is considered a high priority for identification of potential natural areas.

BOUNDARIES: In Michigan, the boundaries are based on my interpretation of the soils and landforms of Michigan, both my own sampling and Veatch's (1953) soils interpretation. This sub-subsection includes most of the Ottawa National Forest's Map Unit F. In Wisconsin, the ground moraine with (thin) silt cap is separated from the outwash and ice-contact deposits of Subsection IX.5 to the west on the basis of recent soil surveys (Langlade, Vilas, Oneida, Marinette County) and works by Attig (1985) and Mickelson (1986). The extreme northwestern boundary is based on Clayton's Florence County glacial landform map (1986), showing the boundary of silt-capped vs. uncapped glacial drift. The recent Oconto County soil survey did not recognize any silt cap (even where the adjacent Langlade County survey did), so this part of the boundary was based on drumlin features without textural data. I include a larger area of ground moraine and drumlin features than Hole (1968) did in his soils interpretation of Wisconsin.

One difficulty encountered in mapping this unit is that drumlin fields consist of interdigitated drumlin ridges and adjacent outwash deposits.

These outwash deposits continue south, where they interdigitate with end-moraine lobes. Thus, the boundary between the end moraine to the south and the drumlin ridge to the north is some what arbitrary. More detailed localized mapping will allow for the identification of individual areas of end moraine, ground moraine (drumlins), and outwash.

The boundary between the drumlin field (Sub-subsection IX.3.1) and adjacent units (Sub-subsection IX.3.4 and Subsection IX.5) was based primarily on the southern extent of the drumlin features; a smoothed boundary could have been chosen, but would not have expressed the irregular boundary of the drumlin field as well. For a more detailed map of the drumlins and outwash channels, see the ECS maps of both the Ottawa and Nicolet National Forests, which are done at the more local LTA level, allowing for a more detailed treatment.

SUB-SUBSECTION IX.3.2. Winegar Moraine**; coarse-textured ice-stagnation moraines (with numerous kettle lakes); northern hardwood forest, bog.**

DISCUSSION: Much of this sub-subsection is characterized by irregular ice-disintegration topography, with steep, sandy ridges, kettle lakes, and wetlands.

ELEVATION: 1,275 to 1,846 feet (389 to 563 m).

AREA: 2,516 square miles (6,520 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Continental, with heavy snows and extremely cold winters. See subsection.

BEDROCK GEOLOGY: The Archean-age metamorphic and igneous rocks include granite, metavolcanics (including wacke, conglomerate, and iron formation) and metamorphosed mafic-intermediate volcanic rock (including greenstone, gneiss, and amphibolite) (Morey *et al.* 1982). In most of the sub-subsection, glacial drift is generally thick, 200 to 300 feet over the Precambrian bedrock.

LANDFORMS: Ice-stagnation features, end moraines, ground moraine, and outwash. Irregular lobes of end moraine, in which kettles and steep ridges make up most of the landscape, are characteristic of both the Michigan and Wisconsin part of this sub-subsection.

LAKES AND STREAMS: Drainage system is poorly developed due to the irregular topography. In large areas, there are almost no streams; instead, ground-water flow is important for water movement. Kettle lakes are quite common. The water of the kettle lakes is acidic and low in nutrients.

SOILS: The glacial drift of the entire sub-subsection is acidic, rocky, red sandy loam or loamy sand, derived from the iron-rich, local Precambrian bedrock. Soils are podzolized sandy loams and loamy sands. Fragipans are common throughout (Hole 1976, Spies 1983, Albert 1983, Spies and Barnes 1985). Most of the soils are classified as Fragiorthods and Haplorthods (Hole 1976).

PRESETTLEMENT VEGETATION: Northern hardwood forests of sugar maple, hemlock, yellow birch, red maple, and basswood dominated the uplands. Forests of hemlock and white pine occupied the more fire-prone lake margins on steep south and west aspect slopes. Bogs and low productivity black spruce and tamarack swamps are common wetland types in the kettles. The forested ecosystems of the Sylvania Recreation (Wilderness) Area, a large tract of virgin forest, are described in detail by Spies (1983), Spies and Barnes (1985), Voice (1983), Hix (1983), and Hix and Barnes (1984).

NATURAL DISTURBANCE: Windthrow common. Individual windthrows were often relatively small on the stagnation moraine due to the irregularity of the landscape and the smallness of the ridge tops. In contrast, windthrows were probably much larger on the rolling ground moraine of adjacent Sub-subsection IX.3.1.

PRESENT VEGETATION AND LAND USE: Major land uses are forestry and recreation. Following logging, the upland forests are dominated by hardwoods, primarily sugar maple and red maple, with very little hemlock or white pine present, although stumps and the soils characteristic of these conifers remain.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Michigan and Wisconsin: *Botrychium mormo* (goblin moonwort), *Calypso bulbosa* (Calypso or fairy-slipper), *Dryopteris expansa* (expanded woodfern), *Dryopteris fragrans* (fragrant cliff woodfern), *Potamogeton confervoides* (alga pondweed). **Wisconsin only:** *Polystichum braunii* (Braun's holly fern), *Tiarella cordifolia* (foamflower). **Michigan only:** *Botrychium hesperium* (western moonwort), *Botrychium psuedopinnatum* (grapefern), *Gratiola lutea* (hedge-hyssop).

RARE ANIMALS: Michigan: *Gavia immer* (common loon), *Erebia discoidalis* (red-disked alpine (butterfly), *Martes americana* (marten).

NATURAL AREAS: Michigan: Wilderness Areas (Ottawa National Forest): Sylvania; The Nature Conservancy Preserves: Ford Eagle. **Wisconsin:** State Natural Areas: High Lake Spruce-Balsam Forest, Moose Lake Hemlocks, Sajdak Springs, Dunn Lake Pines, Moose Lake, Mary Lake; Wilderness Areas (Chequamegon National Forest): Porcupine Lake, Rainbow Lake.

PUBLIC LAND MANAGERS: Michigan: National Forests: Ottawa; State Forests: Copper Country, Escanaba River. **Wisconsin:** National Forests: Nicolet, Chequamegon; State Forests: Northern Highland.

CONSERVATION CONCERNS: The Sylvania Wilderness Area is a large preserve characteristic of the northern part of the sub-subsection. Smaller State natural areas are scattered throughout the sub-subsection in Wisconsin. Most of the sub-subsection is managed as State or National Forest land; these lands provide important habitat for both large mammals and migratory song birds. Fragmentation of the landscape is not generally an important issue, except around some of the lakes that have recreational and residential development. The numerous lakes provide important habitat for bald eagles, ospreys, and common loons.

BOUNDARIES: Sub-subsection IX.3.2 includes parts of the Ottawa National Forest and Chequamegon National Forest. The Chequamegon National Forest classification extends this sub-subsection further to the south based on soil characteristics; sandier soils without a silt cap (loess) are included within this unit and separated from soils with a silt cap to the south. I chose to emphasize landform instead and included steep, irregular ice-contact topography in this sub-subsection, as distinct from the drumlinized ground moraine separated by outwash deposits in Sub-subsection IX.3.3 to the south. The general pattern of upland and wetland vegetation, plus major differences in wetland vegetation, corresponds well to the difference in landform. The sandier soils at the northern edge of Sub-subsection IX.3.3 can be treated at the next, more local level of the hierarchy. See ECS mapping units of the Ottawa and Chequamegon National Forests for further detailed classification and mapping.

SUB-SUBSECTION IX.3.3. Central Wisconsin Loess Plains; **silt-loam-capped ground moraine with drumlins; northern hardwood forest, conifer swamps.**

DISCUSSION: Sub-subsection IX.3.3 is an undulating to nearly level plain; rolling topography accounts for about one-fifth of the land area (Hole and Germain 1994). Lakes are much less common here than in the other three sub-subsections.

ELEVATION: 1,082 to 1,673 feet (330 to 510 m).

AREA: 3,981 square miles (10,315 sq km).

STATES: Wisconsin.

CLIMATE: Continental, with moderately heavy snows and extremely cold winters. See subsection.

BEDROCK GEOLOGY: Precambrian bedrock is generally less than 50 feet below the surface in the south and from 50 to 300 feet below the surface in the north. Bedrock includes gneiss, amphibolite, mafic metavolcanic rock, rhyolite, granite, and diorite (Morey *et al.* 1982). The underlying bedrock forms an undulating plain with scattered bedrock-cored ridges (Hole and Germain 1994). Basalts (Precambrian) and Cambrian sandstone are present to the west in Polk, Barron, and Washburn Counties.

LANDFORMS: Ground moraine with southwest-trending drumlins characterizes the uplands. There are smaller inclusions of stagnation moraine and end moraine. Narrow, poorly drained outwash channels are numerous.

LAKES AND STREAMS: Almost no large lakes on this ground moraine; many peatlands; many small creeks and rivers. Most of the rivers flow to the southwest, including the Brunet, Thornapple, Flambeau, and Jump. In the northeast, two rivers flow to the southeast, the Somo and Spirit. Peatlands are concentrated to the north in Ashland and Price Counties; wetlands are smaller and much less common farther to the south, where the streams are parallel and closely spaced.

SOILS: Acid silt loams, podzolized, rocky, and often poorly drained (Hole 1976, Hole and Germain 1994). As much as 30 inches of windblown silt cover the underlying acidic, reddish sandy loam till. Sandy and stony material of the till has been worked into the overlying loess by windthrow, animal digging, and frost action. The loess cap is less continuous in the western portion (Polk, Washburn, and Barron Counties). Spodozols are more distinct, and the amount of clay in the B horizon is less than in the soils found on the till plain in Sub-subsection IX.4.1 to the south (my interpretation of Hole 1976). The reduced amount of clay may be related to a shorter period of time for soil development (Hole 1976); but based on soils sampled just to the north in Michigan (Albert 1983, 1990; Spies 1983), it may also be related to the low amount of clay-forming minerals in the parent material.

PRESETTLEMENT VEGETATION: The original vegetation was largely mesic northern forests of hemlock, sugar maple, and yellow birch, with white pine and red pine (Finley 1976). Forested wetlands occupied about 25 to 50 percent of the sub-subsection in Ashland and Price Counties to the north. Common dominants included northern white-cedar, black ash, balsam fir, and tamarack. In the west (Polk, Barron, and Washburn Counties), there is no hemlock in the forests and wetlands are much less common and less extensive.

NATURAL DISTURBANCE: Windthrow, the predominant disturbance, was common in both the east and west parts of the sub-subsection (Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: The primary land use is for forest products. The silt-loam soils are also used for dairy farming and locally for crops, in contrast to nearby sandier soils, which are managed as forest or pasture (Hole 1976). Rockiness, poor drainage, and relatively steep, small upland features restrict agriculture.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: State Natural Areas: Flambeau River Hardwood Forest, Lake of the Pines Conifer-Hardwoods, Plagge Woods, Tula Lake.

PUBLIC LAND MANAGERS: Chequamegon National Forest.

CONSERVATION CONCERNS: Relatively few areas are protected as natural areas. Forest management for hardwoods is intensive, with short rotation time, due to the high productivity on the silt-loam soils. Conflicts between forest management goals and biodiversity goals might be expected to be greater here than in the remainder of the subsection.

BOUNDARIES: See comments under the BOUNDARIES section of Sub-subsection IX.3.2. Small areas of end moraine along the boundary between Sub-subsection IX.3.3 and Subsection IX.5 have not been mapped at this scale. The Chequamegon National Forest maps this end moraine as part of Sub-subsection IX.3.2; but I felt that the mosaic of end moraine, ground moraine, and outwash in Iron, Price, and Oneida Counties was better treated at the more local LTA level. See the Chequamegon National Forest's ECS classification.

SUB-SUBSECTION IX.3.4. Chippewa-Green Bay Lobes**; stagnation moraine with sandy soils, kettle lakes; northern hardwood forest and bogs.**

DISCUSSION: Sub-subsection IX.3.4 consists of a narrow band of stagnation moraine that separates Subsection IX.3 from IX.4. In the east, there are several parallel end moraines separated by outwash, and also inclusions of ground moraine (till plain). In the west, there is a broad area of stagnation moraine, with end moraine along its margins.

ELEVATION: 688 to 1,952 feet (210 to 595 m).

AREA: 5,997 square miles (15,539 sq km).

STATES: Wisconsin.

CLIMATE: Continental, with moderately heavy snowfall and extremely cold winters. See subsection.

BEDROCK GEOLOGY: See subsection. Because of its length, this map unit is underlain by a broad range of Precambrian bedrock.

LANDFORM: Sub-subsection is a narrow band of stagnation moraine formed at the front of the Chippewa, Wisconsin Valley, Langlade, and Green Bay lobes during the Wisconsin Glaciation (Clayton *et al.* 1991). The Green Bay lobe part of the sub-subsection to the east consists of several narrow end-moraine ridges separated by outwash channels and includes areas of ground moraine. At the western edge, there is also stagnation moraine (Goebel *et al.* 1983).

LAKES AND STREAMS: Small kettle lakes are common on the moraines, but there are few large lakes. The moraines are also headwater to several streams.

SOILS: Diverse soils, as could be expected from a linear ridge that crosses much of Wisconsin. Soil texture is typically sandy loam to loam, developed from either brown or red glacial drift. To both the east and west, substrates are neutral; in the center of the State, substrates are acidic. Stoniness is variable. Soils of the Wisconsin Valley lobe are rich in fragments of iron formation and basalt. Soils of the Green Bay lobe are typically underlain by outwash deposits of sand and gravel. Wetland soils are not extensive, but peat bogs are common throughout in ice-block kettles. Soils are classified as Fragiochrepts, Eurochrepts, Fragiorthods, Hapludalfs, and Glossoboralfs (Hole 1976).

PRESETTLEMENT VEGETATION: Northern hardwoods, dominated by a mix of hemlock, sugar maple, basswood, and white pine, were present throughout. American beech occurred at the eastern edge.

NATURAL DISTURBANCE: Windthrow as documented by Canham and Loucks (1984).

PRESENT VEGETATION AND LAND USE: Most of the sub-subsection remains forested. Major land uses are forestry and recreation.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: State Natural Areas: Flora Spring Pond, Blue Hill Felsenmeer, Dory's Bog, Jung Hemlock-Beech Forest, Atkins Lake, Krueger Pines, Oxbow Rapids, Mud Lake Bog, Keller Whitcomb Creek Woods, Dalles of the St. Croix River, Interstate Lowland Forest, Tula Lake.

PUBLIC LAND MANAGERS: National Forests: Chequamegon, Nicolet.

CONSERVATION CONCERNS: The Menominee Indian Reservation, near the eastern edge of the sub-subsection, is unique in Wisconsin, in that much of the forested land there has never been clearcut. The forest probably closely approximates the presettlement conditions in ways that small isolated old-growth remnants elsewhere cannot.

BOUNDARIES: It has been suggested that the Green Bay lobe, at the eastern edge of the sub-subsection, should be treated as a separate sub-subsection. Based on differences in soils (more

calcareous) and vegetation (large amounts of American beech), it is reasonable to separate the Green Bay lobe from the remainder of the sub-subsection. However, I would separate the lobe at the next, more local level of the hierarchy.

SUBSECTION IX.4. Lincoln Formation Till Plain**; till plain over bedrock, thin silt-capped soils over 25,000- to 130,000-year-old till; northern hardwood forest with hemlock.**

DISCUSSION: Subsection IX.4, characterized by silt-capped ground moraine, has been heavily used for agriculture, in contrast to Sub-subsections IX.3.3 and IX.3.4; Hole and Germain (1994) treat Sub-subsections IX.3.3 and IX.4.1 as part of the same subdivision.

SUB-SUBSECTIONS: Marshfield (IX.4.1), Rib Mountain (IX.4.2), Neillsville Sandstone Plateau (IX.4.3). (See figure 4.)

ELEVATION: 886 to 1,924 feet (270 to 586 m).

AREA: 5,247 square miles (13,594 sq km).

STATES: Wisconsin.

CLIMATE: Annual precipitation averages 32 to 33 inches and annual snowfall is 44 to 52 inches (Wisconsin Statistical Reporting Service 1967, Wendland *et al.* 1992). Extreme low temperatures are -45˚F to -50˚F (Wisconsin Statistical Reporting Service 1967). Growing season is between 115 and 135 days.

BEDROCK GEOLOGY: There are local exposures of bedrock throughout the subsection; weathered Cambrian sandstone and shale are near the surface or exposed in the west, and Precambrian granites are in the east, especially in Sub-subsection IX.4.2. Other Precambrian bedrock types found in the east include gneiss, amphibolite, and felsic and mafic metavolcanic rock (Morey *et al.* 1982).

LANDFORMS: Ground moraine, with outwash deposits in Sub-subsection IX.4.2. The till was deposited 25,000 to 790,000 years ago; as a result, the topography is more dissected than more recent ground moraines from the Wisconsin Glaciation in the three States.

LAKES AND STREAMS: The Big Eau Pleine and the Wisconsin Rivers flow through the subsection. Outwash deposits associated with the Wisconsin River are extensive to the southeast. Streams are numerous, but generally small. The drainage system is much more dendritic than that of Sub-subsection IX.3.3, where many of the streams are parallel.

SOILS: Bedrock is within 50 feet over much of the subsection. Soils are generally shallow, silt loams over bedrock. Much of Sub-subsection IX.4.1 is underlain by Cambrian sandstone; Sub-subsection IX.4.2 is underlain by granite. Poor drainage characterizes the soils on the undulating topography of Sub-subsections IX.4.1 and IX.4.3. Much of Sub-subsection IX.4.2 is well drained.

PRESETTLEMENT VEGETATION: Northern hardwood forest, dominated by sugar maple, hemlock, yellow birch, white pine, and red pine, covered most of the subsection; conifer swamps were concentrated in Sub-subsection IX.4.3.

NATURAL DISTURBANCE: Windthrows were quite common in Sub-subsections IX.4.1 and IX.4.3, but much less common in the more dissected, well-drained landscape of IX.4.2 (my interpretation of Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: Agriculture, including both row crops and pasture, is intensive within Sub-subsection IX.4.1. Forestry is more important in the remaining sub-subsections.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: Forest fragmentation is severe in much of this subsection.

SUB-SUBSECTION IX.4.1. Marshfield**; undulating to rolling silt-capped till plain over Cambrian sandstone and Precambrian igneous and metamorphic bedrock; northern hardwood forest with hemlock.**

DISCUSSION: This Sub-subsection is a silt-capped till plain, with shallow soils over bedrock.

ELEVATION: 885 to 1,675 feet (270 to 511 m).

AREA: 3,370 square miles (8,732 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: In the west, underlying bedrock is Cambrian sandstone, with some shale and dolomite (Morey *et al.* 1982). The eastern half is underlain by Precambrian gneiss, amphibolite, and felsic and mafic metavolcanic bedrock.

LANDFORMS: A till plain, with glacial deposits 25,000 to 790,000 years old. Stream erosion has created a plain that is more dissected than more recent Wisconsinan-age till plains. The topography is largely inherited from the underlying bedrock surface, which is only thinly mantled with glacial drift (Hole 1976). The plain has received recent deposits of late Wisconsinan-age loess.

LAKES AND STREAMS: Many small creeks and rivers dissect the plain, creating a dendritic drainage system. Few lakes.

SOILS: Bedrock is within 50 feet over much of the sub-subsection. Soils are generally poorly drained silt loams, shallow over compact acidic loamy till (Hole 1976).

PRESETTLEMENT VEGETATION: Northern hardwoods, dominated by sugar maple and hemlock, covered most of the landscape. Small areas of conifer swamps were common, especially near the headwaters of streams.

NATURAL DISTURBANCE: Windthrows were common throughout (Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: Sub-subsection IX.4.1 has been more extensively converted to dairy farms and crop lands than any other part of Section IX.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: State Natural Areas: Schmidt Maple Woods.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS: Because of the extensive conversion to dairy farms and crop lands, there are few high-quality occurrences of natural plant communities.

SUB-SUBSECTION IX.4.2. Rib Mountain**; rolling ridges underlain by Precambrian granitic bedrock, some outwash deposits; northern hardwood forest with hemlock.**

DISCUSSION: The topography is steeper here than in the remainder of the subsection, with few wetlands. Bedrock exposures are common.

ELEVATION: 1,115 to 1,924 feet (340 to 586 m).

AREA: 1,023 square miles (2,650 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Underlain by Precambrian granitic rock (Morey 1982). Rib Mountain is quartzite.

LANDFORMS: This sub-subsection is the most dissected part of a 25,000- to 790,000-year-old, pre-Wisconsinan till plain underlain by granitic bedrock (Clayton *et al.* 1991).

LAKES AND STREAMS: No natural lakes. Rivers include the Big Rib, Little Rib, Trappe, and Wisconsin. Many of these rivers have eroded steep ravines into the glacial drift, and there are bedrock exposures along their streams.

SOILS: Soils are well-drained, shallow silt loams over weathered granitic bedrock. Till forms a thin, discontinuous veneer over clayey saprolite developed on granitic and metavolcanic rocks (Farrand *et al.* 1984). Soils are classified as Glossoboralfs and Hapludalfs (Hole 1976).

PRESETTLEMENT VEGETATION: Most of this sub-subsection was dominated by northern hardwood forests of hemlock, sugar maple, yellow birch, white pine and red pine (Finley 1976); but there were also forests of white pine and red pine as well as jack pine barrens along the broad alluvial deposits of the Wisconsin River.

NATURAL DISTURBANCE: Windthrow was much less common here than in either Sub-subsections IX.4.1 or IX.4.3.

PRESENT VEGETATION AND LAND USE: Much of this sub-subsection remains forested.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: State Natural Areas: Dells of the Eau Claire River, Powers Bluff Maple Woods, Big Eau Pleine Woods.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS:

SUB-SUBSECTION IX.4.3. Neillsville Sandstone Plateau**; thin, sandy pre-Wisconsinan drift on shaly sandstone; transitional hardwood forests with some hemlock and white pine, conifer-dominated wetlands.**

DISCUSSION: Sub-subsection IX.4.3 consists of thin, sandy loams or silty loams over sandstone or shaly sandstone.

ELEVATION: 886 to 1,300 feet (270 to 396 m).

AREA: 853 square miles (2,212 sq km).

STATES: Wisconsin.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Underlying bedrock, which is locally exposed or near the surface throughout, is sandstone or shaly sandstone (Morey *et al.* 1982, Hole 1976).

LANDFORMS: Most of this area has not been glaciated for several hundred thousand years (pre-Illinoian); the resulting landscape is variable, including level to hilly landscape. There are exposed bedrock, residuum, sheet-wash sediment, and broad deposits of stream sediment (Hole 1976, Goebel *et al.* 1983).

LAKES AND STREAMS: No natural lakes; many small creeks and rivers.

SOILS: Soils in the west are primarily well-drained, infertile loamy sands and sandy loams over shallow sandstone bedrock. In the east, poorly drained and very poorly drained silt loams are formed over shaly sandstone (Hole 1976).

PRESETTLEMENT VEGETATION: Upland sites supported several forest types; forests of sugar maple, yellow birch, white pine, and red pine were most common (Finley 1976). There were

also forests of sugar maple and basswood with oaks and smaller areas dominated by oak forest. Swamp forests were common and supported diverse hardwood and conifer species, including hemlock, white pine, black spruce, red maple, red oak, white birch, and elm (Hole 1976).

NATURAL DISTURBANCE: Windthrows were common throughout (Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: Large parts of the sub-subsection remain forested, either because of low fertility or poor drainage. However, some lands have been converted to either pasture or crop land.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: None identified to date.

NATURAL AREAS: State Natural Areas: Dory's Bog.

PUBLIC LAND MANAGERS:

CONSERVATION CONCERNS:

SUBSECTION IX.5. Lac Veaux Desert Outwash Plain **(Northern Highland Lakes Barrens); pitted outwash plain, kettle lakes; jack pine barrens, white pine-red pine forest, conifer swamp, bog.**

DISCUSSION: Kettle lakes, ponds, and peatlands are common on the pitted outwash. There are also flat plains with few kettles, as well as end moraine of sandy till.

ELEVATION: 1,450 to 1,935 feet (442 to 590 m).

AREA: 2,473 square miles (6,409 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Continental, with cold winters and warm summers. Extreme low temperatures are between -45˚F and -50˚F (Wisconsin Statistical Reporting Service 1967). Annual precipitation averages 30 to 34 inches, and average annual snowfall is 50 to 90 inches; both annual precipitation and snowfall increase to the northwest due to the influence of Lake Superior. Growing season ranges from approximately 100 days in the north to more than 120 days in the south.

BEDROCK GEOLOGY: Precambrian bedrock is covered by 100 to 300 feet of glacial drift. In the south, underlying bedrock is Precambrian mafic and felsic metavolcanic rock (Morey *et al.* 1982). To the north, quartzose sedimentary rock predominates, including mafic metavolcanic rocks and small bodies of granite and pegmatite. There are local areas of gneiss, amphibolite, and foliated granite.

LANDFORMS: Largely pitted outwash plain; also includes coarse-textured end moraines and ice-contact sands and gravels (Simpkins *et al.* 1987).

LAKES AND STREAMS: Kettle lakes are abundant throughout, especially on the pitted outwash. A few of the larger lakes include Tomahawk, Big St. Germain, Fence, Crawling Stone, Trout, Presque Isle, Star, and Lac Vieux Desert. Many streams originate in this flat outwash plain, including the Wisconsin River. Extensive wetlands occur near the headwaters of these streams.

SOILS: Soils are acidic sands over large areas, often tens of feet thick (Hole 1976). Soil productivity is generally low because of low moisture-holding capacity and loss of soil humus through burning. Throughout the barrens, Omega loamy sands (Spodic Udipsamments) are common on upper slopes, while Vilas loamy sands (Entic Haplorthods) are common in depressions (Hole and Germain 1994). Spodosols will develop where there is stable vegetation (Hole 1976).

PRESETTLEMENT VEGETATION: White pine and red pine forests dominated most of the pitted outwash plain. In the southwest between the Tomahawk and the Wisconsin Rivers, where the outwash plain is rolling and least dissected by kettle lakes, there is a broad area of barrens dominated by jack pine and northern pin oak.

Hardwood-conifer swamps are also common along the margins of the subsection. Extensive peatlands occupy kettle depressions and the headwater areas of many streams.

NATURAL DISTURBANCE: GLO surveyors documented many fires in this area of barrens, similar to the levels documented for the Bayfield Barrens (X.1) and Spread Eagle-Dunbar Barrens (IX.1) (Finley 1976). Fire frequency and intensity were greatest in the jack pine barrens, which are concentrated in areas of rolling topography not broken by kettle lakes. Few windthrows occurred on the pine-dominated landscape (Canham and Loucks 1984).

PRESENT VEGETATION AND LAND USE: This subsection is important for recreation, forest products (pulp), and wildlife management (grouse and other upland game birds). Some wetlands are used for cranberry production (Hole 1976). At the turn of the century, white pine and red pine were heavily logged, resulting in conversion of many of these stands to paper birch and aspen.

RARE PLANT COMMUNITIES: Deep sterile seepage lakes with distinctive "rosette" flora; jack pine barrens.

RARE PLANTS: Michigan and Wisconsin: *Littorella americana* (American shore-grass). **Wisconsin only:** *Eleocharis robbinsii* (Robbins spike-rush), *Oryzopsis canadensis* (Canadian rice grass), *Ultricularia resupinata* (small purple bladderwort).

RARE ANIMALS: Michigan and Wisconsin: *Gavia immer* (common loon), *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey). **Wisconsin only:** *Aeshna clepsydra* (mottled darner, dragonfly), *Coturnicops noveboracensis* (yellow rail), *Oporornis agilis* (Connecticut warbler).

NATURAL AREAS: Michigan: Wilderness Areas: Sylvania (Ottawa NF). **Wisconsin:** State Natural Areas: Trout Lake Conifer Swamp, Bose Lake Hemlock Hardwoods, Rice Lake-Thunder Lake Marsh, Finnerud Pine Forest, Black Tern Bog, Holmboe Conifer Forest, Stone Lake Pines, Wind Pudding Lake, Gobler Lake, Aurora Lake, Plum Lake Hemlock, Bittersweet Lakes, Goodyear Springs East, High Lake Spruce-Balsam Forest, Frog Lake and Pines, Day Lake, Johnson Lake Barrens, Escanaba Lake Hemlocks, Tomahawk River Pines, Patterson Hemlocks, Squirrel River Pines; The Nature Conservancy Preserves: Bass Lake Preserve.

PUBLIC LAND MANAGERS: Michigan: National Forests: Ottawa. **Wisconsin:** National Forests: Nicolet; State Forests: Northern Highland (includes Manitowish River Wilderness Area), American Legion; Wildlife Areas: Powell Marsh.

CONSERVATION CONCERNS: There is the potential for restoration of pineries within the subsection. The Northern Highland-American Legion State Forest occupies an important location between the Nicolet, Ottawa, and Chequamegon National Forests that allows large-scale biodiversity concerns to be considered in management plans for all of these Forests.

Figure 26.—*Subsection IX.5: Plum Lake-Star Lake Hemlocks, Vilas County, Wisconsin. The pitted outwash forms a landscape of kettle lakes and fire-dependent forests of white pine, red pine, red oak, and paper birch growing on flat, sandy plains. From the air, this landscape superficially resembles that of the Winegar moraine (sub-subsection IX.3.2) immediately to the north. Upon closer examination, the forests of the steep, irregular Vilas moraine are dominated by northern hardwoods and eastern hemlock. Photo by E. Epstein.*

SUBSECTION IX.6. Bergland**; bedrock-controlled topography, dissected lake plain, broad ridges of sandy till; northern hardwoods, upland conifers, conifer swamp.**

DISCUSSION: The subsection is divided into three sub-subsections on the basis of landform and bedrock.

SUB-SUBSECTION: The Gogebic-Penokee Iron Range sub-subsection (IX.6.1) consists of steep ridges of volcanic bedrock; the Ewen sub-subsection (IX.6.2) is a highly dissected clay lake plain; and the Baraga sub-subsection (IX.6.3) is primarily broad ridges of rocky, sandy till derived from underlying sandstone. (See figures 4 and 6.)

ELEVATION: 900 to 1,890 feet (275 to 576 m).

AREA: 2,426 square miles (6,286 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Annual precipitation averages 32 to 36 inches. Annual snowfall is 100 to 180 inches; snowfall is greatest at the northern edge of the subsection in Michigan, on high elevation areas near Lake Superior (Eichenlaub *et al.* 1990, Wisconsin Statistical Reporting Service 1967). Growing season ranges from 100 to 130 days, longest near the Lake Superior shoreline and rapidly shortening inland. Extreme minimum temperature ranges from -40˚F to -50˚F, with coldest temperatures inland.

BEDROCK GEOLOGY: The entire subsection is underlain by Precambrian bedrock, primarily Keweenawan basalts and conglomerates; it also includes iron-rich marine sandstones and dolomites of Huronian age (the Gogebic-Penokee Range) and Archean bedrock (Dorr and Eschman 1984, Morey *et al.* 1982). There are localized to extensive bedrock exposures throughout, except in Sub-subsection IX.6.2. Bedrock is diverse and includes Jacobsville sandstone (feldspathic to quartzose sandstone and shale), granitic rock, mafic volcanic rock, quartzite, basalt, and other minor sedimentary bedrock types (Morey *et al.* 1982).

LANDFORMS: Sub-subsections IX.6.1 and IX.6.3 consist primarily of ground moraine; Sub-subsection IX.6.2 consists of highly dissected lacustrine deposits (Farrand *et al.* 1984, Goebel *et al.* 1983, Clayton 1984). Much of Sub-subsection IX.6.1 is mapped as thin till over bedrock, with discontinuous deposits of till separated by numerous or extensive bedrock outcrops.

LAKES AND STREAMS: The only large lake here is Lake Gogebic in Michigan. Several streams flow north across the subsection and drain into Lake Superior. Many of these streams originate near the southern edge of the subsection. Small waterfalls are common, and many of the streams have steep, bedrock ravines. In Sub-subsection IX.6.2, the streams have formed deep ravines in the clay soils.

SOILS: Soils are classified as Haplorthods and Fragiorthods on the ground moraine and Eutroboralfs and Haplaquepts on the clay lake plain (USDA Soil Conservation Service 1967). In Sub-subsection IX.6.1, soils are red loams and sandy loams, derived from the iron formations eroded and abraided by the glaciers (Hole 1976). On the lake plain of Sub-subsection IX.6.2, soils are red, silty, acidic clays. On the ground moraines of Sub-subsection IX.6.3, soils are rocky, loamy sands and sandy loams, not generally as red as those in Sub-subsection IX.6.1. These soils are classified as Orthods and Inceptisols (Hole 1976).

PRESETTLEMENT VEGETATION: Northern hardwood forests of sugar maple, hemlock, basswood, and yellow birch occupied most of the well-drained soils. On the dissected clay plain, diverse swamp forests of hardwoods and conifers were common on poorly drained sites; common species included balsam fir, white spruce, northern white-cedar, trembling aspen, and paper birch (Albert 1990). White pine occurred locally as pure stands on the lake plain.

NATURAL DISTURBANCE: Windthrows occurred frequently on the steep bedrock-cored ridges, as noted by GLO surveyors (Albert 1990, Albert *et al.* 1986).

PRESENT VEGETATION AND LAND USE: Northern hardwoods continue to dominate the well-drained moraine ridges, but the hardwood-conifer swamps of the lake plain have become

largely dominated by hardwoods after logging. Iron mining was an important industry, but most mines here have been abandoned. Much of the timber from early logging operations was used for construction of mine shafts and buildings within the mining towns.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION IX.6.1. Gogebic-Penokee Iron Range**; bedrock and large moraine ridges; northern hardwoods, white pine-red pine forest on thin soils.**

DISCUSSION: Sub-subsection IX.6.1 is noted for steep ridges of Keweenawan (late Precambrian) basaltic lavas and conglomerates, which rise several hundred feet above the adjacent lake and till plains. The ridges extend from northern Wisconsin to the northern end of the sub-subsection and on to the tip of the Keweenaw Peninsula of Michigan; they are part of the Lake Superior syncline.

ELEVATION: 850 to 1,890 feet (259 to 576 m).

AREA: 1,361 square miles (3,526 sq km).

STATES: Michigan and Wisconsin.

CLIMATE: Growing season ranges from 100 to 114 days in Wisconsin (Wisconsin Agricultural Statistics Service 1987) to 120 to 130 days in Michigan (Eichenlaub *et al.* 1990). Extreme minimum temperatures ranges from -40˚F near Lake Superior to -50˚F farther inland. Average annual precipitation ranges from 31 to 36 inches. Annual snowfall ranges 60 to 200 inches; highest amounts are in Michigan along Lake Superior, and lowest amounts are in Wisconsin, further inland.

BEDROCK GEOLOGY: The sub-subsection is underlain by Precambrian bedrock, primarily Keweenawan basalts and conglomerates, but also including iron-rich marine sandstones and dolomites of Huronian age, as well as Archean bedrock. A part of the narrow band of Huronian-age (middle Precambrian) bedrock forms the iron-rich Gogebic-Penokee Range near the Michigan towns of Ironwood and Bessemer and the Wisconsin towns of Hurley, Pence, and Upson. Erosion-resistant conglomerates form the steep ridges, between which veins of highly eroded lavas form lakes and wetlands. Copper-rich lava flows were extensively mined.

LANDFORMS: Beginning south of the Keweenaw Peninsula, the volcanic bedrock ridges form a narrow, 1- to 2-mile-wide, 200- to 400-feet-high linear rock ridge, from Houghton in the northeast to Bergland in the southwest. This ridge is broken in several places by streams that have eroded through the bedrock. The Porcupine Mountains are a band 3 to 4 miles wide and 10 miles long, of Keweenawan basalt and conglomerate ridges.

South of Bergland and into Wisconsin, the Keweenawan bedrock ridge is partially or completely covered with either fine- or coarse-textured till.

LAKES AND STREAMS: The only large lake is Lake Gogebic, near the southern edge of the sub-subsection. A few small lakes are on the till plain; two lakes are among the bedrock ridges of the Porcupine Mountains: Lake of the Clouds and Mirror Lake. Rivers include the Presque Isle, Montreal, and Black, rapid streams on bedrock.

SOILS: Soils are red loams and sandy loams, derived from the iron formations eroded and abraided by the glaciers (Hole 1976). These are classified as Orthods and Inceptisols (Hole 1976). Locally there are areas of boulders and broken rock.

PRESETTLEMENT VEGETATION: On the bedrock ridges, red pine, white pine, red oak, and paper birch grew on the thin soils. On till, northern hardwood forests were dominated by sugar maple and hemlock, with basswood and yellow birch. Wetland forests were dominated by conifers.

NATURAL DISTURBANCE: Windthrow was locally common on exposed bedrock ridges and on large ground-moraine ridges. In Michigan, these windthrows were occasionally quite large, baring entire ridgetops of trees (Albert 1990). Canham and Loucks (1984) also show areas of windthrow on similar landscapes in Wisconsin.

PRESENT VEGETATION AND LAND USE: Tourism and forestry remain important to the economy. Copper and iron mining were major industries, but almost all mines are now closed.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Wisconsin: *Dryopteris fragrans* (fragrant fern), *Polystichum braunii* (Brown's holly fern).

RARE ANIMALS: *Falco peregrinus* (peregrine falcon).

NATURAL AREAS: Michigan: State Wilderness Areas: Porcupine Mountains; State Scenic Sites: Presque Isle River, Union Springs.

PUBLIC LAND MANAGERS: Michigan: State Parks: Porcupine Mountains, Lake Gogebic; State Forests: Copper Country; National Forests: Ottawa. **Wisconsin:** National Forests: Chequamegon.

CONSERVATION CONCERNS:

BOUNDARIES: Parts of the sub-subsection have been mapped in greater detail by the ECS mappers on the Ottawa and Chequamegon National Forests. My treatment is similar to that of the Ottawa National Forest. Detailed studies of the bedrock exposures and glacial drift depths along the southern boundary might justify expansion of this sub-subsection unit to the south; the GLO surveyors mapped several exposures of volcanic bedrock farther south, but these exposures were very localized.

SUB-SUBSECTION IX.6.2. Ewen**; highly dissected lake plain; northern hardwood forest, white pine forest, spruce-fir forest.**

DISCUSSION: In Michigan, a relatively small area of older glacial lake plain created by Glacial Lake Ontonagon (Leverett 1929) extends about 25 miles further inland than the lake plain of Subsection IX.8. This lake bed is deeply dissected by several rivers and is separated from Subsection IX.8 by a narrow band of steep volcanic bedrock ridges.

ELEVATION: 700 to 1,350 feet (213 to 411 m).

AREA: 482 square miles (1,249 sq km).

STATES: Michigan.

CLIMATE: Growing season is 110 to 120 days (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -44˚F near Lake Superior to -48˚F farther inland. Average annual precipitation ranges from 34 to 36 inches. Average annual snowfall is 120 to 180 inches, with heavier amounts closer to the Lake Superior shoreline.

BEDROCK GEOLOGY: Bedrock is not exposed at the surface except in localized outcrops along streams. Bedrock consists of Keweenawan-age Precambrian sedimentary bedrock, primarily sandstone, shale, and conglomerates. The shales are locally copper-rich.

LANDFORMS: A relatively small area of older glacial lake plain that extends about 35 miles inland. This lake bed is deeply dissected by several rivers.

At the east edge of the sub-subsection, there are some small sand dunes, distinct from the rest of the clay lake plain. Also at the southeast is an area of flat, poorly drained lake plain. The dunes were originally dominated by forests of white and red pine, which have been replaced largely by

bigtooth aspen after logging and post-logging fires. The poorly drained lake plain remains dominated by swamp forest, but there are no data to detail its composition.

LAKES AND STREAMS: The lake plain contains no lakes. Several rivers cut deep ravines, 100 feet deep or more, into the clay soils. Rivers include the South, East, and Middle Branches of the Ontonagon River, and the Baltimore, Firesteel, and Flintsteel Rivers.

SOILS: Primarily lacustrine clays, with some dune sands at the eastern margin.

PRESETTLEMENT VEGETATION: The vegetation of the clay lake plain cannot be easily characterized; drainage conditions varied greatly over small distances on the dissected clay plain, and with these changes came major vegetation changes (Albert 1990, Comer *et al.* 1993a). Flat headwater areas supported a diverse mix of balsam poplar, northern white-cedar, eastern hemlock, white spruce, trembling aspen, and yellow birch. Locally there were also almost pure stands of hemlock and white pine in some flat stream headwaters. Alder formed dense, streamside thickets. On well-drained ridge tops, northern hardwood forests of sugar maple, hemlock, yellow birch, and basswood were locally common.

The dunes in the east were originally dominated by forests of white and red pine.

NATURAL DISTURBANCE: No disturbances noted.

PRESENT VEGETATION AND LAND USE: The upland ridge tops were grazed; almost no examples of original vegetation persist. Pine was harvested for mining timbers. White pine and red pine on the small sand dunes have been replaced largely by bigtooth aspen after logging and post-logging fires.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Carex assiniboinensis* (assiniboia sedge).

RARE ANIMALS: None identified to date.

NATURAL AREAS: None.

PUBLIC LAND MANAGERS: Ottawa National Forest.

CONSERVATION CONCERNS: The dissected topography along streams contains many seepage areas of botanical interest, but only preliminary investigations have been done.

BOUNDARIES: This sub-subsection is part of the Ottawa National Forest, which has done more detailed ECS mapping.

SUB-SUBSECTION IX.6.3. Baraga**; broad ridges of coarse-textured rocky till; northern hardwood forest, few wetlands.**

DISCUSSION: Sub-subsection IX.6.3 consists of broad, ground-moraine ridges (150 to 500 feet high) of well-drained sands and sandy loam soils. Poorly drained soils are not extensive.

ELEVATION: 602 to 1,250 feet (183 to 381 m).

AREA: 583 square miles (1,510 sq km).

STATES: Michigan.

CLIMATE: Relatively cool growing season ranges from 110 to 130 days and is longest near Lake Superior (Eichenlaub *et al.* 1990). Extreme minimum temperature ranges from -34˚F near Lake Superior to -44˚F farther inland. Average annual precipitation ranges from 30 to 36 inches. Heavy lake-effect snowfalls, ranging from 140 to 200 inches, characterize the sub-subsection.

BEDROCK GEOLOGY: Most of the sub-subsection is underlain by Precambrian sedimentary bedrock, the Jacobsville feldspathic to quartzose sandstone and shale (Reed and Daniels 1987, Morey *et al.* 1982).

LANDFORM: Predominant features are large, broad ridges 150 to 500 feet high. Gullying is severe on the steep slopes of the moraines,

especially on the broad ridges near the lake. Lake plain also occurs near Lake Superior; much of the lake plain is poorly drained.

LAKES AND STREAMS: The Sturgeon River flows across both outwash and lake plain. On the outwash and sandy lake plain near the inland edge of the sub-subsection, the river has eroded a deep gorge. Near the Lake Superior shoreline, the river meanders across the flat lake plain. There are many small creeks. Small lakes are concentrated in the west. The largest lakes are Otter Lake, Roland Lake, and Lake Gerald.

SOILS: Acidic, well-drained sands and sandy loams, derived from local sandstone and shale. Rock fragments are common. Poorly drained soils are restricted to stream edges and occasional depressions between the large moraine ridges.

PRESETTLEMENT VEGETATION: The large, sandy and loamy moraines east of L'Anse and north of Baraga supported mostly forests of eastern hemlock and northern hardwoods (Albert 1990, Bourdo 1954). Isolated American beech were noted in the northern hardwood forests northeast of L'Anse near Lake Superior. In moderately drained soils, eastern hemlock grew along with northern white-cedar, balsam fir, and white spruce.

Most wetlands on these moraines were located along river drainages, with northern white-cedar, tamarack, and white spruce as dominants. Speckled alder also grew in thickets along streams. Large, open swamps grew on the flat sand lake plain near Keweenaw Bay; these swamps were dominated by northern white-cedar, [black] spruce, balsam fir, and tamarack. Coastal marshes, quite bog-like in character and noted as containing cranberries, were located at the north end of Huron Bay and on Sand Bay.

Swamps on the clay lake plain, which was restricted to west of Baraga and L'Anse, were dominated by black ash and northern white-cedar. Better drained sites on the clay plain were dominated by hemlock and balsam fir. Alluvial soils along the Sturgeon River supported extensive northern white-cedar and black ash swamps among meandering sloughs, which were bordered by speckled alder and sweet gale. A broad emergent marsh was located at the mouth of the river.

NATURAL DISTURBANCE: A small windthrow at the southern end of Huron Bay, and just south of L'Anse. No major wildfires noted.

PRESENT VEGETATION AND LAND USE: Most of the sub-subsection remains forested. Many roads and several sawmills and missions were already established in this area at the time of GLO surveys in 1845. Land use since that time has involved mining, logging, urban development, and recreation. As noted elsewhere in this region, logging-era activities probably greatly reduced the amount of white pine and hemlock in forests here. Many rivers and streams were diverted for use in mining and logging activities, resulting in impacts to associated wetlands. Roads have also altered wetland hydrology in places.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Arenaria macrophylla* (bigleaf sandwort), *Calypso bulbosa* (Calypso or fairy-slipper), *Castilleja septentrionalis* (pale Indian paintbrush), *Crataegus douglasii* (black hawthorn), *Elymus glaucus* (blue wild-rye), *Epilobium palustre* (marsh willow-herb), *Salix pellita* (satiny willow), and *Scirpus torreji* (Torrey's bulrush), and various *Botrychium* ssp.

RARE ANIMALS: *Erebia discoidalis* (red-disked alpine).

NATURAL AREAS: None.

PUBLIC LAND MANAGERS: National Forests: Ottawa; State Forests: Copper Country; Environmental Areas: Pequaming.

CONSERVATION CONCERNS: Upland conifers, originally common in much of this sub-subsection, have been greatly reduced by logging. There is little conifer regeneration.

SUBSECTION IX.7. Keweenaw**; igneous and sedimentary bedrock ridges, sandy broad ridges; northern hardwood forest with hemlock, upland conifers, upland hardwood-conifer forest, conifer swamps.**

DISCUSSION: Subsection IX.7 is distinguished from adjacent subsections by its strongly lake-influenced climate, which results in a relatively long, cool growing season and heavy lake-effect snowfall. The volcanic bedrock forms steep, exposed bedrock ridges throughout much of the subsection.

SUB-SUBSECTIONS: The Gay sub-subsection (IX.7.1) has coarse-textured, broad ridges over sandstone; the Calumet and Isle Royale sub-subsections (IX.7.2, IX.7.3) have steep ridges of volcanic bedrock.

ELEVATION: 602 to 1,490 feet (183 to 454 m).

AREA: 1,365 square miles (3,535 sq km).

STATES: Michigan.

CLIMATE: Climate in the north is strongly affected by lacustrine influences; this lacustrine influence is somewhat less in the southern interior. Except for air masses from the southwest, all air masses pass over Lake Superior before reaching this subsection, resulting in a relatively long, cool growing season (Albert *et al.* 1986). Winter temperatures are moderated by Lake Superior, but this effect drops off rapidly at the south end of the subsection; extreme minimum temperature is -34˚F along Lake Superior (Eichenlaub *et al.* 1990). Heavy lake-effect snowfall, ranging from 140 to more than 200 inches, characterizes the subsection. Average annual precipitation is 32 inches.

BEDROCK GEOLOGY: Erosion-resistant Precambrian conglomerates and amygdaloidal basalt form the steep ridges along the northern half of the Keweenaw Peninsula and on Isle Royale (Dorr and Eschman 1984, Reed and Daniels 1987). Between the ridges are depressions formed from veins of more easily eroded lavas. Freda sandstone and Nonesuch shale are exposed along the northern half of the Keweenaw Peninsula; the Jacobsville sandstone (also of Precambrian age) forms the southern half of the peninsula. The bedrock ridges of the Keweenaw Peninsula and of Isle Royale are part of the Lake Superior syncline, which extends from northern Wisconsin to the tip of the Keweenaw Peninsula of Michigan.

LANDFORMS: Gay sub-subsection (IX.7.1): broad ridges of sandy till. Calumet (IX.7.2) and Isle Royale (IX.7.3) sub-subsections: steep, linear bedrock ridges, lakes, and wetlands. See sub-subsections.

LAKES AND STREAMS: See sub-subsections.

SOILS: See sub-subsections.

PRESETTLEMENT VEGETATION: See sub-subsections.

NATURAL DISTURBANCE: See sub-subsections.

PRESENT VEGETATION AND LAND USE: See sub-subsections.

RARE PLANT COMMUNITIES: See sub-subsections.

RARE PLANTS: See sub-subsections.

RARE ANIMALS: See sub-subsections.

NATURAL AREAS: See sub-subsections.

PUBLIC LAND MANAGERS: See sub-subsections.

CONSERVATION CONCERNS: See sub-subsections.

SUB-SUBSECTION IX.7.1. Gay**; coarse-textured broad ridges and swamps; sandy till plain; rocky, sandy ground moraine; northern hardwood forest, hardwood-conifer and conifer swamp bog.**

DISCUSSION: Sub-subsection IX.7.1 consists of broad sandy ridges, up to 550 feet high, with gentle to moderate slopes.

ELEVATION: 602 to 1,000 feet (184 to 305 m).

AREA: 850 square miles (2,200 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: Jacobsville sandstone of Precambrian age is only locally exposed (Reed and Daniels 1987, Morey *et al.* 1982).

LANDFORMS: Broad ground-moraine ridges characterize most of the sub-subsection, but a narrow band of sand lake plain extends along the Keweenaw Bay shoreline for approximately 25 miles. Abandoned, poorly drained beach terraces occur far above the present Lake Superior water levels.

LAKES AND STREAMS: A few large lakes occur on both the ground moraine and the lake plain parts of the sub-subsection. The large lakes on the ground moraine include Lake Linden, Mud Lake, and Lake Gratiot. The lakes on the sand lake plain include Rice and Deer Lakes and Lac La Belle. Lac La Belle is part of an embayment of Bete Grise Bay of Lake Superior, which has been separated from the bay by sandbars. Extensive shallow peatlands surround the lakes on the sand lake plain. Several extensive wetlands occupy depressions between the ridges and the shoreline near Keweenaw Bay at the northeastern end of the subsection. The largest of these coastal wetlands, 1 to 4 miles wide and 25 miles long, is on a plain of lacustrine sand. The Tobacco and Traverse Rivers meander across the flat sand plain.

SOILS: Gravelly sands and sandy loams. Soils of the uplands are typically well-drained, acidic, loamy sands and sandy loams derived largely from the underlying Jacobsville sandstone and shale. Soils tend to be rockier in the north. Soils on abandoned lake terraces are often rocky and poorly drained.

PRESETTLEMENT VEGETATION: On the sandy ground moraine of the eastern Keweenaw Peninsula, northern hardwoods covered most of the landscape. Sugar maple, basswood, and hophornbeam were the most common species. Eastern hemlock was more common along the shorelines, where it often had more than 50 percent relative dominance in the overstory (Bourdo 1954).

Poorly drained portions of the moraines were dominated by northern white-cedar, black spruce, and balsam fir. Cedar swamps ringed by thickets of speckled alder were common in narrow valleys between ridges.

On the sandy lake plain along Keweenaw Bay, complexes of forested beach ridges and swales occurred. The wide swales had shallow organic (peat) soils dominated by stunted tamarack and black spruce. The larger ridges supported white pine and red pine; the smaller, lower ridges often supported northern white-cedar and other swamp hardwoods or conifers. An extensive shallow peatland, with a narrow border of emergent marsh, surrounded Lac La Belle.

Hardwood-conifer swamps, containing northern white-cedar, balsam fir, black spruce, paper birch, and black ash, were also found on rocky, poorly drained beach terraces far above the present lake level.

NATURAL DISTURBANCE: GLO surveyors noted many windthrows throughout the poorly drained soils of this sub-subsection.

PRESENT VEGETATION AND LAND USE: Native American encampments were noted by surveyors around Little Traverse Bay in 1845. Logging, mining, and pasture have been the historically important land uses here. The deposition of mine tailings along the shoreline is most evident at Gay; but mining tailings have

been deposited in many other areas, both wetland and upland, throughout the sub-subsection.

Recently, recreational and cottage development along the shoreline and along inland lakes has intensified.

RARE PLANT COMMUNITIES: None are known.

RARE PLANTS: *Arenaria macrophylla* (bigleaf sandwort), *Calypso bulbosa* (Calypso or fairy-slipper), *Castilleja septentrionalis* (pale Indian paintbrush), *Crataegus douglasii* (black hawthorn), *Elymus glaucus* (blue wild-rye), *Epilobium palustre* (marsh willow-herb), *Salix pellita* (satiny willow), and *Scirpus torreji* (Torrey's bulrush).

RARE ANIMALS: *Falco columbarius* (merlin).

NATURAL AREAS:

PUBLIC LAND MANAGERS: State Forests: Copper Country; State Environmental Areas: Traverse Island.

CONSERVATION CONCERNS: Forest cutting has been recent and severe, eliminating most or all mature forest. At the northern end of the sub-subsection, on the Keweenaw Peninsula, development of second homes may occur, but probably not to the degree expected along the western, rocky shoreline of the peninsula.

SUB-SUBSECTION IX.7.2. Calumet**; basalt and conglomerate "trap rock"; bedrock knobs and shoreline; northern hardwood forest, balds, white pine forest, white pine-red pine-red oak on bedrock, spruce-fir forest, bog.**

DISCUSSION: Sub-subsection IX.7.2 is noted for steep ridges of Keweenawan (late Precambrian) basaltic lavas and conglomerates, which rise several hundred feet above the adjacent lake and till plains. The ridges of the Keweenaw Peninsula are part of the Lake Superior syncline, which extends from northern Wisconsin to the tip of the Keweenaw Peninsula of Michigan.

ELEVATION: 850 to 1,490 feet (259 to 454 m).

AREA: 285 square miles (740 sq km).

STATES: Michigan.

CLIMATE: See subsection.

BEDROCK GEOLOGY: The Precambrian bedrock is primarily Keweenawan basalts and conglomerates, but also includes sedimentary bedrock, such as the Freda sandstone and Nonesuch shale (Dorr and Eschman 1984, Reed and Daniels 1987). Erosion-resistant conglomerates and amygdaloidal basalt form the steep ridges of the sub-subsection, between which veins of more easily eroded lavas are sites for lakes and wetlands. The Lake Superior shoreline also consists of rugged volcanic bedrock. Copper-rich lava flows, common on the Keweenaw Peninsula, were extensively mined. The Nonesuch shale also contains copper, but often in concentrations too low for profitable mining.

The bedrock ridges of the Keweenaw Peninsula and of Isle Royale are both part of the Lake Superior syncline, which extends from northern Wisconsin to the tip of the Keweenaw Peninsula of Michigan. Isle Royale, located at the northern end of the syncline, is treated as another sub-subsection because of its climate, which is even more strongly influenced by surrounding Lake Superior than that of Sub-subsection IX.7.2.

LANDFORMS: The steep ridges of exposed bedrock rise several hundred feet above the broad plateau of the adjacent Gay sub-subsection (IX.7.1). Steep slopes occur along the north face of ridges, and high cliffs occur on the south face. Narrow wetlands are found in many of the depressions between the parallel ridges of resistant conglomerate and amygdaloidal basalt. At the foot of ridges, the landscape is strewn with boulders.

There are local areas of lacustrine sands, including small dunes, along the Lake Superior shoreline to the north. Broad areas of rocky ground moraine are in the west.

LAKES AND STREAMS: Two large lakes: Lake Medora, surrounded by bedrock, and Schlatter

Lake on sand lake plain at the southeast edge of the sub-subsection. Rivers: the Gratiot and Montreal.

SOILS: Rocky, red sandy loams and silt loams. Soils are classified as moderately sloping Haplorthods plus Fragiorthods in the south and moderately to steeply sloping Haplorthods plus rock lands in the north (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: On bedrock ridges, red pine, white pine, red oak, and paper birch grew on the thin soils (Comer *et al.* 1993a). Krummholz, resulting from strong winds and heavy snow, was found on most extreme knobs. In protected bedrock valleys and on till, northern hardwood forests were dominated by sugar maple and hemlock. Forests dominated by northern white-cedar, balsam fir, hemlock, and paper birch were located in uplands on thin till and ground moraine west of Ahmeek.

Black spruce, northern white-cedar, and tamarack-dominated swamps occurred along the northern shoreline where soils are poorly drained till over bedrock. Cedar, hemlock, and balsam fir also dominated poorly drained parts of the sand lake plain west of Eagle Harbor, where jack pine grew on excessively drained sand dunes.

NATURAL DISTURBANCE: Windthrows noted in swamps along the northern shoreline.

PRESENT VEGETATION AND LAND USE: European settlements, including Fort William, and several mines and roads had already been established in this sub-subsection by 1845 when the area was surveyed. Major land uses in this sub-subsection have included copper mining, logging, and more recently, recreational/cottage development along the shoreline and inland lakes.

As elsewhere in this subsection, rivers were heavily affected by historical mining and logging activities. The deposition of mine tailings has had a negative impact on coastal wetlands in several places. The large swamp/marsh complex at the north end of Portage Lake was nearly eliminated in the construction of the shipping channel linking that lake to Lake Superior.

RARE PLANT COMMUNITIES: Bedrock balds with krummholz occur on several of the conglomerate or basalt ridges, and bedrock beach occurs along the Lake Superior shoreline. Both of these plant communities have floras rich in boreal and disjunct western montaine species.

RARE PLANTS: *Arenaria macrophylla* (bigleaf sandwort), *Arnica cordifolia* (heart-leaved arnica), *Carex pallescens* (pale sedge), *Carex rossii* (Ross's sedge), *Calypso bulbosa* (Calypso or fairy-slipper), *Castilleja septentrionalis* (pale Indian paintbrush), *Ceanothus sanguineus* (redstem ceanothus or wild lila), *Chamaerhodos erecta* var. *keweenawensis* (Keweenaw rock-rose), *Collinsia parviflora* (small blue-eyed Mary), *Crataegus douglasii* (black hawthorn), *Dryopteris filix-mas* (male fern), *Elymus glaucus* (blue wild-rye), *Epilobium palustre* (marsh willow-herb), *Pellaea atropurpurea* (purple cliff-brake), *Phleum alpinum* (mountain timothy), *Potentilla pensylvanica* (prairie cinquefoil), *Sagina nodosa* (pearlwort), *Salix pellita* (satiny willow), *Scirpus torreji* (Torrey's bulrush), *Senecio indecorus* (rayless mountain ragwort), *Trisetum spicatum* (downy oat-grass).

RARE ANIMALS: *Falco columbarius* (merlin).

NATURAL AREAS: The Nature Conservancy Preserves: Horseshoe Harbor; Michigan Nature Association Preserves: Estivant Pines, Keweenaw Shore #1 and #2, Dan's Point, Hylton Memorial, K.W. and T.S. Gunn Memorial, R. and M. Grinnel Memorial, Brockway Mountain, J.H. Klipfel.

PUBLIC LAND MANAGERS: State Forests: Copper Country; State Parks: Fort Wilkins.

CONSERVATION CONCERNS: Mining has heavily degraded the shoreline, as well as creeks and rivers. The full impact upon the biota of mining has not been evaluated.

The area is targeted by some of its major landowners for condominium and second-home development. Bedrock shorelines, and to some extent ridges, are the major focus of this development. To date, no conservation organization is developing a comprehensive plan for protecting this sensitive habitat, even though it is recognized as biologically important and fragile.

SUB-SUBSECTION IX.7.3. Isle Royale**; island of volcanic bedrock ridges and wetlands; hardwood-conifer-dominated upland and wetland vegetation.**

DISCUSSION: The bedrock ridges of the Keweenaw Peninsula and of Isle Royale are both part of the Lake Superior syncline, which extends from northern Wisconsin to the tip of the Keweenaw Peninsula of Michigan. Isle Royale, located at the northern end of the syncline, is treated as a separate sub-subsection because of its climate, which is even more strongly influenced by surrounding Lake Superior than that of Sub-subsections IX.7.1 and IX.7.2.

ELEVATION: 602 to 1,362 feet (184 to 415 m).

AREA: 230 square miles (595 sq km).

STATES: Michigan.

CLIMATE: Climatic data are not available for Isle Royale. Lake Superior has a strong climatic influence on the island; even in the middle of the summer, temperatures are low. Fog occurs commonly.

BEDROCK GEOLOGY: Erosion-resistant conglomerates and amygdaloidal basalt form the ridges of the sub-subsection, between which veins of more easily eroded lavas are sites for lakes and wetlands (Dorr and Eschman 1984, Reed and Daniels 1987). The Lake Superior shoreline consists of rugged volcanic bedrock. Copper-rich lava flows were extensively mined.

LANDFORM: Linear bedrock ridges and narrow wetlands characterize most of the island, while thin, rocky till covers the southwestern end. There are several steep bedrock peaks, including Sugar Mountain (1,362 feet), Mount Ojibway (1,136 feet), and Mount Siskiwit (1,205 feet).

LAKES AND STREAMS: Several linear, inland lakes: Siskiwit, Desor, Feldtmann, and Sargent; numerous narrow embayments connected to Lake Superior. Streams on the island are small.

SOILS: Soils are thin and sandy or loamy; boulders are common. Bedrock is at the surface over most of the island. Depressions in the bedrock contain organic soils.

PRESETTLEMENT VEGETATION: The thin, rocky soils of Isle Royale supported trembling aspen, white spruce, and balsam poplar. Sugar maple grew on areas with deeper soils.

NATURAL DISTURBANCE: Both windthrows and fires noted.

PRESENT VEGETATION AND LAND USE: Copper was mined by Native Americans and by early European settlers. The entire island is now a National Park.

RARE PLANT COMMUNITIES: Bedrock balds and bedrock beaches support a diverse flora of boreal and disjunct northwestern montaine species.

RARE PLANTS: *Carex atratiformis* (sedge), *Carex media* (sedge), *Castilleja septentrionalis* (pale Indian paintbrush), *Clematis occidentalis* (purple clematis), *Collinsia parviflora* (small blue-eyed Mary), *Cryptogramma acrostichoides* (American rock-brake), *Draba arabisans* (rock whitlow-grass), *Draba incana* (twisted whitlow-grass), *Dryopteris expansa* (expanded woodfern), *Empetrum nigrum* (crowberry), *Euphrasia arctica* (American eyebright), *Lactuca pulchella* (blue lettuce), *Lonicera involucrata* (fly honeysuckle), *Luzula parviflora* (small-flowered woodrush), *Nymphaea tetragona* (pygmy water-lily), *Oplopanax horridus* (devil's club), *Osmorhiza depauperata* (sweet cicely), *Parnassia palustris* (marsh grass-of-Parnassus), *Phacelia franklinii* (Franklin's phacelia), *Phleum alpinum* (mountain timothy), *Poa alpina* (alpine bluegrass), *Polygonum viviparum* (alpine bistort), *Potentilla pensylvanica* (prairie cinquefoil), *Ranunculus macounii* (Macoun's buttercup), *Ranunculus rhomboideus* (prairie buttercup), *Ribes oxyacanthoides* (northern gooseberry), *Sagina nodosa* (pearlwort), *Salix planifolia* (tea-leaved willow), *Saxifraga paniculata* (encrusted saxifrage), *Saxifraga tricuspidata* (prickly saxifrage), *Senecio indecorus* (rayless mountain-ragwort), *Tofieldia pusilla* (false asphodel), *Trisetum spicatum* (downy oat-grass), *Vaccinium*

uliginosum (alpine blueberry), *Vaccinium vitis-idaea* (mountain-cranberry), *Viburnum edule* (squashberry or mooseberry).

RARE ANIMALS: *Alces alces* (moose), *Canis lupis* (gray wolf), *Falco columbarius* (merlin), *Falco peregrinus* (peregrine falcon), *Felis lynx* (lynx), *Lycaeides idas nobokovi* (northern blue butterfly).

NATURAL AREAS: Wilderness Natural Parks: Isle Royale; Research Natural Areas: Passage Island.

PUBLIC LAND MANAGERS: National Park Service: Isle Royale.

CONSERVATION CONCERNS: The combination of remoteness and wilderness status makes this a secure landscape.

Figure 27.—*Sub-subsection IX.7.3: Isle Royale Wilderness Natural Park, Michigan. Isle Royale was formed from the extensive Keweenawan-age lava flows. The lava flows more resistant to erosion by waves and ice remain as small islands off the coast of Isle Royale; the less resistant flows have been eroded away. The lava, which was laid down as numerous, thin horizontal layers on land, has been greatly deformed; the layers now slope at 30 to 40 degrees from the horizontal. Photo by P. Melhop.*

SUBSECTION IX.8. Lake Superior Lake Plain**; level clay lake plain and water-reworked moraine of clayey till; spruce-fir forest, white pine-hemlock forest.**

DISCUSSION: Subsection IX.8 is a relatively narrow band of lacustrine clays and clayey till reworked by water, ranging from 1 to 24 miles wide, located along the south and west shore of Lake Superior. It consists of nearly 200 miles of Lake Superior shoreline in Michigan, Minnesota, and Wisconsin. It is widest in Minnesota. Most of the subsection was part of proglacial Lake Superior.

ELEVATION: 602 to 1,280 feet (184 to 390 m).

AREA: 2,167 square miles (5,612 sq km).

STATES: Minnesota, Wisconsin, Michigan.

CLIMATE: Growing season ranges from 110 to 140 days; with the shortest growing season at the western edge of the subsection (Eichenlaub *et al.* 1990, University of Minnesota *et al.* 1977). Annual snowfall is heavy in Michigan, where lake-effect snows range from 120 to 160 inches. Annual snowfall decreases rapidly to the west, from about 100 inches at the Wisconsin-Michigan border to less than 60 inches at the western edge in Minnesota (Wendland *et al.* 1992). Total annual precipitation is 29 to 34 inches. Extreme minimum temperature ranges from -30˚F to -40˚F.

BEDROCK GEOLOGY: Bedrock is not exposed at the surface except in localized outcrops along streams and at isolated parts of the shoreline. Bedrock consists of Precambrian (middle Proterozoic) sedimentary bedrock, primarily feldspathic to quartzose sandstone and shale, and including lithic sandstone and siltstone (Morey *et al.* 1982). The shale is locally copper-rich (Dorr and Eschman 1984).

LANDFORMS: Glacial lake plain and water-reworked moraine cover almost all the subsection. Parts of this subsection are relatively flat east of the Porcupine Mountains in Michigan and along most of the Wisconsin shoreline. In these stretches, the lake plain and water-reworked moraine are dissected by numerous small rivers with straight, shallow valleys. Between the Porcupine Mountains and the Wisconsin border, the subsection is narrow and steeply sloping, with deeply eroded streams, often with waterfalls. At the west end in Minnesota, the broad lake plain is deeply dissected by the St. Louis and Nemadji Rivers and several smaller tributaries.

LAKES AND STREAMS: No lakes; many streams. See LANDFORMS.

SOILS: Leached calcareous red loams and clays as well as pink sands that are podsolized. Most of the soils are moderately well drained, but peat is extensive in some wetlands in Wisconsin (Hole and Germain 1994). Wetland soils are not extensive in either Michigan or Minnesota. Soils are derived from local, iron-rich, volcanic bedrock and shale. They are classified as Aquepts and Boralfs (USDA Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The conifer- and hardwood-conifer-dominated vegetation of both the flat uplands and the steep ravines has been called boreal forest in Wisconsin. In Michigan, common dominants included hemlock, northern white-cedar, balsam fir, white spruce, black ash, basswood, American elm, balsam poplar, and trembling aspen (Albert 1990, Comer *et al.* 1993a). In Wisconsin, balsam fir and white spruce were dominant and persist in parts of the Apostle Islands National Lakeshore. In Minnesota, eastern hemlock, spruce, northern white-cedar, and white pine were noted as present; this is the western extent of hemlock. Sugar maple and other northern hardwoods were dominant on only local better drained sites.

NATURAL DISTURBANCE: In Michigan, no large disturbances were mapped by the original surveyors (Albert 1990, Comer *et al.* 1993a). Along all other Great Lakes shorelines in Michigan, the surveyors noted small areas of windthrow; it is assumed that such windthrows were also relatively common along Lake Superior. Fluctuating levels of Lake Superior are critical natural disturbances that influence coastal wetlands.

PRESENT VEGETATION AND LAND USE: Following logging, trembling aspen is a common dominant throughout the subsection. In Minnesota, yellow birch is more common here than elsewhere in the State. In Michigan, mining for copper occurred into the early 20th century, and white pine was extensively cut for the mining industry and local construction. A small percent of the land near Lake Superior is used for pasture, but most of the land remains forested. Many rivers were diverted for mining/logging. Large tailings ponds are located here.

Species composition in forests has changed since the logging era; white pine and hemlock have become much less abundant. Urban development along the shoreline has eliminated or altered some coastal wetlands.

RARE PLANT COMMUNITIES: Spruce-fir or boreal forest is found throughout. Several rare plants grow on cliffs, where sandstone (Orienta formations) is exposed along the shoreline of the mainland and on Devil's Island. Sand dunes occur in Wisconsin, as does a large Great Lakes estuary.

RARE PLANTS: Michigan only: *Mimulus guttatus* (western monkey-flower). **Minnesota:** *Tsuga canadensis* (eastern hemlock), *Viola novae-angliae* (New England violet). **Wisconsin only:** *Listera auriculata* (auricled twayblade), *Listera convallarioides* (broad-leaved twayblade), *Lycopodium selago* (fir clubmoss), *Osmorhiza chilensis* (Chilean sweet cicely), *Trisetum spicatum* (spike trisetum), *Pinguicula vulgaris* (butterwort), *Senecio indecorus* (plains ragwort).

RARE ANIMALS: *Catharus ustulatus* (Swainson's thrush), *Dendroica tigrina* (Cape May warbler), *Dendroica fusca* (Blackburnian warbler), *Empidonax flaviventris* (yellow-bellied flycatcher), *Sterna hirundo* (common tern), *Charadrius melodus* (piping plover).

NATURAL AREAS: Michigan: National Forests: Ottawa, Black River (old-growth white pine and hemlock forest); State Parks: Porcupine Mountains Wilderness State Park (largest protected areas of northern hardwoods in Midwest). **Minnesota:** Hemlock Ravine State Natural Area. **Wisconsin:** National Lakeshore: Apostle Islands; State Natural Areas: Bark Bay Sloughs, Port Wing Boreal Forest, Big Bay Sand Spit and Bog, Apostle Islands Maritime Forest, Apostle Islands Maritime Cliffs, Apostle Islands Sandscape, Apostle Islands Critical Species Sites, Lost Creek Bog, Bibon Marsh.

PUBLIC LAND MANAGERS: Michigan: National Forests: Ottawa; State Forests: Copper Country. **Minnesota:** State Parks: Jay Cooke; State Forests: Nemadji; Municipal Forests: Magney-Snivley. **Wisconsin:** National Forests: Chequamegon; National Park Service: Apostle Islands.

CONSERVATION CONCERNS: The Kakagon-Bad River Sloughs, a huge wetland complex, occurs in the subsection and is owned by the Bad River Band of the Lake Superior Chippewa. The Bad River Band should be included in future efforts to assess and protect biodiversity.

BOUNDARIES: Both the Ottawa and Chequamegon National Forests have done more detailed ECS mapping of this subsection.

Figure 28.—*Subsection IX.8: Kakagon Sloughs, Ashland County, Wisconsin. The sloughs are the largest intact wetland of their kind along Lake Superior. The sloughs support numerous wetland plant communities, including extensive beds of wild rice. A coastal sand spit separates the wetlands from Lake Superior. Most of the uplands surrounding the sloughs have red clay soils derived from the local iron-rich bedrock. The forests of the uplands were dominated primarily by a mix of both upland and wetland conifers, with paper birch, trembling aspen, and balsam poplar; northern hardwoods were restricted to well-drained sites. Photo by T. Cline, Photair Inc.*

SECTION X. NORTHERN MINNESOTA**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Humid Warm-Summer Continental Division, Laurentian Mixed Forest Province; drought prone with low winter precipitation; Precambrian Shield bedrock, late Wisconsinan-age glaciated landscape; upland conifer forests, extensive paludified peatlands and conifer swamps.**

SUBSECTION X.1. Bayfield Barrens**; ice-stagnation topography with kettle lakes and outwash; jack pine barrens.**

DISCUSSION: Subsection X.1 is an interlobate area with extensive areas of pitted outwash. Barrens dominated by jack pine and northern pin oak cover most of the subsection.

SUB-SUBSECTIONS: None.

ELEVATION: 760 to 1,505 feet (232 to 459 m).

AREA: 2,141 square miles (5,546 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: Growing season ranges from 120 to 140 days (Reinke *et al.* 1993). Extreme minimum temperature ranges from -40˚F to -45˚F. Annual precipitation averages 30 to 32 inches (Wendland *et al.* 1992). Annual snowfall ranges from 48 inches at the southern edge of the subsection to 68 inches in the north along Lake Superior.

BEDROCK GEOLOGY: Precambrian and Cambrian bedrock are covered with 100 to 600 feet of glacial drift; thickest deposits are in the northern half of the subsection (Trotta and Cotter 1973). The underlying bedrock is Cambrian (undivided) quartzose and glauconitic sandstone and siltstone at the southern edge (Morey *et al.* 1982). Farther north the bedrock is Precambrian basalt, lithic conglomerate, sandstone, and shale, and feldspathic to quartzose sandstone.

LANDFORMS: A large plain of pitted outwash (Hole 1976, Hadley and Pelham 1976). The landscape consists of two distinctly different landforms: the flat plains or terraces (outwash) formed from sediments of proglacial meltwater rivers, and the hummocky sediments deposited by proglacial meltwater rivers on masses of stagnant glacial ice (Clayton 1984). The hummocky collapsed "outwash" is lower in elevation than nearby uncollapsed plains and is scattered throughout the subsection. One of the most conspicuous Pleistocene landforms in Wisconsin, the spillway of Glacial Lake Superior, is now occupied by the St. Croix and Brule Rivers.

LAKES AND STREAMS: Several hundred kettle lakes on the pitted outwash plain.

SOILS: Deep loamy sands, low in organic material, are common throughout the barrens, both on upper slopes and in depressions (Hole and Germain 1994). These soils are classified as Psamments and Orthods.

PRESETTLEMENT VEGETATION: Barrens of jack pine and northern pin oak were the dominant vegetation on the southern two-thirds of the subsection, where the landscape was least broken by lakes and streams (Sweet 1880). Red and white pine grew on parts of the landscape that were both hilly and broken by lakes, and therefore more protected from extreme fires.

White pine-red pine forest dominated the northern end of the subsection, where the combination of an east-west-trending end moraine and hillier outwash may have reduced fire intensity; even here, jack pine barrens occupied close to half of the land surface. Local areas of oak forest or savanna of white oak, red oak, and bur oak occurred. There were extensive sedge meadows in western Burnett County.

NATURAL DISTURBANCE: Fire occurred commonly and was important for maintaining the conifer-dominated upland forests (Murphy 1931, Curtis 1959).

PRESENT VEGETATION AND LAND USE: Large areas remain as barrens, which are managed by the Wildlife Bureau of the Wisconsin Department of Natural Resources for sharp-tailed grouse. Because of the heavy burn regime on these barrens, little timber remains; they are actually more like brush prairies. Large areas are also managed as jack pine plantations for pulpwood. Some wetlands are used for cranberry production (Hole 1976).

RARE PLANT COMMUNITIES: Wisconsin has several large jack pine barrens within this subsection. A fairly sharp climatic break appears to strongly influence the prairie component in the barrens understory. North and east of Namekagon barrens in northern Burnett County, the prairie flora is depauperate; the barrens to the south and west have a rich prairie flora and fauna, including herptiles and invertebrates.

RARE PLANTS: *Botrychium ternatum* (ternate grape fern), *Liatris punctata* var. *nebraskana* (dotted blazing star).

RARE ANIMALS: Insects: *Lycaeides melissa samuelis* (northern blue butterfly); Birds: *Ammodramus caudacutus* (sharp-tailed sparrow), *Coturnicups noveboracensis* (yellow rail).

NATURAL AREAS: Wisconsin: State Natural Areas: Crex Sand Prairie, Brant Brook Pines and Hardwoods, Ekdall Brook Conifer Swamp, Kohler-Peet Swamp Hardwoods, St. Croix River Barrens and Cedar Swamp, Sterling Barrens, St. Croix River Swamp Hardwoods, Lampson Moraine Pines, Totagatic Highlands Hemlocks, Solon Springs Sharptail Barrens, Upper Brule River, Bois Brule Conifer Bog, Sajdak Springs, Moquah Barrens, Kissick Alkaline Bog Lake.

PUBLIC LAND MANAGERS: Wisconsin: National Forests: Chequamegon; Scenic Riverways: St. Croix, St. Croix-Namekagon; State Forests: Governor Knowles, Brule River; State Parks: Lucius Woods; Wildlife Areas: Crex Meadows and Fish Lake.

CONSERVATION CONCERNS: Planting of pine monocultures, wetland alteration, fire exclusion, and recreational development. The St. Croix-Namekagon River system is a high conservation priority in Wisconsin.

Figure 29.—*Subsection X.1: Solon Springs Sharptail Barrens, Douglas County, Wisconsin. The flat to rolling outwash sands of the subsection support extensive areas of open jack pine barren, with sedge meadows in shallow depressions. Prescribed burns are being conducted to improve habitat for sharptail grouse. Photo by E. Epstein.*

SUBSECTION X.2. Mille Lacs Uplands**; rocky, loamy ground moraine and end moraines; white pine-sugar maple, white pine-red pine, and aspen-birch forests, oak forests at south and west edge of subsection, conifer swamps.**

DISCUSSION: Subsection X.2 consists primarily of rolling ground moraine with large drumlin fields, but a narrow, steep, clayey band of end moraines occurs along the northern edge of the subsection and along the western and southeastern end of Mille Lacs Lake.

SUB-SUBSECTIONS: None.

ELEVATION: 800 to 1,395 feet (244 to 425 m).

AREA: 6,489 square miles (16,813 sq km).

STATES: Minnesota and Wisconsin.

CLIMATE: Climate here is moderated little by Lake Superior. Total annual precipitation ranges from 27 inches in the west to 30 inches in the east; growing season precipitation ranges from 12 to 13 inches (University of Minnesota *et al.* 1971, 1977). Snowfall is relatively light, 52 to 60 inches (Wendland 1992); the location, primarily southwest of Lake Superior, is not characterized by lake-effect snows. Growing season length ranges from 97 to 135 days; the longest growing season is in the south and the shortest is on the outwash plains at the northern edge (University of Minnesota *et al.* 1977, 1980b). Extreme minimum temperature ranges from -40˚F to -45˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Glacial drift is typically less than 100 feet thick; bedrock is locally exposed throughout the northern part of the subsection, but not in the southeastern part, where drift thickness is 100 to 300 feet (Olsen and Mossler 1982, Trotta and Cotter 1973). Although bedrock of most of the subsection is Precambrian in age, at the southeastern edge are Cretaceous marine shale, sandstone, and variegated shale (Morey 1976, Morey *et al.* 1982, Ostrom 1981). In the north there is lower Precambrian (Archean) undivided granite, metavolcanic, and metasedimentary rocks (Morey 1976, Morey *et al.* 1982). Further south are middle Precambrian (Proterozoic) argillite, siltstone, quartzite, and graywacke, as well as iron formation. Surrounding Mille Lacs Lake are both middle Precambrian undifferentiated granite and lower Precambrian metasedimentary and metaigneous gneiss, schist, and migmatite, as well as amphibolite.

LANDFORMS: Subsection consists primarily of Superior lobe ground moraine and includes the Brainerd-Pierz and Automba drumlin fields and the McGrath till plain (University of Minnesota *et al.* 1977, 1980b; Hobbs and Goebel 1982). The depressions between drumlin ridges contain peatlands with shallow organic material. Small areas of Des Moines lobe ground moraine are in the southeast part (Hobbs and Goebel 1982). In the northeast, the Sawyer-Cloquet and the Willow River outwash plains occupy more than 100,000 acres (University of Minnesota *et al.* 1977).

End moraines, concentrated at the northern edge of the subsection and along the western and southern edges of Mille Lacs, are prominent features with rolling to steep, irregular topography (University of Minnesota *et al.* 1971, 1977).

LAKES AND STREAMS: Few lakes on most of the ground moraine; numerous shallow peatlands. In contrast, bogs, small wetlands, and kettle lakes are common on the end moraines north and west of Mille Lacs. More than 70 lakes are larger than 160 acres, and lakes cover 7 to 8 percent of the surface area of the end moraines. Kettle lakes and peatlands also occur on the Sawyer-Cloquet and Willow River outwash plains.

SOILS: At the eastern end of the subsection, the end moraines and ground moraines have loamy soils; farther to the west, the soils are stony sands. Soils are described as acidic, stony, reddish sandy loams, silt loams, and loamy sands (Hole 1976, Hobbs and Goebel 1982). The parent material in the Grantsburg (Des Moines lobe) part of the subsection is generally more calcareous and finer textured; but Superior lobe drift underlies the Grantsburg deposits and is locally exposed.

On the end moraines surrounding Mille Lacs, most soils are derived from silt- or clay-rich

glacial drift, but there are also sandy and gravelly soils (University of Minnesota *et al.* 1971, 1977). The glacial drift in the north is calcareous; the drift in the south is typically acidic.

Soils are classified as Psamments on the outwash and both Boralfs and Ochrepts on the ground moraines (Anderson and Grigal 1984). On the end moraines surrounding Mille Lacs, the soils are classified primarily as Boralfs and Hemists, but there are also Aqualfs and Ochrepts (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: The original vegetation consisted of a mosaic of forest types on the ground moraine. East of Mille Lacs Lake, on the sandy, stony till of the Mille Lacs moraine, vegetation consisted primarily of white pine-red pine forest and aspen-white birch-white pine forest on the uplands, with equally as much conifer swamp (northern white-cedar, hemlock, larch, and black spruce) on the lowlands (Marschner 1974, Finley 1976). Mixed hardwood-white pine forests were less common than the above mentioned forest types. The Sawyer-Cloquet and the Willow River outwash plains, also located east of Mille Lacs Lake, were dominated by white pine-red pine forests and less commonly by pure stands of white pine. Both of these outwash plains had large areas of jack pine barrens near their northeastern ends.

To the southwest, on the drumlin south of Mille Lacs Lake, the dominant forest types were mixed hardwoods-white pine to the north; areas of pure white pine were concentrated on several narrow outwash channels, which were oriented north-south. In this area, the vegetation changes to forest types containing more oaks. Marschner (1974) called these his Big Woods type, which included bur, white, red, and black oaks, elm, basswood, ash, maple, and many other hardwood species. The Big Woods type continued along the southern edge of the subsection on both the Superior lobe and Des Moines lobe glacial drift. White pine and sugar maple commonly occurred together here. White pine often formed a superstory, with sugar maple as smaller overstory or understory trees.

Both mixed hardwood-pine forests and white pine-red pine forests were well represented on the irregular moraines (Marschner 1974). Aspen-birch forest was also present, and conifer swamps and bogs were common in the kettle depressions of the moraines. Large concentrations of sugar maple grew at the south end of Mille Lacs. White pine-red pine forest was abundant on the moraines north and east of that lake.

NATURAL DISTURBANCE: Both fire and windthrow were important in determining the vegetation of the subsection.

PRESENT VEGETATION AND LAND USE: White pine lumbering was concentrated in this section in Minnesota at the turn of the century (Kratz and Jensen 1983). High-quality examples of the following plant communities are well represented in this subsection: maple-basswood forest, mesic oak forest, northern hardwood forest, white pine-hardwood forest, black ash swamp, forested bog, poor fen, tamarack swamp, wet meadow.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Minnesota only: *Hydrocotyle americana* (American water-pennywort), *Poa paludigena* (bog bluegrass), *Polygonum arifolium* var. *pubescens* (halberd-leaved tearthumb). **Minnesota and Wisconsin:** *Tsuga canadensis* (eastern hemlock).

RARE ANIMALS: Minnesota only: Birds: *Buteo lineatus* (red-shouldered hawk), *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey), *Seiurus motacilla* (Louisiana waterthrush); Fish: *Acipenser fulvescens* (lake sturgeon); Reptiles: *Clemmys insculpta* (wood turtle), *Emydoidea blandingii* (Blanding's turtle); Mollusks: *Quadrula fragosa* (winged mapleleaf). **Wisconsin only:** *Alces alces* (moose), *Canis lupis* (gray wolf), great gray owl.

NATURAL AREAS: Wisconsin: State Natural Areas: Bois Brule Conifer Bog, Black Lake Bog.

PUBLIC LAND MANAGERS: Minnesota: State Forests: Nemadji, Chengwatana, St. Croix, Rum River, Snake River; Wildlife Management Areas: Mille Lacs; State Parks: Mille Lacs Kathio, St. Croix Wild River, and St. Croix.

CONSERVATION CONCERNS: The St. Croix River has been identified as a critical landscape

for biodiversity protection by the Minnesota Heritage Program. There is some concern over accelerated timber harvest with loss of old-growth and larger blocks of mature forest. Maintaining roadless areas is considered ecologically critical in Wisconsin.

BOUNDARIES: As treated here, the boundaries include most of Kratz and Jensen's (1983) Mille Lacs and Grantsburg Landscape Regions in Minnesota.

Figure 30.—*Subsection X.2: Black Lake Bog Scientific and Natural Area, Pine County, Minnesota. Bogs occur commonly in depressions on both the rolling ground moraines and the more irregular end moraines of the subsection. Minnesota Department of Natural Resources photo.*

SUBSECTION X.3. Laurentian Highlands**; drumlins on ground moraine of acidic, rocky loams; aspen-birch forest and conifer swamps.**

DISCUSSION: The drumlin field consists of northeast-southwest-oriented ovoid hills separated by bogs or swamp forests (University of Minnesota *et al.* 1981b).

SUB-SUBSECTIONS: None.

ELEVATION: 1,350 to 1,900 feet (411 to 579 m).

AREA: 731 square miles (1,892 sq km).

STATES: Minnesota.

CLIMATE: Annual precipitation ranges from 28 to 29 inches (Hargrave 1992). Growing season precipitation is 11 to 12 inches. Annual snowfall ranges from 60 to 64 inches (Wendland *et al.* 1992). Growing season ranges from 106 to 121 days. Extreme minimum temperature ranges from -40˚F to -45˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Glacial drift thickness over bedrock is generally less than 100 feet; and there are localized outcrops of bedrock, especially along the eastern edge (Olsen and Mossler 1982). The bedrock of the entire subsection is Precambrian in age. In the north, Keweenawan bedrock includes sandstone, arkose, shale, basaltic to rhyolitic lava flows and pyroclastic rocks, gabbro, troctolite, ferrogabbro, anorthosite, and peridotite (Morey 1976, Morey *et al.* 1982). To the south, upper Precambrian quartzite is extensive.

LANDFORMS: Drumlin ridges, about a mile long, a quarter mile wide, and 30 to 50 feet high (University of Minnesota *et al.* 1981b). The narrow depressions between the drumlins, generally less than a mile wide, are usually poorly or very poorly drained; they support either conifer swamps or bogs.

Subsection X.3 also includes the Brimson outwash plain along its eastern edge. Most of the plain is level, but there are steep slopes along the Cloquet River.

LAKES AND STREAMS: There are 17 lakes of more than 160 acres (University of Minnesota *et al.* 1977, 1981b). Most of these lakes have narrow basins 1 to 3 miles long and less than a mile wide, oriented in the same direction as the adjacent drumlins. Several rivers and creeks occupy the wetland depressions between the drumlins.

SOILS: Soils on the upland parts of the drumlin field are well-drained gravelly, sandy loams. Between the drumlins are narrow or broad depressions with very poorly drained soils; these account for nearly half of the surface area of the subsection. Almost 90 percent of the soils of the Brimson outwash plain are excessively drained sands; the remainder are very poorly drained.

Soils of the drumlin fields are classified as Ochrepts, Aquepts, and Hemists; those of the outwash are Orthents, Orthods, Ochrepts, and Psamments (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: The major forest type mapped on the drumlin ridges was aspen-birch, with only small areas of white pine-red pine forest (Marschner 1974). Mixed hardwood-pine was infrequent. Conifer-swamp or bog occupied the depressions between most of the drumlins.

White pine-red pine was well represented in the Brimson outwash plain, where it was the most common forest type. At the northeastern end of the plain, jack pine barrens dominated a strip 8 to 10 miles long and 1 to 3 miles wide. Small conifer bogs or swamps were scattered across the outwash. Aspen-birch was also present there.

NATURAL DISTURBANCE: Fire was important for maintaining both upland conifer forests and forests of aspen-birch.

PRESENT VEGETATION AND LAND USE: Very little biological survey has been done to determine which plant communities are well represented in this subsection.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: None identified to date.

RARE ANIMALS: *Clemmys insculpta* (wood turtle).

NATURAL AREAS:

PUBLIC LAND MANAGERS: Cloquet Valley State Forest, Finland State Forest.

CONSERVATION CONCERNS: Concern has been expressed over accelerated timber harvest.

BOUNDARIES: Subsection is bounded on the east by the Lake Superior Highlands (Subsection X.9), on the north by the Nashwauk uplands (Subsection X.8), on the west by the Tamarack Lowlands (Subsection X.4), and on the south by the Mille Lacs Uplands (Subsection X.2).

SUBSECTION X.4. Tamarack Lowlands **(Upham lake plain and Aurora till plain); loamy glacial lake plain and ground moraine; conifer swamp, bog, aspen-birch forest.**

DISCUSSION: The Tamarack Lowlands subsection consists of the Upham lake plain, a flat to gently rolling plain, and the surrounding clay-soiled ground moraines of the Aurora till plain. Poor drainage characterizes most of the lake plain and much of the surrounding ground moraine.

SUB-SUBSECTIONS: None.

ELEVATION: 1,250 to 1,350 feet (381 to 412 m).

AREA: 2,794 square miles (7,237 sq km).

STATES: Minnesota.

CLIMATE: Total annual precipitation ranges from 26 inches in the west to 28 inches in the east; about 40 percent falls during the growing season (University of Minnesota *et al.* 1971). Annual snowfall ranges from 52 inches in the west to 64 inches in the northeast (Wendland *et al.* 1992). The growing season is short, from 92 to 115 days, because the low-lying subsection forms a frost pocket with late spring frosts and early fall frosts. Extreme minimum temperature ranges from -40˚F to -45˚F (Reinke *et al.* 1993) and probably colder in local areas.

BEDROCK GEOLOGY: Glacial drift within the lake bed ranges from 100 to 300 feet thick; some of the thickest sediments are at the northern edge of Glacial Lake Upham, where it meets the Mesabi Range (Olsen and Mossler 1982). The bedrock beneath Lake Upham is middle Precambrian (early Proterozoic) argillite, siltstone, quartzite, or graywacke, weakly metamorphosed (Morey 1976, Morey *et al.* 1982). There is also Cretaceous shale, sandstone, and clay near the southwest end of the basin and along the border with the Mesabi Range.

LANDFORMS: Glacial lacustrine deposits occupy much of the subsection. There are beach ridges, but most are not well defined. There is ground moraine along the borders of Glacial Lake Upham, including low drumlin ridges.

LAKES AND STREAMS: The St. Louis and Whiteface Rivers and several creeks meander across the flat lake plain. No lakes.

SOILS: Extensive areas of Histosols (peats) over both fine-textured (both silt- and clay-rich) and sandy lacustrine deposits. Soils are classified by Anderson and Grigal (1984) as primarily Ochrepts, Hemists, Aquents, and Boralfs.

PRESETTLEMENT VEGETATION: A large part of the lowlands was dominated by sedge meadow, black spruce-sphagnum bog, and northern white-cedar and black ash swamp (Marschner 1974). Uplands supported aspen-birch and spruce-fir forest, and locally, northern hardwood forests. White pine-red pine forests were located on the ground moraine at the edges of the lake plain, but were not extensive.

NATURAL DISTURBANCE: Fire was probably important, on both the hardwood-conifer-dominated uplands and wetlands. Windthrow was probably important in the conifer swamps. In this type of flat, lacustrine setting, natural water level fluctuations and flooding behind beaver dams often cause extensive tree mortality.

PRESENT VEGETATION AND LAND USE: Present land use is estimated to be 35 to 45 percent forest, 40 to 50 percent cultivated land, and 10 to 20 percent pasture (University of Minnesota *et al.* 1971). Most of the agriculture is on silt-loam soils. The vegetation of the uplands is presently more heavily dominated by trembling aspen and birch than originally. Much of the remaining old-growth northern hardwood forests in the State are found in this subsection. The conifer- and sedge-dominated peatlands remain largely dominated by the original vegetation.

Insufficient biological survey has been done to determine which plant communities have good examples here.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Caltha natans* (floating marsh-marigold), *Tsuga canadensis* (eastern hemlock).

RARE ANIMALS: *Clemmys insculpta* (wood turtle).

NATURAL AREAS: State Parks: Savanna Portage; State Natural Areas: McGregor Marsh.

PUBLIC LAND MANAGERS: State Forests: Savanna, Solana, Cloquet Valley, Golden Anniversary; State Parks: Savanna Portage; Wildlife Management Areas: Aitkin, Grayling, Great Scott, Kimberly, Roberts-Wickstrom; Other: Rice Lake National Wildlife Refuge.

CONSERVATION CONCERNS: Concern about accelerated timber harvest; need to protect remaining old-growth northern hardwood and hardwood swamp forests.

BOUNDARIES: The boundaries of this subsection have been modified to include the Aurora till plain, located along the southeastern and northern edges of Glacial Lake Upham. This ground moraine has clayey soils, large parts of which are poorly drained; it also forms a relatively flat plain ecologically similar to the adjacent lacustrine plain.

SUBSECTION X.5. Pine Moraines and Outwash Plains**; steep, sandy moraines surrounded by outwash; jack pine barrens, white pine-red pine forest, paper birch-trembling aspen forest.**

DISCUSSION: Subsection X.5 consists of a number of steep, end-moraine ridges surrounded by large expanses of outwash. The subsection has been subdivided into two sub-subsections on the basis of landform and soil texture.

SUB-SUBSECTIONS: The Itasca, Alexandria, and St. Croix Moraines sub-subsection (X.5.1) consists of sandy end moraines, and the Park Rapids-Staples and Crow Wing Outwash Plains sub-subsection (X.5.2) consists of several outwash plains. (See figure 3.)

ELEVATION: 1,100 to 1,850 feet (335 to 564 m).

AREA: 5,602 square miles (14,497 sq km).

STATES: Minnesota.

CLIMATE: Total annual precipitation ranges from 24 inches in the northwest to 27 inches in the east; about 40 percent occurs during the growing season (University of Minnesota *et al.* 1969, 1980a). Only 12 to 16 percent of the annual precipitation falls during winter (based on Wendland *et al.* 1992). Annual snowfall is 44 to 52 inches, heaviest in the east (Wendland *et al.* 1992). Growing season ranges from 111 to 131 days. Extreme minimum temperature ranges from -40˚F to -45˚F (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Thick glacial drift covers bedrock over most of the subsection. Drift thicknesses range from 200 to more than 600 feet; the greatest thicknesses are in the southwest (Olsen and Mossler 1982). At the southeastern edge, drift is thin, with very localized bedrock exposures just south of the Crow Wing River and west of the Mississippi River.

The underlying bedrock consists of diverse Precambrian rock, including early Precambrian (late Archean) and middle Precambrian (early Proterozoic) gneiss, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks (Morey 1976, Morey *et al.* 1981). There is also iron formation at the southeastern edge of the subsection, along with argillite, siltstone, quartzite, and graywacke. Cretaceous marine shale, sandstone, and variegated shale are localized in the southwest.

LANDFORMS: Large outwash plains, narrow outwash channels, and end moraines (Hobbs and Goebel 1982). Subsection X.5 is divided into sub-subsections because of the diversity of these landforms. The relatively large moraines of the subsection were formed from parts of several glacial lobes; most of the glacial drift was sandy.

LAKES AND STREAMS: Kettle lakes are common within most of the larger outwash plains and within the stagnation moraines; thousands of lakes are within the subsection. Leech Lake forms the northeastern boundary. Large rivers flowing through the outwash plains include the Mississippi, Pine, and Crow Wing.

SOILS: Soils of the moraines are predominantly sands and sandy loams (University of Minnesota *et al.* 1969, 1980a). Soils of the outwash plains are primarily excessively or well drained sands, but there are also numerous wetlands with very poorly drained soils. More than 10 percent of the soils are peats.

Soils are classified as Psamments and Aquents on the outwash plains (Anderson and Grigal 1984). Boralfs are the predominant soils on the moraines.

PRESETTLEMENT VEGETATION: Jack pine, with northern pin oak, dominated the excessively drained parts of the broad outwash plains, but trembling aspen-paper birch forest dominated large expanses and conifers dominated the very poorly drained portions of the outwash (Marschner 1974). Red pine-white pine forests, along with trembling aspen-paper birch forests, occupied the rolling to irregularly sloped end moraines. Mixed hardwood and pine forests, dominated by a diverse mix of northern hardwoods and white pine, were found in the most fire-protected areas at the eastern edge of the subsection. Fire protection was provided by irregular topography, broad wetlands, and relatively large lakes. Some of the hardwood-pine forests mapped by Marschner (1974) may have been dominated by red oak and basswood, without sugar maple.

Sugar maple may have always been an understory or minor overstory component in some of the white pine and white pine-red pine forests; drought broke the water column in the sugar maple, and it remained a lower canopy species. On the Chippewa National Forest in the east, sugar maple was a significant component of several upland ecosystems (Grigal and Kernik 1980).

A common original forest type mapped by Marschner (1974) within the subsection was aspen-birch. This designation was probably used for several very different vegetation types found on very different soils and landforms. The floristic analysis of Grigal and Kernik (1980) on the Chippewa National Forest describes paper birch and trembling aspen as a major component on both excessively drained outwash plains and moist ground moraine. Trembling aspen, with little or no associated paper birch, was also common on sandy moraines and poorly drained lake plain. Bigtooth aspen was also present, sometimes in combination with trembling aspen, on moist outwash plains, and sometimes with red oak and sugar maple on drier moraines. It thus appears that this vegetation type, as delineated by Marschner, actually represents several vegetation types found on several ecosystems, and it is less useful for characterizing ecological relationships than jack pine barrens, white pine-red pine forest, white pine forest, or mixed hardwood-pine forest.

Approximately 6,000 years ago, this subsection was the eastern extent of prairie. A strong prairie component remains in the groundcover. Balsam fir occurs commonly as an understory species, but it is an overstory dominant only at upland/wetland edges.

NATURAL DISTURBANCE: Fire occurred on a 10- to 40-year rotation within much of the subsection, accounting for the dominance by upland conifers and trembling aspen-birch forests (Frissel 1973).

PRESENT VEGETATION AND LAND USE: After logging of white and red pines, paper birch and trembling aspen became more common dominants within much of the subsection (Frissel 1973).

High-quality examples of the following plant communities are well represented in this subsection: dry oak savanna, jack pine barrens, mixed pine-hardwood forest, mesic oak forest, red pine forest, white pine forest, black ash swamp, black spruce swamp, tamarack swamp, wet meadow, and poor fen.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Malaxis paludosa* (bog adder's-mouth).

RARE ANIMALS: *Buteo lineatus* (red-shouldered hawk), *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey), *Emydoidea blandingii* (Blanding's turtle).

NATURAL AREAS: State Natural Areas: Iron Springs Bog, Itasca Wilderness Sanctuary (National Natural Landmark); Research Natural

Areas: Height of Land, Pine Point (NNL), Sugarbush; The Nature Conservancy Preserves: Paul Bunyan Savanna; Other: Lake Alexander Preserve, Spearhead Lake.

PUBLIC LAND MANAGERS: National Forests: Chippewa; State Forests: Badoura, Crow Wing, Foot Hills, Huntersville, Land O'Lakes, Mississippi Headwaters, Paul Bunyan, Pillsbury, Smokey Hills, Two Inlets; State Parks: Itasca, Big Island; Wildlife Management Areas: Birchdale, Bull Moose, Crow Wing Chain, Dry Sand Lake, Huntersville, Kabekona, Lowell, Upper Rice; Other: Camp Ripley Military Reservation, Belle Prairie Park, Paul Bunyan Arboretum, Smith Memorial Forest.

CONSERVATION CONCERNS: The Minnesota Department of Natural Resources planning team has recommended (1) maintaining a certain percentage of each forest community in old-growth conditions, (2) increasing the amount of oak, northern white-cedar, and white pine within the subsection, (3) maintaining large areas of contiguous forest for forest-interior dwelling species, (4) maintaining semi-primitive conditions (few or no roads), (5) providing habitat for endangered, threatened, and special concern biota, and (6) protecting cultural resources.

Itasca State Park Pines was identified as a critical landscape for biodiversity protection by the Minnesota Heritage Program. Accelerated timber harvest is a concern throughout the subsection. Fragmentation, loss of conifers, simplification of forest stand structure and communities, and a reduction in the extent of mature forests are special concerns. The only remaining large areas of old-growth red pine and white pine forest, in Itasca State Park, exhibit little pine regeneration due to high deer populations and lack of fire.

BOUNDARIES: The Park Rapids-Staples plain, along the southern edge of the subsection, has been treated by others as part of Sub-subsection III.1.1. I have included it within this subsection, along with parts of the Wadena drumlins and the St. Cloud moraine, because northern species, such as jack pine, white pine, and red pine, are the dominant vegetation. Along the eastern boundary, the finer textured Sugar Hills have been excluded; instead, they have been joined with other fine-textured moraines into Subsection X.6. These moraines also support white pine-red pine forest and northern hardwood-pine forests, but almost no jack pine.

Figure 31.—*Subsection X.5: Stumphages Rapids Natural Heritage Registry, Hubbard County, Minnesota. Outwash plains of the subsection support extensive forests of jack pine. Minnesota Department of Natural Resources photo by K.A. Rusterholz.*

SUB-SUBSECTION X.5.1. Itasca, Alexandria, and St. Croix Moraines**; sandy stagnation and end moraines; white pine-red pine forest and paper birch-trembling aspen forest.**

DISCUSSION: The sandy moraines of this sub-subsection are surrounded by pitted outwash plains with excessively drained soils. As a result, the vegetation on the moraines was subject to regularly recurring fires that originated on the outwash plains, and it was dominated by either upland conifers or aspen-paper birch forest.

ELEVATION: 1,100 to 1,890 feet (335 to 576 m).

AREA: 3,632 square miles (9,391 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK: See subsection.

LANDFORM: Common landforms are stagnation or end moraines, but ground moraine with drumlins is included at the southern margin of the sub-subsection. Moraines are cut by narrow, steep outwash channels, buried channels, and tunnel valleys (Hobbs and Goebel 1982).

LAKES AND STREAMS: Kettle lakes are common on the southwestern part of the Itasca moraine and also in the northern part of the St. Croix moraine. The buried channels and tunnel valleys are often occupied by small kettle lakes and potholes.

SOILS: Most of the soils are sandy loams derived from sandy loam to loam till; gravelly till is also present (University of Minnesota *et al.* 1969, 1980a). Soils are classified as Boralfs (Anderson and Grigal 1984).

PRESETTLEMENT FOREST: Red pine-white pine forests, along with trembling aspen-paper birch forests, occupied the rolling to irregularly sloped end moraines. Mixed hardwood-pine forest, dominated by a diverse mix of northern hardwoods and white pine, were found in the most fire-protected areas at the eastern edges of the sub-subsection, where fire protection was provided by irregular topography, broad wetlands, and relatively large lakes. Immediately downwind from the outwash plains of Sub-subsection X.5.2, white pine-red pine forests or aspen-birch forests were probably the result of frequent fires that originated on the outwash.

NATURAL DISTURBANCE: Fire was the most prevalent form of disturbance, recurring every 10 to 40 years (Frissell 1973). Windthrow was probably more prevalent in the hardwood-pine forests.

PRESENT VEGETATION AND LAND USE: Present forests contain much more paper birch and trembling aspen than the original forests.

RARE PLANT COMMUNITIES:

RARE PLANTS: *Malaxis paludosa* (bog adder's-mouth).

RARE ANIMALS: See subsection.

NATURAL AREAS: See subsection.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: See subsection.

SUB-SUBSECTION X.5.2. Park Rapids-Staples and Crow Wing Outwash Plains**; jack pine-northern pin oak barrens, paper birch-trembling aspen forest, conifer swamps.**

DISCUSSION: Sub-subsection X.5.2 consists of three outwash plains separated by sandy end moraines. The flat, droughty outwash plains burnt regularly, resulting in an open forest or barrens dominated by jack pine.

ELEVATION: 1,100 to 1,492 feet (335 to 455 m).

AREA: 1,970 square miles (5,106 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK: See subsection.

LANDFORM: Broad outwash plains.

LAKES AND STREAMS: Surfaces of the plains are pitted by numerous small kettle lakes. More than 160 lakes larger than 160 acres are found within the sub-subsection (University of Minnesota *et al.* 1969, 1980a). Several major rivers flow across the outwash, including the Mississippi, Crow Wing, and Pine.

SOILS: Loamy sands or sandy loams, derived from outwash sands and gravels. From 65 percent to 85 percent of the soils are excessively or well drained (University of Minnesota *et al.* 1969, 1980a). The amount of peat soils differs by outwash plain; the Park Rapids-Staples plain (X.5.2a) has almost 20 percent very poorly drained soils, and the Crow Wing (X.5.2b) has 5 percent. Soils of the outwash are classified primarily as Psamments, but include Hemists (Anderson and Grigal 1984).

PRESETTLEMENT FOREST: Jack pine, with northern pin oak, dominated the excessively drained portions of the broad outwash plains, but trembling aspen-paper birch forest dominated large expanses and conifers dominated very poorly drained parts of the outwash (Marschner 1974).

NATURAL DISTURBANCE: Fire.

PRESENT VEGETATION AND LAND USE: Most of the outwash plains remain forested. Jack pine is used principally in the pulpwood industry.

RARE PLANT COMMUNITIES: See subsection.

RARE PLANTS: See subsection.

RARE ANIMALS: See subsection.

NATURAL AREAS: See subsection.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: See subsection.

BOUNDARIES: Outwash at the southern end of the Park Rapids-Staples plain supported prairie and oak opening. This part of the outwash plain was treated as belonging to Subsection III.1.1.

SUBSECTION X.6. Chippewa Plains**; calcareous, clayey moraines and the Bemidji and Bagley outwash plains; upland conifers and both lowland hardwoods.**

DISCUSSION: Subsection X.6 consists primarily of loamy stagnation and ground moraines, but includes the Bemidji and Bagley outwash plains.

SUB-SUBSECTIONS: Black Duck Till Plain (X.6.1), Bemidji and Bagley Outwash Plains (X.6.2). (See figure 3.)

ELEVATION: 1,200 to 1,610 feet (366 to 491 m).

AREA: 3,176 square miles (8,232 sq km).

STATES: Minnesota.

CLIMATE: Average annual precipitation ranges from 22 to 25 inches (University of Minnesota *et al.* 1980a). Annual snowfall is 44 to 56 inches, highest in the east (Wendland *et al.* 1992). Growing season ranges from 110 to 120 days. The longest growing season is near Lower Red Lake in the north and Leach Lake in the south; these lakes extend the growing season approximately 10 days. Extreme minimum temperatures are -45˚F or colder (Reinke *et al.* 1993).

BEDROCK: Glacial drift thickness over bedrock is generally between 200 and 500 feet. However, at the extreme northeastern edge of the subsection, drift thickness is 100 feet or less (Olsen and Mossler 1982). The bedrock beneath the subsection is early Precambrian (middle to late Archean) and middle Precambrian (early Proterozoic) gneiss, amphibolite, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks, iron formation, metasediments, quartzose sedimentary rocks, slate, metagraywacke, and quartzite.

LANDFORM: The primary landforms are flat, water-reworked till plain, ground moraine, and

stagnation moraine, with a broad band of outwash along the southern margin of the subsection. Glacial Lake Aitkin forms the eastern edge. Subsection X.6 forms the headwaters of the Mississippi River.

LAKES AND STREAMS: Large lakes include Cass and Bemidji Lakes, and Lake Winnibigoshish. Kettle lakes are common on both stagnation moraine and pitted outwash.

SOILS: Soils of the moraines are clay and silt loams (University of Minnesota *et al.* 1969, 1980a). Soils of the outwash plains are primarily excessively or well drained sands, but there are also numerous wetlands with very poorly drained soils. More than 10 percent of the soils are peats.

Soils are classified as Psamments and Aquents on the outwash plains (Anderson and Grigal 1984). Boralfs are the predominant soils on the moraines. Fine-textured soils, ranging from loams to silty clays, characterize the subsection. Approximately 70 to 85 percent of the soils are well drained, depending on the landform (University of Minnesota *et al.* 1980a). The predominant soils are Boralfs (Anderson and Grigal 1984).

PRESETTLEMENT FOREST: Mixed hardwood and pine forests, dominated by a diverse mix of northern hardwoods and white pine, were found in the most fire-protected areas at the northern edge of the subsection (Marschner 1974). The original vegetation on the more steep and irregular stagnation moraines was largely white pine-red pine forest. The ground moraine supported both aspen-birch and hardwood-pine forests. Jack pine and northern pin oak dominated the droughty outwash plains. Bogs and swamp conifers occupied poorly drained outwash.

NATURAL DISTURBANCE: Fire was probably an important disturbance factor within the white pine-red pine forests, but it is not clear whether the fires were from the Bemidji outwash plain immediately to the south or from lightning fires originating within the pine stands themselves.

PRESENT VEGETATION AND LAND USE: High-quality examples of the following plant communities are well represented in this subsection: northern hardwood forest, red pine forest, black spruce swamp, tamarack swamp, and northern white-cedar swamp.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Botrychium mormo* (goblin fern), largest concentration in the three States.

RARE ANIMALS: *Haliaeetus leucocephalus* (bald eagle).

NATURAL AREAS: State Natural Areas: Pennington Bog; Research Natural Areas: Battle Point, Stony Point.

PUBLIC LAND MANAGERS: State Forests: Battleground, Big Fork, Blackduck, Bowstring, Buena Vista, Mississippi Headwaters, Pine Island; State Parks: Lake Bemidji; Wildlife Management Areas: Carmen Borgerding, Mudgoose, Sugar Lake; National Forests: Chippewa, Superior; Other: Three Island Lake County Park.

CONSERVATION CONCERNS: Accelerated timber harvest with resulting fragmentation, loss of mature and old-growth forests, and simplification of forest communities.

SUB-SUBSECTION X.6.1. Black Duck Till Plain**; white pine-red pine forest, mixed hardwood-pine forest, paper birch-trembling aspen.**

DISCUSSION: Sub-subsection X.6.1 is an area of loamy lake-modified till, ground moraine, stagnation moraine, and lake plain, making up the northern part of the subsection. The combination of loamy soils and fire protection results in much less jack pine dominance on the moraines than in Subsection X.5 (Pine Moraines) to the south.

ELEVATION: 1,200 to 1,585 feet (366 to 483 m).

AREA: 2,661 square miles (6,897 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK: Glacial drift thickness over bedrock is generally 200 to 400 feet (Olsen and Mossler 1982). The bedrock beneath the sub-subsection is early Precambrian (middle to late Archean) and middle Precambrian (early Proterozoic) gneiss, amphibolite, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks, iron formation, metasediments, quartzose sedimentary rocks, slate, metagraywacke, and quartzite.

LANDFORM: Beginning in the north, the primary landforms include lake-modified till plain, ground moraine, and stagnation moraine. Glacial Lake Aitkin, at the east edge, also includes areas of ground moraine and outwash. Except for the stagnation moraine, the rest of this sub-subsection is flat and poorly drained.

LAKES AND STREAMS: The stagnation moraines contain many small and large kettle lakes. More than 50 kettle lakes larger than 160 acres occur in the sub-subsection; Lake Winnibigoshish is the only large lake.

SOILS: Soils of the Black Duck till plain are clay and silt loams (University of Minnesota *et al.* 1969, 1980a). These clayey soils are derived from shales and limestones of Manitoba and eastern North Dakota (Hobbs and Goebel 1982). More than 10 percent of the soils are peats.

Fine-textured soils, ranging from loams to silty clays, characterize the sub-subsection. Approximately 70 to 85 percent of the soils are well drained, depending on the landform (University of Minnesota *et al.* 1980a). The predominant soils are Boralfs (Anderson and Grigal 1984).

PRESETTLEMENT FOREST: Mixed hardwood and pine forests, dominated by a diverse mix of northern hardwood species and white pine, were found in the most fire-protected areas at the northern edge of the subsection (Marschner 1974). On the west part of the Black Duck till plain, where soils were thick, mixed forests of northern hardwoods and white pine occurred. To the east, where the soils of the till plain were thin over bedrock, birch-aspen forest and conifer swamp were more common. The original vegetation on the more steep and irregular stagnation moraines (Erskine and Clearbrook moraines) was largely white pine-red pine forest. Northern hardwoods grew locally on the stagnation moraine just west of Lake Winnibigoshish, possibly as a result of protection from late spring frosts.

NATURAL DISTURBANCE: Fire was probably an important disturbance within the white pine-red pine forests, but it is not clear whether the fires were from the Bemidji outwash plain immediately to the south or from lightning fires originating within the pine stands themselves.

PRESENT VEGETATION AND LAND USE: See subsection.

RARE PLANT COMMUNITIES: See subsection.

RARE PLANTS: See subsection.

RARE ANIMALS: See subsection.

NATURAL AREAS: See subsection.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: See subsection.

SUB-SUBSECTION X.6.2. Bemidji and Bagley Outwash Plains**; jack pine-northern pin oak barrens, paper birch-trembling aspen forest, conifer swamps.**

DISCUSSION: Sub-subsection X.6.2 consists of the Bemidji and Bagley outwash plains. The flat, droughty outwash plain burned regularly, resulting in an open forest or barrens dominated by jack pine.

ELEVATION: 1,295 to 1,610 feet (395 to 491 m).

AREA: 515 square miles (1,334 sq km).

STATES: Minnesota.

CLIMATE: See subsection.

BEDROCK: See subsection.

LANDFORM: A broad pitted outwash plain.

LAKES AND STREAMS: Surfaces of this plain are pitted by numerous small kettle lakes. Forty-five lakes larger than 160 acres are found within the sub-subsection; Cass and Bemidji Lakes are the largest (University of Minnesota *et al.* 1980a). More than 18 percent of the Bemidji outwash plain surface is covered by large lakes. Large lakes on the Bagley outwash plain are less numerous, covering approximately 5 percent of the landscape. The headwaters of the Mississippi River are located here.

SOILS: Loamy sands or sandy loams, derived from outwash sands and gravels. From 65 percent to 85 percent of the soils are excessively or well drained (University of Minnesota *et al.* 1969, 1980a). The Bemidji plain has approximately 12 percent peat soils, and the Bagley plain has about 5 percent. Soils of the outwash are classified primarily as Psamments, but include Hemists (Anderson and Grigal 1984).

PRESETTLEMENT FOREST: Jack pine, with northern pin oak, dominated the excessively drained parts of the broad outwash plains, but trembling aspen-paper birch forest also dominated large expanses (Marschner 1974). Swamp conifers dominated very poorly drained portions of the outwash.

NATURAL DISTURBANCE: Fire.

PRESENT VEGETATION AND LAND USE: Most of the outwash plains remain in second-growth forest with jack pine on the dry outwash, and large expanses of shrub swamp in wetlands. Jack pine is used principally in the pulpwood industry.

RARE PLANT COMMUNITIES: See subsection.

RARE PLANTS: See subsection.

RARE ANIMALS: See subsection.

NATURAL AREAS: See subsection.

PUBLIC LAND MANAGERS: See subsection.

CONSERVATION CONCERNS: See subsection.

BOUNDARIES: Sub-subsection X.6.2 does not include the north-south trending part of the Bagley plain, located west of Clearwater County.

SUBSECTION X.7. St. Louis Moraines**; end moraines, kettle lakes, some ground moraine; white pine-red pine forests, some sugar maple.**

DISCUSSION: This subsection consists primarily of rolling to steep end moraines, including the Marcell moraine complex in the north; the Sugar Hills in the south; and a small, steep portion of the Nashwauk-Warba moraine between the Giant Range and the Tamarack Lowlands. At the southern edge of the subsection is an area of ground moraine, the Swatara plain. All these features have calcareous loamy or clayey soils.

SUB-SUBSECTIONS: None.

ELEVATION: 1,200 to 1,600 feet (366 to 488 m).

AREA: 1,634 square miles (4,233 sq km).

STATES: Minnesota.

CLIMATE: Growing season length ranges from 111 to 131 days (University of Minnesota *et al.* 1971, 1977). Total annual precipitation ranges from 26 to 28 inches, and annual snowfall is 48 to 52 inches (Wendland *et al.* 1992). Only 12 to 16 percent of the annual precipitation falls during winter. Extreme minimum temperatures are -45°F or colder (Reinke *et al.* 1993).

BEDROCK GEOLOGY: Glacial drift is relatively thick, ranging from 100 to 400 feet (Olsen and Mossler 1982). Lower Precambrian undivided granites, metavolcanics, and metasedimentary rocks underlie the glacial drift (Sims *et al.* 1970).

LANDFORMS: Subsection consists primarily of distinct end moraines, but there is also pitted outwash at the northeast edge and ground moraine at the southern edge; Hobbs and Goebel (1982) treat the end moraines as part of the Sugar Hills moraine association of the Des Moines lobe, and the ground moraine of the

Swatara plain as part of the Culver moraine of the same lobe.

LAKES AND STREAMS: Potholes and small bogs are common, and lakes are numerous (University of Minnesota *et al.* 1971). The moraines and outwash contain more than 100 lakes larger than 160 acres; lakes account for approximately 8 percent of the surface area.

SOILS: Clay loam and loam soils account for most of the soils (University of Minnesota *et al.* 1971, 1977). Soils are classified as Boralfs, Aqualfs, Hemists, and Psamments, with Boralfs most common (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: White pine-red pine forest covered large parts of the steep moraines and parts of the pitted outwash along the eastern edge of the subsection. Aspen-birch forest also grew on the moraines, but it was best represented on the outwash, most of which had well to excessively drained sandy soils. Local areas of mixed hardwood-pine forest were found on the moraines, generally near large lakes, where there were possibly better fire protection and less severe spring frost. Some of the best northern hardwood forest, dominated by sugar maple, grew on the moraines near Grand Rapids. Conifer swamp and bogs were scattered throughout the subsection, occupying both kettles and linear depressions in the pitted outwash and moraines.

NATURAL DISTURBANCE: Both fire and windthrow were probably common.

PRESENT VEGETATION AND LAND USE: High-quality examples of the following plant communities are well represented in this subsection: northern hardwood forest, red pine forest, white pine forest, northern white-cedar swamp, and poor fen. Inventories have been insufficient to adequately evaluate most plant communities in the subsection.

RARE PLANT COMMUNITIES: Some of the best examples of old-growth red pine and white pine forests occur in Scenic State Park.

RARE PLANTS: Little inventory work has been done in this subsection. None identified to date.

RARE ANIMALS: *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey). Generally little inventory work has been done in this subsection.

NATURAL AREAS: State Natural Areas: Botany Bog, Ladies-tresses Swamp; Research Natural Areas: Clustered Bur Reed Bog.

PUBLIC LAND MANAGERS: State Forests: Big Fork, Bowstring, Crow Wing, George Washington, Hill River, Land O'Lakes, Remer; State Parks: Scenic; Wildlife Management Areas: Little Hill River, Little Willow River; National Forests: Chippewa.

CONSERVATION CONCERNS: Accelerated timber harvest with resulting fragmentation, loss of mature forests, and simplification of forest communities.

SUBSECTION X.8. Nashwauk Uplands**; steep to gently sloping ground moraine with calcareous, loamy soils and sandy outwash plains; aspen-birch forest, mixed hardwood-pine forest, jack pine barrens; conifer bog, conifer swamp, and muskeg.**

DISCUSSION: Subsection X.8 is characterized by diverse landforms and soils, which provide the basis for further subdivision into several sub-subsections or landtype associations. Most of the subsection consists of noncalcareous, loamy glacial drift of the Rainy lobe (Hobbs and Goebel 1982). Probably the most distinctive feature of the subsection is the Giants Range, a narrow ridge of thin till over bedrock, which is part of the Mesabi Range. The subsection contains several outwash plains and sandy end moraines along its northern and eastern edge, including the Prairie River and Big Rice outwash plains and the Big Rice and Vermilion moraines. Loamy moraines include the Nashwauk-Warba moraines, and parts of the Highland moraine.

SUB-SUBSECTIONS: None.

ELEVATION: 1,300 to 1,850 feet (396 to 564 m).

AREA: 2,120 square miles (5,494 sq km).

STATES: Minnesota.

CLIMATE: Average annual precipitation ranges from 24 to 27 inches; the lowest amounts are at the western edge (University of Minnesota *et al.* 1971). About half of the precipitation arrives during the summer. Annual snowfall is 56 to 64 inches; heaviest amounts are in the east, closer to Lake Superior (Wendland *et al.* 1992). Growing season ranges from 106 to 121 days. Extreme minimum temperatures are -40˚F to -45˚F or colder (Reinke *et al.* 1993).

The narrow upland ridge of the Giants Range, rising 400 to 450 feet above the adjacent plain, is probably less prone to late spring frost. Lack of late spring frosts may be responsible for increased dominance of northern hardwood forest.

BEDROCK GEOLOGY: Glacial drift thickness is quite variable. The Mesabi Range has thin, sandy glacial drift overlying bedrock (Olsen and Mossler 1982), as does the Prairie River and Big Rice outwash and associated sandy moraines. The Nashwauk-Warba moraine, between the outwash plains and the Mesabi Range, has glacial drift less than 100 feet thick, but few areas of bedrock outcrop.

Along the northern edge of the Mesabi Range is a 200- to 400-foot highland of lower Precambrian granite known as the Giants Range (Wright 1972). Immediately to the south of the Giants Range is quartzite and the iron formation of the Mesabi Range (Sims *et al.* 1970, Southwick *et al.* 1988). The iron formation, a major source for iron ore, has been heavily mined, first for "soft" iron ore and later for taconite (Wright 1972). The Precambrian (late Archean and early Proterozoic) bedrock includes gneiss, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks. Metasediments, quartzose sedimentary rocks, slate and metagraywacke and quartzite are also present, as are middle Proterozoic basalt, rhyolite, gabbro, diabase, anorthosite, granite, sandstone, and shale (Morey 1976).

LANDFORMS: Ground moraines, stagnation moraines, end moraines, and outwash plains (Hobbs and Goebel 1982). Outwash covers much of the northern part of the subsection. The outwash plains are flat to rolling; outwash deposits are thicker at the west end. Within and adjacent to the outwash plains, there are also narrow, steep end moraines with sandy to gravelly soils. These include the Vermilion and Big Rice moraines. Bedrock is locally exposed both in the end moraines and on outwash plains.

The Nashwauk moraine, which occupies the western part of the subsection, consists of rolling moraines with some steeper moraines. The Giants Range, a ridge of bedrock with a thin veneer of sandy till, has some of the highest relief in the State. South of the Giants Range is rolling ground moraine of clayey till (University of Minnesota *et al.* 1971).

LAKES AND STREAMS: Lakes on the outwash plains are concentrated at both the northeast and northwest edges of the subsection; Big Rice plain contains six lakes larger than 160 acres, and the Prairie River plain contains 27 lakes in that size range (University of Minnesota *et al.* 1971). On the Nashwauk moraine, small bogs and potholes are common, and 27 lakes are larger than 160 acres (University of Minnesota *et al.* 1971). Kettle lakes are also common on the Vermilion moraine. The headwaters of the St. Louis River are located within the subsection. Other rivers are the Prairie, Little Fork, and Bear (Hargrave 1992).

SOILS: Soils of the outwash plains are sands and loamy sands developed from thick sandy and gravelly glaciofluvial deposits (University of Minnesota *et al.* 1971). Soils of the Vermilion and Big Rice moraines are also sands and gravelly sands, with some sandy loams. Stones and cobbles are locally abundant. The till is variable in depth, and there are localized bedrock outcrops. Soils are classified as Orthents, Orthods, Ochrepts, Psamments, and Boralfs (Cummins and Grigal 1981).

Soils of the Nashwauk moraine are calcareous clay loams, but there are also shallow, sandy soils over loamy till (University of Minnesota *et al.* 1971). Small areas of rock outcrop occur northwest of Chisholm. Soils of the Giants Range are cobbly loamy sands and sandy loams; these soils are well to excessively drained (University of Minnesota *et al.* 1971). Soils of the ground moraine to the south of the Giants Range are silty or clayey. Most of these fine-textured tills are well drained, but poorly drained soils are included. Soils are classified as Boralfs, Aqualfs,

and Hemists on the ground moraine and as Ochrepts and Boralfs on the thin soils of the Giants Range (Cummins and Grigal 1981).

PRESETTLEMENT VEGETATION: Forest types represented within the subsection included white pine-red pine forest, aspen-birch forest, mixed hardwood-pine forest, and jack pine barrens on the uplands (Marschner 1974). The original vegetation of the outwash included jack pine barrens, aspen-birch forest, white pine-red pine forest, and conifer swamps and bogs. Jack pine was most common in areas of outwash not dissected by streams, kettle lakes, or kettle wetlands. Aspen-birch was common in the west; white pine-red pine was more common in the east, where there were more lakes and narrow moraines to provide partial fire protection. The conifer swamps were concentrated in kettle depressions and drainages within the outwash.

On the Nashwauk moraine, aspen-birch forest was most common in the west; further to the east, white pine-red pine forest was much more prevalent (Marschner 1974). The aspen-birch forest appeared to be concentrated where the topography was flattest and where there were many small streams. White pine-red pine forest was on more rolling to steep topography. Jack pine barrens were much less extensive, restricted to small fire-prone outwash deposits at the western edge of the moraines. Conifer swamps and bogs were also found in depressions and along drainageways throughout.

The Giants Range supported a forest of mixed hardwood-pine, and the adjacent ground moraine to the south supported primarily white pine-red pine forest, along with aspen-birch forest and conifer swamps and bogs (Marschner 1974). Dominance by northern hardwoods (mixed hardwood-pine) may be the result of protection from both fire and late spring frosts on the large ridge.

Wetland vegetation includes conifer bogs and swamps and open muskeg. The largest area of wetlands was at the southeastern edge of the subsection, just north of the drumlin fields of the Laurentian Highland (Toumi drumlins).

NATURAL DISTURBANCE: Fire was important on the outwash plains and probably, to a lesser degree, on the moraines. Windthrow had the strongest impact on the moraines, especially on the exposed ridges of the Giants Range.

PRESENT VEGETATION AND LAND USE: Forestry, mining, and tourism are important land uses (Hargrave 1992). Aspen, the most common tree species, is used for paper and waferboard. Tourism is important, especially where lakes are numerous. Historically, iron mining was an important industry, but it has decreased significantly in recent years.

Inventory work is insufficient to determine which plant communities are well represented in this subsection.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: *Geocaulon lividum* (northern comandra), *Viola novae-angliae* (New England violet).

RARE ANIMALS: *Clemmys insculpta* (wood turtle).

NATURAL AREAS: State Natural Areas: Sand Lake Peatland; The Nature Conservancy Preserves: Wabu Woods.

PUBLIC LAND MANAGERS: State Forests: Bear Island, Finland, George Washington, Pat Bayle, Sturgeon River.

CONSERVATION CONCERNS: Accelerated timber harvest with resulting fragmentation, loss of mature forest, and simplification of forest communities.

SUBSECTION X.9. North Shore (Lake Superior) Highlands**; end moraine, ground moraine, and clay lake plain; white pine-red pine and aspen-birch forests on uplands, localized sugar maple on uplands near the Lake Superior shoreline.**

DISCUSSION: Major landscapes within Subsection X.9 are the Highland moraine, Highland Flutes, and the Nemadji-Duluth lake plain (University of Minnesota *et al.* 1981b). Also included is the Brimson outwash plain. The forests were almost completely dominated by conifers; isolated pockets of sugar maple and yellow birch occupied small upland areas within 3 to 4 miles of the Lake Superior shoreline.

SUB-SUBSECTIONS: None. Two potential sub-subsections could be identified on the basis of forest dominance. White pine and red pine originally dominated the clay lake plain and the rocky soils in the southern half of the subsection; aspen-birch forest dominated the northern half of the subsection.

ELEVATION: 602 to 1,900 feet (184 to 579 m).

AREA: 1,753 square miles (4,540 sq km).

STATES: Minnesota.

CLIMATE: Total annual precipitation ranges from 28 to 30 inches, about 40 percent of which occurs during the growing season (Hargrave 1992). Growing season ranges from approximately 121 to 135 days; the longest growing season is along the shore of Lake Superior, where it is about 10 days longer than farther inland at the equivalent latitude (University of Minnesota *et al.* 1981b). Annual snowfall ranges from 60 to 64 inches (Reinke *et al.* 1993). The lake effect increases the amount of snowfall by about 10 inches within 5 miles of the Lake Superior shoreline, but a similar trend is not apparent in the annual precipitation data. Extreme minimum temperatures are -30˚F to -40˚F (Reinke *et al.* 1993).

The absence of late spring frosts on the ridges within a few miles of Lake Superior may account for the presence of sugar maple-basswood forests; Rosendahl and Butters (1928) noted the importance of large lakes and ridges with free air drainage for occurrence of this forest type in northern Minnesota.

BEDROCK GEOLOGY: Glacial drift is thin over the entire subsection, and bedrock is exposed or near the surface in large areas. The underlying bedrock consists of upper Precambrian (middle Proterozoic) basalt, rhyolite, gabbro, diabase, anorthosite, granite, sandstone, and shale (Morey 1976). The southeastern-dipping Keweenawan basalt and diabase resurface on the Keweenaw Peninsula in the Upper Peninsula of Michigan.

LANDFORMS: Ground moraine and end moraine of the Superior lobe cover much of the subsection (Hobbs and Goebel 1982). Clay lake plain forms a broad band along the Lake Superior shoreline in the southern half of the subsection. The clay plain is flat to rolling, with steep, narrow ravines along many streams. Outwash deposits occur along the western edge. Numerous short streams, 10 to 15 miles long, lead directly from the highland to the shores of Lake Superior; most of the streams have water falls near the shoreline (Wright 1972).

Lakes make up about 2 to 3 percent of the subsection; 20 lakes are larger than 160 acres in size. Of these, 17 are located on the Highland moraine along the western edge of the subsection and 3 are located on the Highland Flutes, near Lake Superior along the eastern edge of the subsection (University of Minnesota *et al.* 1981b). There are no lakes on the lacustrine clays along Lake Superior.

SOILS: Soils are developed from the rocky, red tills of the Superior lobe; textures range from sand to clay (Hobbs and Goebel 1982). Sands and sandy loams are the predominant soils on the Highland moraine, which occupies much of the western and central parts of the subsection. The Highland Flutes, along the eastern edge of the subsection, have a predominance of thin soils over bedrock and clayey soils (University of Minnesota *et al.* 1981b). The Nemadji-Duluth lacustrine plain has approximately 95 percent clay soils. Much of the till contains abundant clasts derived from the local igneous and metamorphic bedrock. The most common soils of the

subsection are classified as Orthents, Ochrepts, and Boralfs (Anderson and Grigal 1984).

PRESETTLEMENT VEGETATION: Marschner (1974) recorded aspen-birch forest, white pine-red pine forest, mixed hardwood-pine forest, and conifer bogs and swamp. White pine-red pine forest was most common on the clay lake plain and on thin soil over bedrock in the southern half of the subsection. Mixed hardwood-pine forest, with sugar maple, was concentrated on the ridges of the dissected clay lake plain and the Highland Flutes. On the clay plain, these sites were probably some of the best drained; on both the lake plain and the moraines of the Highland Flutes, these sites were probably best protected from late spring frosts (Grigal and Arneman 1970, Flaccus and Ohmann 1964). Aspen-birch forest was less abundant on the clay plain and the thin soils in the southern half of the subsection, but became more common, along with conifer bogs and swamps, farther inland. It is not clear which soils and climatic conditions are responsible for the increase in aspen-birch.

In the northern half of the subsection, aspen-birch became the dominant vegetation, with very little white pine-red pine forest or mixed hardwood-pine forest. Where mixed hardwood-pine forest persists, it is within 6 to 10 miles of the shoreline on ridgetops.

NATURAL DISTURBANCE: Fire and spruce budworm defoliation.

PRESENT VEGETATION AND LAND USE: Almost the entire subsection remains forested; forest management and recreation are the major land uses (Hargrave 1992). Following logging, the extensive white pine-red pine forests have been replaced by forests of trembling aspen-paper birch.

Jahns (1983) mapped the presence of sugar maple within the Tofte subsection of the Superior National Forest. Sugar maple was concentrated within 8 to 10 miles of the Lake Superior shoreline.

High-quality examples of the following plant communities are well represented in this subsection: northern hardwood forest, upland northern white-cedar forest, forested bog.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Most of the following rare plants have a northern distribution, and most are found close to the Lake Superior shoreline. *Adoxa moschatellina* (moschatel), *Arnica chionopappa* (arnica), *Claytonia caroliniana* (Carolina spring-beauty), *Crataegus douglasii* (Douglas thorn-apple), *Draba arabisans* (Whitlow grass), *Eleocharis nitida* (neat spike-rush), *Empetrum atropurpureum* (purple crowberry), *Euphrasis hudsoniana* (Hudson Bay eyebright), *Listera auriculata* (auricled twayblade), *Luzula parviflora* (small-flowered woodrush), *Osmorhiza chilensis* (Chilean sweet cicely), *Pinguicula vulgaris* (butterwort), *Polygonum viviparum* (alpine bistort), *Polystichum braunii* (Braun's holly fern), *Sagina nodosa* ssp. *borealis* (knotty pearlwort), *Selaginella selaginoides* (northern spikemoss), *Tofieldia pusilla* (small false asphodel), *Vaccinium uliginosum* var. *alpinum* (Alpine bilberry), *Woodsia glabella* (smooth woodsia).

RARE ANIMALS: *Falco peregrinus* (peregrine falcon).

NATURAL AREAS: State Natural Areas: Butterwort Cliffs, Lutsen, Moose Mountain, Spring Beauty Northern Hardwoods, Sugar Loaf; Research Natural Areas: Marble Lookout, Schroeder; The Nature Conservancy Preserves: Cathedral Grove, Langley River; Other: Susie Islands, Congdon Park, McNair, Pigeon River #10.

PUBLIC LAND MANAGERS: National Forest: Superior; State Forests: Cloquet Valley, Finland, Grand Portage, Pat Bayle; State Parks: Cascade River, George Crosby-Manitou, Gooseberry Falls, Split Rock Lighthouse, Temperance River, Tettegouche, Judge Magney; State Waysides: Devils Track, Kodonce River, Ray Bergland; Wildlife Management Areas: Canosia.

CONSERVATION CONCERNS: Lake Superior Highlands subsection was identified as critical landscape for biodiversity protection by the Minnesota Heritage Program. The subsection contains significant old-growth northern hardwood and upland northern white-cedar forest. Large populations of deer and sprawling recreational development are concerns near the Lake Superior shoreline.

BOUNDARIES: The inland boundary is located where Superior lobe glacial deposits meet Rainy lobe glacial deposits, as mapped by Hobbs and Goebel (1982).

Figure 32.—*Subsection X.9: Superior National Forest, Cook County, Minnesota. Upland forests of northern white-cedar grow near Lake Superior. Minnesota Department of Natural Resources photo by K.A. Rusterholz.*

SUBSECTION X.10. Border Lakes**; glacially scoured granitic and basaltic bedrock knobs and lakes; spruce-fir forest, jack pine forest, white pine-red pine forest.**

DISCUSSION: Subsection X.10 is characterized by shallow soils upon granitic bedrock. Lakes occupy the glacially scoured depressions in the bedrock. Differential erosion of bedrock has produced the pattern of lakes and ridges (Wright 1972). Soil development is minimal, and bedrock outcrops are common (Kratz and Jensen 1983).

SUB-SUBSECTIONS: None.

ELEVATION: 1,250 to 2,301 feet (381 to 701 m).

AREA: 4,530 square miles (11,740 sq km).

STATES: Minnesota.

CLIMATE: Cool continental climate, with short warm summers and long winters (Heinselman 1973). Annual precipitation averages 28 inches, and the mean annual temperature is 36˚F. Annual snowfall ranges from 52 inches in the west to 64 inches farther east (Wendland *et al.* 1992). Growing season ranges from 108 to 123 days (University of Minnesota *et al.* 1981b). Extreme minimum temperatures are -35˚F to -45˚F (Reinke *et al.* 1993) or colder, with lowest temperatures in the west. Heinselman (1973) considers the area to be transitional between the Great Lakes-St. Lawrence and boreal forest regions due to the presence of white pine and red pine along with boreal tree species.

BEDROCK GEOLOGY: Thin glacial drift covers much of the subsection, and bedrock exposures are common (University of Minnesota *et al.* 1981b). The subsection has Precambrian-age (late Archean and early Proterozoic) bedrock, including gneiss, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks (Sims *et al.* 1970, Morey 1976, Day *et al.* 1990). There are also iron formation and metasediments. Middle Proterozoic bedrock includes basalt, rhyolite, gabbro,

diabase, anorthosite, granite, sandstone, and shale.

Fire causes exfoliation of granite boulders and outcrops, as noted in the Little Sioux fire of 1971 in northern Minnesota (Wright and Heinselman 1973).

LANDFORMS: The subsection, corresponding to a physiographic unit described by Wright (1972), consists of scoured bedrock uplands or shallow soils on bedrock, with many lakes. Several outwash plains also occur in the area; the largest of these is the Sawbill outwash plain.

LAKES AND STREAMS: More than 300 lakes are larger than 160 acres; these cover about 13 percent of the subsection's surface (University of Minnesota *et al.* 1981b).

SOILS: Soils are derived from a mantle of acid, cobbly and gravelly glacial till of variable depth. Sandy loam is the predominant soil texture, along with loamy sands. Soils of the outwash plains are sand. The soils are classified as Ochrepts, with localized Aquents (Anderson and Grigal 1984).

PRESETTLEMENT VEGETATION: Heinselman (1973) describes the vegetation as dominated by jack pine forest, white pine-red pine forest, and hardwood-conifer forest dominated by balsam fir, white spruce, paper birch, and trembling aspen. Fire dependence characterizes all these forest types. Sugar maple was not found growing in the subsection, but there were scattered red oak (in stunted stands on rock outcrops), yellow birch, and basswood.

Jack pine is most prevalent in the two areas where the landscape is least dissected by small lakes, north of Vermilion Lake and within and north of the Sawbill outwash plain. White pine-red pine forests are most common in areas most dissected by lakes, probably as a result of partial fire protection.

NATURAL DISTURBANCE: The average interval between significant fire years was about 4 years in presettlement times, and a natural fire rotation of about 100 years was characteristic of the area (Heinselman 1973). The rotation was shortest (about 50 years) in jack pine and aspen-paper birch forests, and 150 to 350 years in red pine-white pine forests. Lightning caused many fires; the importance of Native American fire management in the area has not been established. Heinselman's work indicated that major fires occurred during drought years. Major drought years occurred two to three times per century. The timing of the fire, spring or fall, determined how severely soils burned and what tree species regenerated. Pollen records indicate that the fire history has not changed substantially for several thousand years.

Windthrows occurred on the thin soils, providing additional fuel for fires (Heinselman 1973). Similarly, insect infestations, especially by spruce budworm, resulted in cyclic heavy balsam fir, white spruce, and black spruce mortality, which added to the fuel load.

PRESENT VEGETATION AND LAND USE: Most of the subsection remains forested; most forest types persist with stand composition and structure similar to those present originally. Logging occurred within the subsection, but large areas remain unlogged. Heinselman (1973) maintained that this was because of the relatively sparse densities of forest stands, particularly white and red pines. However, it has also been maintained that the lack of logging was the result of two other factors; inaccessibility and the public sentiment for preservation when these forests were beginning to be exploited.

High-quality examples of the following plant communities are well represented in this subsection: red pine forest and white pine forest. Inventory is insufficient on many plant communities here.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Most of the rare plants known from the subsection are northern species at the extreme southern edge of their range. *Agrostis geminata* (twin bentgrass), *Arenaria macrophylla* (large-leaved sandwort), *Asplenium trichomanes* (maidenhair spleenwort), *Caltha natans* (floating marsh marigold), *Carex katahdinensis* (Mount Katahdin sedge), *Carex praticola* (prairie sedge), *Carex supina* (sedge), *Cypripedium arietinum* (ram's-head lady's-slipper), *Geocaulon lividum* (northern comandra), *Littorella americana* (American shore-plantain), *Osmorhiza obtusa* (blunt-fruited sweet cicely), *Phacelia franklinii* (wild heliotrope), *Potamogeton vaseyi* (Vasey's pondweed), *Rubus chamaemorus* (cloudberry),

Saxifraga aizoon (encrusted saxifrage), *Saxifraga cernua* (nodding saxifrage), *Subularia aquatica* ssp. *americana* (awlwort), *Tillaea aquatica* (pigmyweed), *Viola novae-angliae* (New England violet), *Woodsia scopularia* (Rocky Mountain woodsia).

RARE ANIMALS: Mammals: *Microtus chrotorrhinus* (rock vole); Birds: *Haliaeetus leucocephalus* (bald eagle), *Pandion haliaetus* (osprey); Insects: *Erebia disa mancinus* (Disa alpine, butterfly), *Cicindela denikei* (tiger beetle).

NATURAL AREAS: State Natural Areas: Burntside Islands, Eagles Nest Island #4, Hovland Woods, Purvis Lake-Ober Foundation; Research Natural Areas: Keeley Creek, Lac La Croix; Other: Lost Lake Peatland Scientific and Natural Area, South Fowl Lake Cliff Natural Heritage Registry site.

PUBLIC LAND MANAGERS: National Forests: Superior; Wilderness Areas: Boundary Waters Canoe Area (Superior NF); State Forests: Bear Island, Burntside, Grand Portage, Kabetogama, Pat Bayle; State Parks: Bear Head Lake, Soudan Underground Mine.

CONSERVATION CONCERNS: Voyageurs National Park and the Boundary Waters Canoe Area were both identified as critical landscapes for biodiversity protection by the Minnesota Heritage Program. There is inadequate protection of significant natural areas outside the BWCA wilderness.

BOUNDARIES: The western boundary of the subsection forms at the boundary with the portion of the Erskine moraine (Des Moines lobe) located between Kabetogama Lake and Nett Lake. This part of the Erskine moraine is treated as Subsection X.11, the Little Fork-Vermilion Uplands.

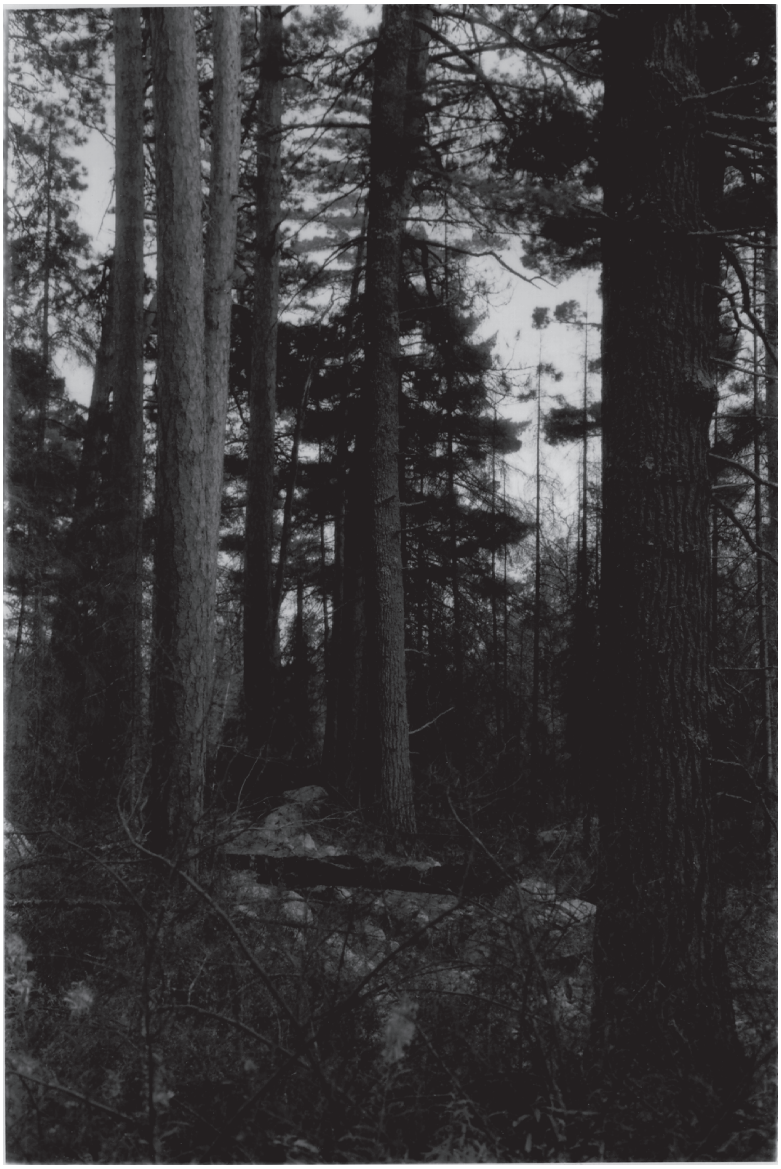


Figure 33.—*Subsection X.10: Lac La Croix Research and Natural Area, Boundary Waters Canoe Area, St. Louis County, Minnesota. Upland conifers grow on the thin soils of this subsection; boulders and bedrock are exposed beneath this old-growth stand of red pine and white pine. Fire dependence characterizes the forests of this subsection; the bark of the large red pine to the left is charred from a recent fire. Minnesota Department of Natural Resources photo by K.A. Rusterholz.*

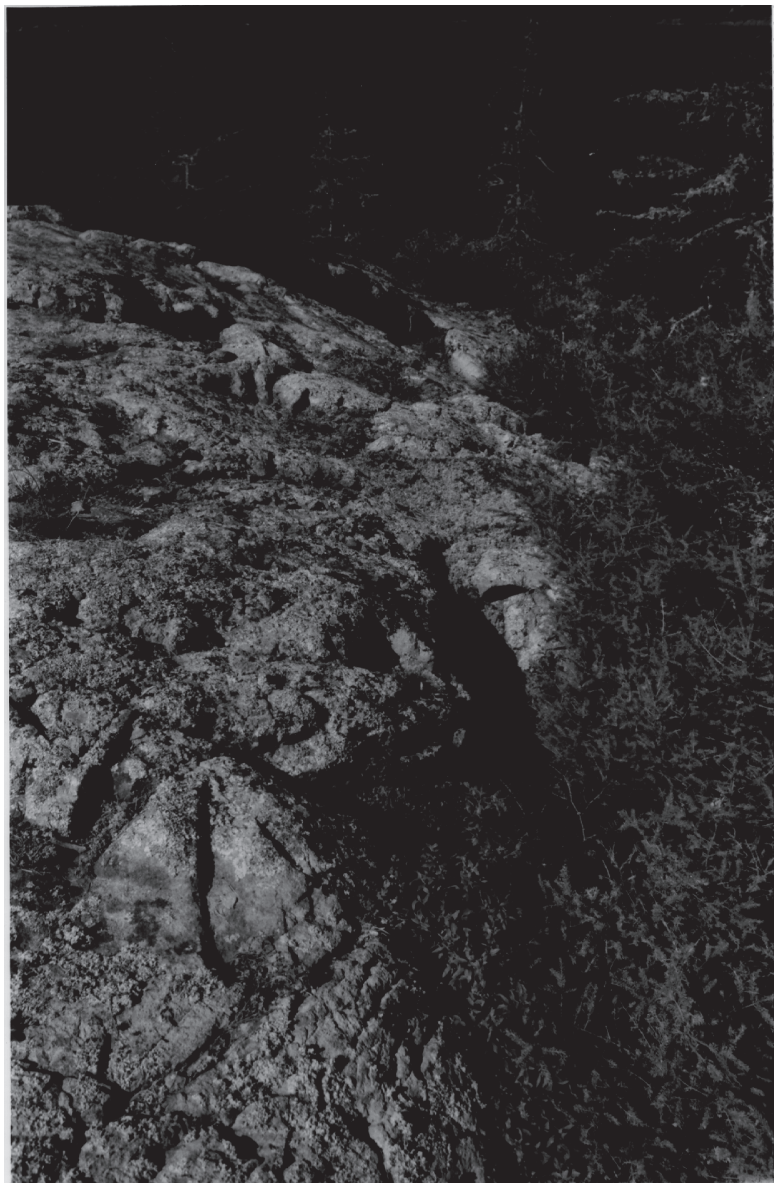


Figure 34.—*Subsection X.10: Boundary Waters Canoe Area, Cook County, Minnesota. Small northern conifers, including tamarack, black spruce, and balsam fir, and lichens cover the granitic bedrock along one of the hundreds of small bedrock lakes of the subsection. Minnesota Department of Natural Resources photo by D.S. Wovcha.*

SUBSECTION X.11. Littlefork-Vermilion Uplands**; lake-modified till and thin ground moraine over bedrock; white pine-red pine forest and aspen-birch forest.**

DISCUSSION: Subsection X.11 is transitional between extensive peatlands to the west and bedrock-controlled landscape to the east (Hargrave 1992). It is characterized by shallow clayey soils upon granitic bedrock.

SUB-SUBSECTIONS: None.

ELEVATION: 1,100 to 1,500 feet (335 to 457 m).

AREA: 2,197 square miles (5,690 sq km).

STATES: Minnesota.

CLIMATE: Cool continental climate, with short warm summers and long winters (Heinselman 1973). Annual precipitation averages 25 to 27 inches; the growing season ranges from 98 to 111 days and is shortest in the west (University of Minnesota *et al.* 1981b). Annual snowfall averages 50 to 64 inches; the greatest amount of snow falls in the east (Wendland *et al.* 1992). Extreme minimum temperatures are -45˚F

(Reinke *et al.* 1993) or colder. Heinselman (1973) considers the area to be transitional between the Great Lakes-St. Lawrence and boreal forest regions due to the presence of white pine and red pine along with boreal tree species.

BEDROCK GEOLOGY: Glacial drift is shallow at the northern and eastern edges of the subsection; it becomes moderately thick in the western part, where thicknesses are up to 300 feet (Hargrave 1992). The underlying bedrock is of Precambrian age (Archean), including gneiss, amphibolite, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks (Sims *et al.* 1970, Morey 1976, Morey *et al.* 1982, Day *et al.* 1990). There are also iron formation, metasediments, and metamorphosed felsic volcanic rocks.

LANDFORMS: Subsection is transitional between extensive peatlands to the west and bedrock-controlled landscape to the east. On the west, it consists of water-worked till. Further to the east is thin ground moraine over bedrock. The features are considered part of the Erskine moraine of the Des Moines lobe (Hobbs and Goebel 1982).

LAKES AND STREAMS: Large lakes include Nett Lake, Pelican Lake, Elbow Lake, and the west half of Vermilion Lake. Lakes cover only a small part of the surface here, in contrast to the Border Lakes subsection to the east. The Little Fork River meanders across the flat till plain.

SOILS: Soils are classified as Ochrepts in the east, with Aqualfs and Hemists further west, along with a large area of Psamments northwest of Nett Lake (Anderson and Grigal 1984).

PRESETTLEMENT VEGETATION: The lake-modified till in the west half of the subsection supported aspen-birch forest; conifer swamp surrounded Nett Lake and occurred in depressions on the till plain (Marschner 1974). A large area of open muskeg occurred on the lake-modified till at the south edge of the subsection in Koochiching and St. Louis Counties. White pine-red pine forests dominated the thin ground moraine to the east. Jack pine forest and aspen-birch forest again became dominant at the east edge, where the soils were thinnest.

NATURAL DISTURBANCE: Both fire and windthrow were probably common forms of disturbance; insect infestations such as spruce budworm attacks were probably common in the conifer-dominated wetlands.

PRESENT VEGETATION AND LAND USE: Most of the subsection remains forested. The subsection is an important source of aspen for pulpwood.

High-quality examples of the following plant communities are represented in this subsection: northern white-cedar swamp, black spruce swamp, spruce-fir forest, and white pine forest. Inventory is insufficient on most plant communities here.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: Little plant inventory has been done.

RARE ANIMALS: Little animal inventory has been done.

NATURAL AREAS: State Natural Areas: Myrtle Lake Peatland.

PUBLIC LAND MANAGERS: National Forests: Superior; State Forests: George Washington, Kabetogama, Koochiching, and Sturgeon River.

CONSERVATION CONCERNS: Accelerated timber harvest with resulting fragmentation, loss of mature and old-growth forests, and simplification of forest communities. Old-growth red pine and white pine stands need to be protected.

BOUNDARIES: Subsection includes the Erskine moraine of the Des Moines lobe. To the east is the exposed bedrock knobs of the Border Lakes subsection. To the west are the Agassiz Lowlands, a subsection of extensive peatlands on lacustrine deposits.

SUBSECTION X.12. Agassiz Lowlands**; poorly drained lake plain and beach ridges; paludified peatland, trembling aspen and spruce-fir forest.**

DISCUSSION: Subsection X.12 consists of a flat, poorly drained lake plain. Local topographic relief is less than 50 feet on most of the lake plain (Wheeler *et al.* 1992a). The wetland occupying the lake basin is a paludified peatland that was once much smaller, but gradually expanded outward (Glaser *et al.* 1981).

SUB-SUBSECTIONS: None.

ELEVATION: 1,100 to 1,350 feet (335 to 411 m).

AREA: 7,530 square miles (19,510 sq km).

STATES: Minnesota.

CLIMATE: Total annual precipitation ranges from 21 inches in the west to 25 inches in the east; 40 to 50 percent occurs during the growing season (Hargrave 1992). Average annual snowfall is as light as 42 inches in the west and as heavy as 56 inches in the extreme east (Wendland *et al.* 1992). Growing season is short, from 98 to 111 days, and shortest near the eastern edge. Extreme minimum temperatures are -45˚F (Reinke *et al.* 1993) or colder.

The Canadian Ecoregions Working Group (1989) maps climatic region LBst (Subhumid Transitional Low Boreal Ecoclimatic Region) as including the Glacial Lake Agassiz Lowland, on the basis of conifer dominance of both upland and lowlands. Based on the Canadian treatment, it may be justified to treat the North Shore (Superior) Highlands, the Border Lakes, the Littlefork-Vermilion Uplands, and the Agassiz Lowlands as yet another climatic region.

BEDROCK GEOLOGY: Glacial drift is shallowest at the northern and eastern edges of the lake plain, where bedrock is locally exposed (Olsen and Mossler 1982). At the western edge of the basin, where drift thicknesses are generally greatest, drift is as thick as 300 feet. The underlying bedrock is Precambrian (late Archean) in age, and includes gneiss, amphibolite, undifferentiated granite, and metamorphosed mafic to intermediate volcanic and sedimentary rocks. There are also iron formation, metasediments, and metamorphosed felsic volcanic rocks (Morey 1976).

LANDFORMS: The peatlands occupy a large glacial lake bed. The mineral substrate consists of calcareous silty till, locally with a thin veneer of lake sediments (Glaser *et al.* 1981, referencing Wright 1972). Sediments vary considerably in texture across the extensive lake bed. Sandy beach ridges are exposed throughout the subsection.

SOILS: Predominantly organic soils (University of Minnesota *et al.* 1980c, 1981b). A greater percentage of organic soils is in the center of the lake basin, with increased amounts of poorly drained mineral soils near the edges. In the northwestern portion of the basin, north of Upper Red Lake, the surface soils are often sandy; but these sandy soils are generally only 2 to 4 feet thick over loamy glacial till (University of Minnesota *et al.* 1980b). About 75 percent of the soils are peats in this part of the basin. In the northeastern portion of the basin (the Big Fork Area), clayey soils are more common (43 percent); organic soils make up about 32 percent and sands 18 percent of the soils (University of Minnesota *et al.* 1981b). As in the northwest, clays and loams underlie the sands at 2 to 4 feet.

Peat depths can exceed 15 feet (Heinselman 1963). See PRESETTLEMENT VEGETATION.

Soils are classified primarily as Hemists, Aqualfs, and Aquents (Anderson and Grigal 1984). Hemists occupy the center of the lake basin; Aqualfs and Aquents are along the margins of the basin.

PRESETTLEMENT VEGETATION: Marschner (1974) mapped much of the subsection as peatland, in which he included sedge fen, black spruce-sphagnum bog, and northern white-cedar and black ash swamp. Low moraines and beach ridges were dominated by jack pine forest or trembling aspen-paper birch forest.

Recent ecologists have classified the peatland as several distinct plant communities; the plant

species present in each community reflect differences in water flow and water chemistry (Heinselman 1963, 1970; Glaser *et al.* 1981; Glaser 1983). Types of peatland described include raised bogs, patterned fen, as well as several bog, fen, and poor fen types. Heinselman describes several conifer-swamp types (1970).

Peat deposition began approximately 7,000 years ago in the western part of the basin, where peat deposits are now thickest, and expanded westward (Glaser *et al.* 1981). Many of the western deposits of sphagnum peat, only 1,000 to 2,000 years old, are relatively shallow. Spruce-fir and trembling aspen forests occupied the drier sand and gravel beach ridges and low ground-moraine ridges. Balsam fir was an overstory tree in these stands.

The stratigraphic record indicates that the peatlands supported forests in the past, but that with peat accumulation, muskeg is becoming the dominant vegetation (Heinselman 1963). This record details several changes in forest vegetation that correspond to climatic changes (Heinselman 1970).

NATURAL DISTURBANCE: Fire occurred on the peatlands. Insect infestations, such as spruce budworm, probably lead to fires. Water level fluctuations, caused both by short-term climatic changes and by beaver dams, probably contributed to tree mortality. Windthrow was common on the poorly drained mineral soils.

PRESENT VEGETATION AND LAND USE: Trembling (quaking) aspen is best developed as both forest stands and as individual trees in this subsection, and it has been heavily harvested for pulp (David Grigal, personal communication). Aspen is probably the best developed forest type on the uplands, and it probably was also common in the presettlement. Logging of conifer forests also occurred.

In the past, attempts were made to farm parts of the peatlands (Heinselman 1963). Ditches were dug along section lines, but were not effective.

High-quality examples of the following plant communities are represented in this subsection: black spruce bog, black spruce swamp, boreal hardwood-conifer forest, lowland hardwood forest, rich fen, tamarack swamp, northern white-cedar swamp, upland northern white-cedar forest, white pine forest.

RARE PLANT COMMUNITIES: None identified to date.

RARE PLANTS: All the rare species within this subsection have a northern, boreal distribution. *Achillea sibirica* (Siberian yarrow), *Arethusa bulbosa* (dragon's mouth), *Cladium mariscoides* (twig-rush), *Cypripedium arietinum* (ram's-head lady's-slipper), *Drosera anglica* (English sundew), *Drosera linearis* (linear-leaved sundew), *Juncus stygius* var. *americanus* (bog-rush), *Nymphaea tetragona* (small white water-lily), *Ranunculus lapponicus* (Lapland buttercup), *Xyris montana* (yellow-eyed grass).

RARE ANIMALS: Mammals: *Synaptomys borealis* (northern bog lemming); Birds: *Ammodramus caudacutus* (sharp-tailed sparrow), *Charadrius melodus* (piping plover), *Coturnicops noveboracensis* (yellow rail), *Grus canadensis* (sandhill crane).

NATURAL AREAS: Minnesota: State Natural Areas: Caldwell Brook Cedar Swamp, Gustafson's Camp, Lost River Peatland, Luxemberg Peatland, Mulligan Lake Peatland (Scientific and Natural Area), Myrtle Lake Peatland, North Black River Peatland, Pine and Curry Island, Pine Creek Peatland, Red Lake Peatland, South Black River Peatland, Sprague Creek Peatland, Winter Road Lake Peatland.

PUBLIC LAND MANAGERS: State Forests: Beltrami Island, Big Fork, Koochiching, Lake of the Woods, Lost River, Northwest Angle, Pine Island, Red Lake; Wildlife Management Areas: Border, Grygla, Red Lake, Roseau River, Thief Lake; National Forests: Chippewa.

CONSERVATION CONCERNS: Maintaining the protected peatlands and the quality of their watersheds is a priority. Glacial Lake Agassiz peatland and Lost Lake peatlands were identified as critical landscapes for biodiversity by the Minnesota Heritage Program.

BOUNDARIES: The western edge of the subsection includes shallow peatlands along the west side of Lower Red Lake. Further west, there are wet prairies, and the uplands contain bur oak as well as trembling aspen. In the east, the subsection meets the ground moraine of the Erskine moraine (Des Moines lobe).

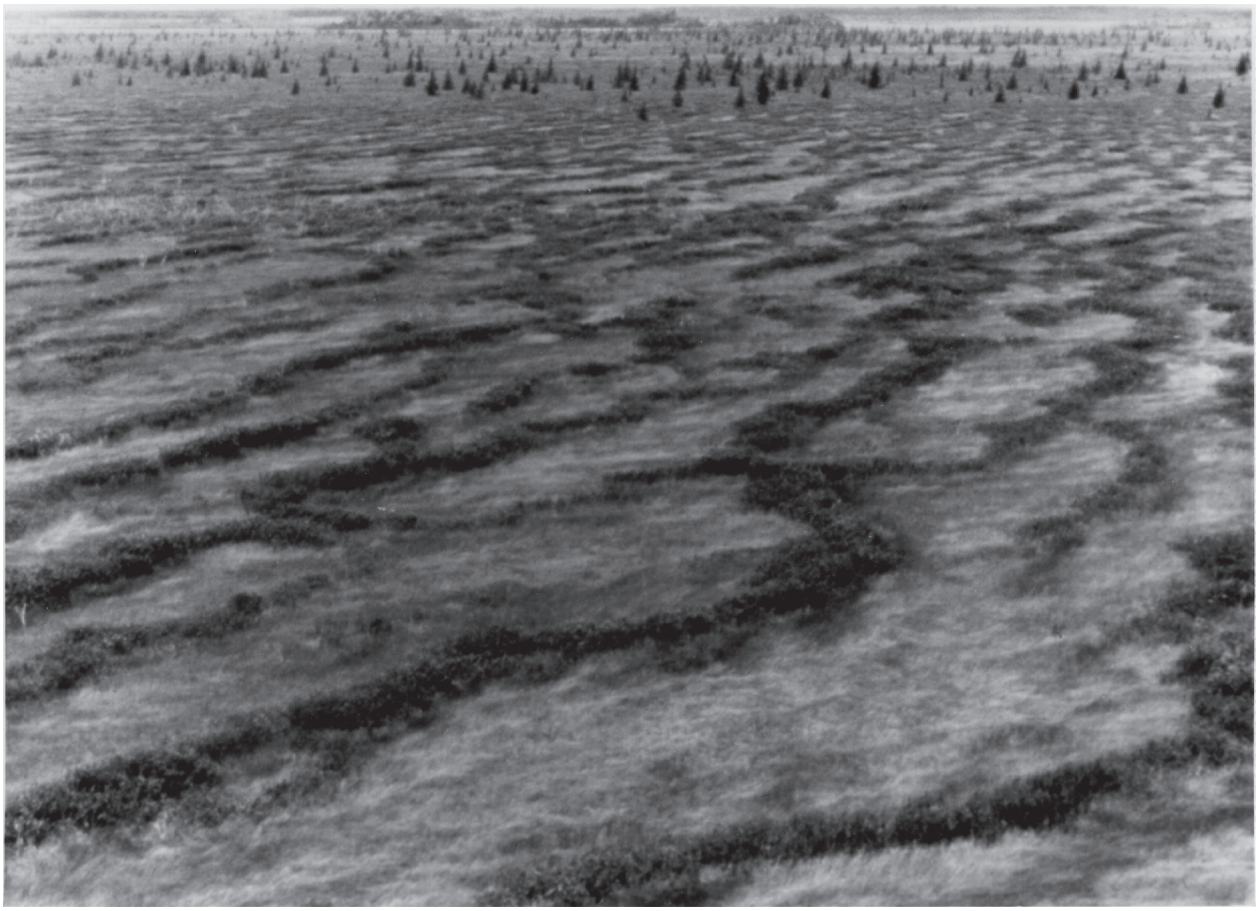


Figure 35.—Subsection X.12: *Winter Road Lake Peatland State Natural Area, Lake of the Woods County, Minnesota. Large patterned peatlands occupy the flat, poorly drained topography of Glacial Lake Agassiz. The wetter portions of the peatland, called flarks, are dominated by* Carex lasiocarpa *and other sedges, while the drier portions, called strings, are dominated by shrubs. Scattered small black spruce and tamarack occur within the peatland, often where there are low ridges of mineral soil. Minnesota Department of Natural Resources photo by B. Coffin.*

SECTION XI. ASPEN PARKLAND**; part of Bailey and Cushwa's (1981) Humid Temperate Domain, Subhumid Prairie Division, Aspen Parkland Province; sand lake plain and water-reworked till on northern Glacial Lake Agassiz (late Wisconsinan age, Des Moines lobe glacial deposits); aspen parkland, tallgrass prairie, wet prairie, fen.**

Section XI, Aspen Parkland, has no subsections.
It is described on pages 53-55.

Figure 36.—*Subsection XI: Twin Lakes Wildlife Management Area, Kittson County, Minnesota. Stunted bur oak grow on a gravelly beach ridge of Glacial Lake Agassiz. Bur oak dominates the driest sites as long as fires occur frequently. Trembling aspen is more common on more mesic sites and replaces bur oak when fires are eliminated. Minnesota Department of Natural Resources photo by C.K. Converse.*

Figure 37.—*Subsection XI: The flat, poorly drained landscape of the Aspen Parkland was originally a mosaic of prairie, wet prairie, marsh, brush prairie, and aspen-oak land. Wet brush prairie dominates most of the landscape shown, with trembling aspen in the background. Willows are the dominant shrubs in the brush prairies, but bog birch, shrubby cinquefoil, hazel, and Saskatoon (*Amelancier *sp.) are also common. Minnesota Department of Natural Resources photo by B.C. Delaney.*

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The Upper Great Lakes Biodiversity Committee is a group of individuals representing wide interests who have come together to promote cooperation in maintaining and restoring biological diversity on a regional scale. Committee members include people from state and federal agencies, private industries, colleges and universities, Native American groups, and conservation organizations. By exchanging information and coordinating activities, we hope to play a positive role in resource management in Michigan, Wisconsin, and Minnesota.

North Central Forest Experiment Station
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
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